

Effect of the Maturity Age on the Organic and Mineral Components of Sweet and Bitter Cassava in Côte d'Ivoire

Olivier Kouadio Kouadio^{1,2}, Claver Degbeu Kouadio¹, Eliane Hadiowe Gnagne¹, Bony Nzué³ & Georges N'Guessan Amani¹

¹ Université Nangui Abrogoua, Laboratoire de Biochimie Alimentaire et Technologie des Produits Tropicaux 02 BP 801, Abidjan 02, Côte d'Ivoire

² Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS), Axe Agriculture Durable et Nutrition 01 BP 1303 Abidjan 01, Côte d'Ivoire, Adiopodoumé- Km 17-Route de Dabou, Côte d'Ivoire

³ Centre National de Recherche Agronomique, Côte d'Ivoire 01 BP 1740 Abidjan 01, Côte d'Ivoire

Correspondence: Kouadio Kouadio Olivier, Université Nangui Abrogoua, Laboratoire de Biochimie Alimentaire et Technologie des Produits Tropicaux 02 BP 801, Abidjan 02, Côte d'Ivoire. E-mail: olivierkouadio@hotmail.com; Olivier.kouadio@csrs.ci

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Abstract

Background: Cassava (*Manihot esculenta* Crantz) is a major root crop grown in many countries worldwide, particularly in West Africa. In Côte d'Ivoire, it is used to produce a variety of local foods such as *attiéké*, *foutou*, *placali*, and *gari*, destined for both national and regional markets. The maturity age of cassava strongly influences its nutritional characteristics and bioactive compounds due to physiological changes occurring in the roots. This study aims to examine the effect of maturity age on the organic and mineral composition of sweet and bitter cassava varieties, and to interpret the technological and nutritional implications.

Six (06) sweet and bitter cassava varieties, classified as traditional or improved, and harvested at two maturity ages (12 and 18 months), were analyzed. Organic and mineral composition was assessed using standard analytical methods. The results showed that both variety and maturity age significantly influence the physicochemical and mineral characteristics of cassava roots. Sweet varieties (A12F, Bonoua2) exhibited higher moisture, protein, and starch contents, particularly at 18 months, while bitter varieties (Yacé, KA13) showed lower ash and moisture contents in their flours but greater mineral stability, suggesting better suitability for flour processing and storage.

Protein, starch, and mineral contents (P, Zn, Cu) increased with maturity, whereas reducing sugars (glucose, fructose) decreased, indicating a transition from soluble sugars to storage carbohydrates. A12F and Yacé were richer in Ca, Mg, and P, while Bonoua2 and KA13 accumulated more Zn and Cu at full maturity.

Overall, early-harvested sweet cassava is more appropriate for direct consumption, whereas late-harvested bitter cassava provides higher starch yield and mineral density for industrial processing. These findings offer a scientific basis for optimizing harvest timing and selecting varieties to enhance the nutritional quality and technological performance of cassava-based products.

Keywords: maturity age of cassava, organic and mineral components, sweet and bitter cassava, Côte d'Ivoire

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a major tuber crop cultivated in many countries worldwide, particularly in West Africa (N'Zué et al., 2014). It is a vital food source for over 500 million people, especially in developing regions, with Africa being the largest consumer (Otekunrin, 2024). Among starchy staples, cassava produces 40% more carbohydrates than rice and 25% more than maize (Bayata, 2019). Its versatility enables its use across the food, medical, chemical, and light industries, notably as a key raw material for starch-based products (Oyeyinka et al., 2019). As highlighted by Adebayo (2023) and Scaria et al. (2024), cassava's importance lies in its high-energy, starch-rich composition. In Côte d'Ivoire, it is the second most important food crop after yam, providing a major source of calories to nearly 26 million people (FAOSTAT, 2023). Cassava is processed into a variety of traditional foods—including *attiéké*, *foutou*, *toh*, flour, starch, and *gari*—which contribute to both national consumption and regional trade (N'Zué, 2009).

The physicochemical composition of cassava roots, including their carbohydrate, protein, lipid, fiber, ash, and cyanogenic compound contents, is central to their nutritional quality, processing potential, and food safety. Several factors influence these components, among which plant age plays a crucial role (Ospina et al., 2024; Alamu et al., 2023; Zidenga et al., 2017). The maturity age of cassava significantly affects the nutritional composition and functional properties of the roots, due to important physiological changes during development (Adeola et al., 2020; Oluwaniyi & Olandipipo, 2017). For instance, water, starch, and protein contents vary markedly with root maturity (Diallo et al., 2013). Adeola et al. (2020) reported that cassava variety TMS 98/0505 harvested 12-15 months after planting exhibited optimal carbohydrate levels. Similarly, Laya et al. (2018) demonstrated that the physicochemical properties of *gari* depend strongly on both variety and harvest timing, highlighting the influence of maturity on cassava root quality. Other factors, such as cultivar, maturity stage, and pre- and post-harvest practices, also affect the properties of cassava flour (Akingbala et al., 2009).

Despite this variability, a uniform practice of harvesting cassava at 12 months after planting remains common, although it is unsuitable for all varieties. Some varieties reach physiological maturity earlier and may lose significant dry matter if harvesting is delayed, whereas others are harvested prematurely before reaching their full yield potential. Furthermore, the optimal harvest age depends on the intended end-use along the value chain (Nzola et al., 2021). Nurdjanah et al. (2025) also confirmed that the physicochemical properties of cassava are strongly influenced by harvest age.

Studying the effect of maturity age on the chemical composition of cassava is therefore essential to optimize cultivation practices, harvest timing, and processing methods, to improve product quality and ensure consumer safety. In this context, this study evaluates both sweet and bitter cassava varieties to compare their organic and mineral compositions at different maturity ages. Specifically, this article aims to analyze the influence of maturity age on the organic and mineral components of sweet and bitter cassava varieties, and to examine the resulting technological and nutritional implications.

2. Materials and Methods

2.1 Matériel

The plant material used in this study consisted of six cassava (*Manihot esculenta* Crantz) varieties, including both sweet and bitter types, harvested at two stages of maturity: 12 and 18 months. The 12-month stage corresponds to the normal maturity age for cassava harvest, while 18 months represents a late maturity stage. Samples were collected from the research station of the Centre National de Recherches Agronomiques (CNRA) in Adiopodoumé, Côte d'Ivoire, as presented in Table 1. Fresh cassava roots were immediately transported to the food processing laboratory at Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS) for subsequent chemical analyses.

Table 1. Characteristics of cassava varieties

Variétés	Sweet varieties	Bitter varieties
Traditional varieties	Bonoua2 (12 et 18 mois)	Yacé (12 et 18 mois)
Improved varieties	A12F (12 et 18 mois)	KA 13 (12 et 18 mois)

2.2 Methods

2.2.1 Flour Production

Flour was prepared from the central portions of 3 kg of each cassava variety using the method described by Roux (1994). These portions were peeled, rinsed, and cut into small cubic pieces (1 mm³) before being frozen at -20 °C. The frozen pieces were then freeze-dried using a Christ Alpha 1-2 freeze-dryer (type 100200, Germany). The resulting dry material was ground with a blender (Moulinex, model AY45RK/81Q-4603, Spain) and passed through a 250 µm mesh sieve. The flours were stored in polystyrene containers at room temperature until further analysis.

2.2.2 Chemical Analyses

- Moisture content was determined by drying samples to a constant weight at 105 °C (AOAC, 2005).
- Total starch (TS) and resistant starch (RS) contents were measured following the method of Brighenti et al. (1998) using a commercial kit (Megazyme, 2018).
- Free sugar content was analyzed by high-performance liquid chromatography (HPLC) according to AOAC (2005), method 977.20.
- Fat content was determined using a Soxhlet apparatus according to AOAC (2005), method 920.39.

2.2.3 Mineral Determination

- Ash content was measured according to AOAC (2005), method 923.03.
- Mineral contents were determined using Atomic Absorption Spectrophotometry, following AOAC (2005), method 984.27.

2.2.4 Statistical Analysis

Data were analyzed using one-way ANOVA, and mean comparisons were performed with Tukey's test at $p < 0.05$ using XLstat software.

3. Results

3.1 Effect of Maturity Age on the Organic Components of Cassava Varieties

The effects of maturity age (12 and 18 months) on the physicochemical characteristics of different cassava varieties are presented in Table 2. Both variety and maturity age significantly influenced the biochemical composition of the roots. The analysis distinguishes between sweet varieties (Bonoua2 and A12F) and bitter varieties (Yacé and KA13).

Moisture content of cassava flour increased significantly ($p < 0.05$) with maturity age in most varieties, except for the improved variety KA13, where the change was not significant. Sweet varieties exhibited significantly higher moisture content ($p < 0.05$) than bitter varieties, indicating that varietal type influences hygroscopicity. A12F and Bonoua2 recorded the highest moisture content (7.5-8.8%), while Yacé and KA13 had lower values (5.63-6.71%), suggesting better stability during storage.

Ash content generally increased with maturity, except in KA13. Sweet varieties (A12F and Bonoua2) showed higher ash content, whereas bitter varieties, particularly KA13 (<1.3%), had lower ash levels, reflecting a cleaner flour suitable for bread and pastry production. These results indicate that both moisture and ash contents are influenced by maturity age, with sweet varieties reaching peak levels at 18 months.

Protein content was also significantly affected by both variety and maturity age, increasing with root maturation ($p < 0.05$), which reflects gradual protein accumulation during development. The highest protein contents were observed in A12F_12 (1.94%), A12F_18 (2.60%), and KA13_12 (2.35%).

Regarding simple sugars, glucose and fructose contents decreased significantly ($p < 0.05$) with increasing maturity, peaking at 12 months. The improved varieties A12F and KA13 exhibited the highest glucose (1.15% and 1.13%) and fructose (0.83% and 0.96%) contents, highlighting the strong influence of genotype and maturity on soluble sugar composition. In contrast, sucrose content increased significantly ($p < 0.05$) with both maturity and variety, with the highest levels observed in the bitter varieties KA13 (7.11%) and Yacé (3.47%) at 18 months, indicating progressive carbohydrate accumulation until full maturity. Lipid content, however, was not influenced by variety or maturity.

Total starch content increased significantly ($p < 0.05$) with maturity in A12F (79.05% to 88.63%) and Yacé (73.22% to 92.79%), reflecting normal physiological development. In contrast, Bonoua2's starch content remained relatively stable, while KA13 showed a decrease with maturity. Resistant starch content was significantly higher ($p < 0.05$) in Bonoua2_12, Yacé_12, and KA13_12 (>3.8%), which is favorable for a low glycemic index and functional nutrition.

Overall, these results demonstrate that both variety and maturity age significantly affect the main organic components of cassava. Sweet varieties are characterized by higher hygroscopicity, whereas bitter varieties, particularly KA13, exhibit greater stability and a composition suitable for industrial processing. Observed changes in protein, sugar, and starch content reflect the biochemical transformations associated with physiological maturation of the roots.

Table 2. Organic components of cassava varieties

Cassava varieties with maturity age	Humidity (%)	Ash (%)	Protein (%)	Glucose (%)	Fructose (%)	Sucrose (%)	Lipid (%)	Total starch (%)	Resistant starch (%)
Bonoua2_12	7,58 ± 0,04 ^b	1,64 ± 0,03 ^c	1,25 ± 0,01 ^{de}	0,58 ± 0,00 ^{bc}	0,48 ± 0,01 ^c	2,26 ± 0,05 ^c	0,55 ± 0,08 ^{cd}	76,07 ± 6,94 ^b	4,14 ± 0,39 ^a
Bounoua2_18	8,82 ± 0,01 ^a	1,93 ± 0,02 ^a	1,65 ± 0,01 ^c	0,21 ± 0,01 ^d	0,13 ± 0,00 ^e	2,32 ± 0,05 ^c	0,63 ± 0,09 ^{bc}	76,97 ± 0,76 ^b	3,00 ± 0,30 ^b
A12F_12	7,53 ± 0,05 ^b	1,79 ± 0,02 ^b	1,94 ± 0,22 ^b	1,15 ± 0,01 ^a	0,83 ± 0,01 ^b	1,37 ± 0,00 ^d	0,45 ± 0,01 ^d	79,05 ± 1,83 ^b	2,90 ± 0,25 ^b
A12F_18	8,67 ± 0,03 ^a	1,81 ± 0,01 ^b	2,60 ± 0,02 ^a	0,28 ± 0,02 ^d	0,14 ± 0,00 ^e	3,09 ± 0,10 ^b	0,44 ± 0,08 ^d	88,63 ± 4,76 ^a	2,79 ± 0,08 ^b
Yace_12	5,63 ± 0,09 ^e	1,25 ± 0,03 ^e	1,21 ± 0,01 ^{de}	0,64 ± 0,08 ^b	0,53 ± 0,06 ^c	2,35 ± 0,36 ^c	0,74 ± 0,03 ^b	73,22 ± 4,09 ^b	3,88 ± 0,29 ^a
Yace_18	6,05 ± 0,01 ^d	1,28 ± 0,00 ^{de}	1,06 ± 0,03 ^e	0,54 ± 0,08 ^c	0,40 ± 0,05 ^d	3,47 ± 0,44 ^b	0,44 ± 0,06 ^d	92,79 ± 3,22 ^a	3,03 ± 0,26 ^b
KA13_12	6,59 ± 0,35 ^c	1,30 ± 0,00 ^d	1,96 ± 0,01 ^b	1,13 ± 0,01 ^a	0,96 ± 0,01 ^a	0,93 ± 0,00 ^d	0,92 ± 0,13 ^a	78,31 ± 4,25 ^b	2,68 ± 0,58 ^b
KA13_18	6,71 ± 0,14 ^c	0,88 ± 0,01 ^f	1,30 ± 0,03 ^d	0,62 ± 0,01 ^{bc}	0,33 ± 0,00 ^d	7,11 ± 0,24 ^a	0,26 ± 0,02 ^e	73,66 ± 0,63 ^b	3,94 ± 0,21 ^a

Note: 1. Values in the same column with the same letters are not significantly different at the 5% threshold according to Duncan's test.

2. The resistant starch value is included in the total starch value

Cassava varieties with maturity age, ex, Bonoua2 is the variety, and 12 is the maturity age

Bonoua2, A12F: sweet varieties

Yacé, KA13: bitter varieties

3.2 Effect of Maturity Age on the Mineral Components of Cassava Varieties

The mineral content of cassava varieties is presented in Table 3. The results indicate that both variety and maturity age significantly influence mineral composition. The A12F and Yacé varieties are notable for their high calcium (Ca), magnesium (Mg), and phosphorus (P) contents, whereas the Bonoua2 variety shows higher zinc (Zn) concentrations, particularly at 18 months (0.86 mg/100 g). Maturity at 18 months appears to favor increased accumulation of phosphorus and certain trace elements, reflecting the physiological maturity of the roots.

Calcium content increased significantly ($p < 0.05$) with maturity in Bonoua2 (26.19 to 37.53 mg/100 g) and KA13 (26.57 to 42.18 mg/100 g). In contrast, A12F showed a significant decrease (50.14 to 40.12 mg/100 g), while Yacé remained relatively stable (~40 mg/100 g). These differences highlight varietal variation in calcium accumulation, likely influenced by genotype-specific physiological traits.

Magnesium content also varied by variety. At 12 months, Yacé and A12F exhibited particularly high Mg levels, indicating substantial mineral presence at typical maturity. With increasing age, Mg content rose significantly ($p < 0.05$) in Bonoua2 (31.91 to 48.13 mg/100 g) and KA13 (34.31 to 38.66 mg/100 g) but decreased in A12F (65.27 to 48.30 mg/100 g) and Yacé (68.15 to 66.40 mg/100 g). These opposing trends suggest distinct physiological strategies for Mg accumulation, likely related to root energy and enzymatic metabolism.

Phosphorus content was significantly affected by maturity ($p < 0.05$), showing a gradual increase from 12 to 18 months across all varieties. This trend reflects the progressive accumulation of organic phosphates in storage tissues as roots reach full maturity. The highest phosphorus levels were recorded in A12F (157.75 mg/100 g) and Yacé (155.83 mg/100 g), confirming their high mineral nutrient potential.

For trace elements, zinc and copper exhibited marked inter-varietal differences. Bonoua2 contained the highest zinc at 18 months (0.86 mg/100 g), whereas KA13 had the highest copper content at the same age (0.44 mg/100 g). These results indicate a gradual accumulation of micronutrients during maturation, likely associated with enhanced enzymatic activity and mobilization of trace elements to storage tissues at advanced maturity.

Table 3. Mineral component of cassava varieties

Cassava varieties with maturity age	Ca	Mg	P	Zn	Cu
Bonoua2_12	26,19 ± 4,28 ^c	31,91 ± 0,28 ^g	116,53 ± 9,90 ^{ab}	0,56 ± 0,04 ^b	0,23 ± 0,07 ^{ab}
Bonoua2_18	37,53 ± 0,73 ^b	48,13 ± 0,68 ^d	131,16 ± 5,51 ^{ab}	0,86 ± 0,27 ^a	0,41 ± 0,30 ^{ab}
A12F_12	50,14 ± 5,11 ^a	65,27 ± 0,11 ^c	121,19 ± 1,85 ^{ab}	0,62 ± 0,02 ^{ab}	0,32 ± 0,05 ^{ab}
A12F_18	40,12 ± 0,65 ^b	48,30 ± 0,00 ^d	157,75 ± 4,69 ^a	0,42 ± 0,02 ^b	0,26 ± 0,00 ^{ab}
Yace_12	40,88 ± 1,53 ^b	68,15 ± 0,16 ^a	99,91 ± 8,21 ^b	0,43 ± 0,08 ^b	0,19 ± 0,01 ^{ab}
Yace_18	40,91 ± 0,49 ^b	66,40 ± 0,07 ^b	155,83 ± 38,02 ^a	0,44 ± 0,05 ^b	0,16 ± 0,00 ^b
KA13_12	26,57 ± 1,59 ^c	34,31 ± 0,30 ^f	115,27 ± 32,78 ^{ab}	0,37 ± 0,05 ^b	0,30 ± 0,00 ^{ab}
KA13_18	42,18 ± 3,70 ^b	38,66 ± 0,68 ^e	142,17 ± 10,98 ^{ab}	0,45 ± 0,03 ^b	0,44 ± 0,03 ^a

Note: 1. Values in the same column with the same letters are not significantly different at the 5% threshold according to Duncan's test.

2. The resistant starch value is included in the total starch value

Cassava varieties with maturity age, ex: Bonoua2 is the variety and 12 is the maturity age

Bonoua2, A12F: sweet varieties

Yacé, KA13: bitter varieties

4. Discussion

This study aims to evaluate the influence of maturity age on the physicochemical and mineral components of sweet and bitter varieties of cassava. Analysis of the results revealed that the moisture content of cassava flour varies significantly ($p < 0.05$) depending on the variety and physiological maturity age of the roots. This variation, observed in the A12F and Bonoua2 varieties, could be explained by the greater capacity of these genotypes to absorb and retain moisture, linked to their starch composition and cell matrix structure. Similar work such as those by Kouadio et al. (2020), Falade and Akingbala et al. (2011), have shown that the moisture content of cassava flour depends on the maturity of the roots and the type of variety. Conversely, the stability observed in the Yacé variety reflects low hygroscopicity, which is favorable for flour preservation and technological suitability.

The ash content increases overall with the maturity age of the varieties, except for the KA13 variety, suggesting a

gradual accumulation of minerals during maturation. This trend is particularly marked in sweet varieties. The low ash content recorded for the KA13 variety ($< 1.3\%$) indicates a flour of good purity, comparable to those reported by Nauluvula et al. (2025); Akingbala et al. (2011) and particularly sought after in bread and pastry making for the whiteness of the finished product.

The comparatively low ash and moisture contents observed in the bitter cassava varieties in our study are not only agronomically interesting but also confer real advantages for industrial processing. Recent studies reinforce the potential of such composition for both bakery and starch-based industries. Such low moisture is beneficial because it reduces water activity, a key factor for microbial growth, thereby enhancing storage stability and extending shelf life (Wambua et al. 2024; Ogiehor & Ikenebomeh, 2006)

Moreover, low ash content indicating fewer minerals, has been shown to correspond to higher purity flour or starch. Low ash and low moisture together improve functional properties of cassava flour: they contribute to better dough behavior and quality, more predictable baking performance, and more consistent crumb and texture in composite breads where cassava flour replaces or complements wheat flour (Robinson & Taş. 2025; Chimphepo et al., 2021)

Protein content increases significantly ($p < 0.05$) with maturity age for all varieties, reflecting an accumulation of nitrogen compounds in storage tissues. This trend is consistent with the observations of Charles et al. (2005), who reported an increase in protein in cassava roots as photosynthesis and nitrogen metabolism intensify during maturation. Varieties A12F and KA13 have the highest contents, demonstrating the improved nutritional potential of the selected genotypes. Regarding simple sugars, glucose and fructose levels decrease with maturity age, while sucrose levels increase. This inverse trend reflects the metabolic conversion of reducing sugars into sucrose or starch, a phenomenon typical of the physiological maturity process described by Montagnac et al. (2009). The accumulation of sucrose observed in KA13 and Yacé at 18 months indicates increased mobilization of reserve sugars at maturity, reflecting the ability of these varieties to store complex carbohydrates (Wang et al., 2016).

The total starch content increases significantly with maturity age, particularly in the A12F and Yacé varieties, confirming normal physiological maturation of the roots. These results are consistent with those of Zidenga et al. (2012), who showed that starch accumulation intensifies up to an optimal maturity age before stabilizing or decreasing depending on the variety (Gomez et al., 1985; Hongbete et al., 2011; De Souza Fernandes et al., 2019). Williams et al. (2019), found starch yields ranging from 18-29%, with the highest yield recorded in the 10th month after planting. Ebah-Djedji et al. (2012) observed peak starch yields for most varieties at 13 months after planting, typically around 20%.

On the other hand, the stability observed in the Bonoua2 variety and the decrease in the KA13 variety could be explained by the mobilization of starch to other metabolic pathways, particularly respiration or the synthesis of secondary compounds. The high resistant starch content observed in the Bonoua2_12, Yacé_12, and KA13_18 varieties ($> 3.8\%$) gives these flours a low glycemic index, making them particularly interesting from a nutritional standpoint for dietary or functional formulations. This result is consistent with the observations of Oladunmoye et al. (2014), according to which resistant starch in cassava has properties that are beneficial to metabolic health.

The study of mineral composition shows that variety and maturity age have a combined influence on the accumulation of macro- and microelements. The A12F and Yacé varieties are distinguished by higher Ca, Mg, and P contents, confirming their mineral richness, while Bonoua2 is characterized by a notable accumulation of zinc at 18 months. This trend corroborates the work of Chavez et al. (2005), who highlighted the role of genotype in the mineral variability of cassava roots. Calcium levels increased significantly with maturity age in the Bonoua2 and KA13 varieties, reflecting gradual absorption linked to root mobilization and structural reinforcement of tissues. On the other hand, the decrease observed in the A12F variety could be explained by intracellular redistribution of calcium to other metabolic functions. Similar observations were made by Oyeyinka et al. (2019) on African cassava varieties. Magnesium content varies depending on the variety and maturity age of development. The high initial values (12 months) for the Yacé and A12F varieties indicate early mineral availability, while the late increase observed in Bonoua2 and KA13 suggests a gradual accumulation linked to maturation. Magnesium plays a central role in chlorophyll synthesis and in many enzymatic reactions, which explains these physiological differences (Adejumo et al., 2011). The phosphorus content increased significantly between 12 and 18 months for all varieties, reflecting a continuous accumulation of organic phosphates in the storage tissues. This trend is consistent with the work of Cardoso et al. (2005), who demonstrated that phosphorus availability is essential for starch formation and root biomass increase. As for trace elements, zinc (Zn) and copper (Cu) contents show marked inter-variety variability. The highest concentrations of zinc (Bonoua2_18: 0.86 mg/100 g) and copper (KA13_18: 0.44 mg/100 g) suggest a gradual accumulation of these elements during maturation. These trace metals are involved in oxidative-reductive enzyme activity and antioxidant defense, as reported by Nweke et al. (2015). Their

presence, therefore, enhances the nutritional and physiological value of flours produced from these varieties.

Overall, the variation in the organic and mineral parameters of cassava varieties is strongly influenced by genotype and maturity age. The improved varieties A12F and KA13 stand out for their superior nutritional performance, while Yacé has a technological stability that is favorable for processing. These results confirm that varietal selection combined with harvesting at the optimal physiological maturity age (18 months) produces flours of better nutritional and functional quality that meet the requirements for industrial processing of cassava.

5. Conclusion

This study demonstrated that both variety and maturity age significantly affect the physicochemical and mineral composition of sweet and bitter cassava roots. The sweet varieties (*A12F*, *Bonoua2*) exhibited higher moisture, protein, and starch contents, particularly at 18 months, while the bitter varieties (*Yacé*, *KA13*) showed lower ash and moisture of flours but higher mineral stability, reflecting better suitability for flour processing and storage.

Protein, starch, and mineral contents (P, Zn, Cu) increased with increasing maturity, whereas reducing sugars (glucose, fructose) decreased, indicating a shift from soluble to storage carbohydrates. *A12F* and *Yacé* were notably richer in Ca, Mg, and P, while *Bonoua2* and *KA13* accumulated more Zn and Cu at full maturity.

Overall, sweet cassava harvested earlier is best suited for direct consumption, whereas bitter cassava harvested later provides higher starch content and mineral density for industrial processing. These findings provide a scientific basis for optimizing harvest timing and varietal selection to improve nutritional quality and technological value of cassava-based products.

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Authors contributions

OKK was responsible for study design and data collection. CDK analyzed the data. EHG drafted the manuscript with inputs from the other authors. BN was responsible for agronomic cassava data management. GNA was responsible for supervision and revision. All authors read and approved the final manuscript.

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No additional data is available.

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References

- Adebayo, W. G. (2023). Cassava production in Africa: A panel analysis of the drivers and trends. *Heliyon*, 9(9), 113-119. <https://doi.org/10.1016/j.heliyon.2023.e19939>
- Adejumo, A. L., Aderibigbe, F., & Layokun, S. K. (2011). Cassava starch: Production, physicochemical properties and hydrolisation-A review. *Advance Food Energy Security*, 2, 8-17.
- Adeola, A. A., Idowu, M. A., Oyatogun, R. M., Adebowale, A.-R. A., Afolabi, W. A. O., & Adigbo, S. O. (2020). Quality of cassava flour as affected by age at harvest, cropping system, and variety. *Agricultura Tropica et Subtropica*, 53(4), 187-198. <https://doi.org/10.2478/ats-2020-0019>
- Akingbala, J., Falade, K., & Ogunjobi, M. (2011). The Effect of Root Maturity, Preprocess Holding, and Flour Storage on the Quality of Cassava Biscuit. *Food and Bioprocess Technology*, 4, 451-457. <https://doi.org/10.1007/s11947-009-0185-z>
- Alamu, E. O., Dixon, G. A., Adesokan, M., & Maziya-Dixon, B. (2023). Correlate the cyanogenic potential and dry matter content of cassava roots and leaves grown in different environments. *Sci Rep*, 13(1), 15382. <https://doi.org/10.1038/s41598-023-42425-2>
- AOAC. (2005). Official Methods of Analysis (18th ed.) of the Association of Official Analytical Chemists. Washington. DC., 920.939, 923.903, 977.920, 984.927.
- Bayata, A. (2019). Review on nutritional value of cassava for use as a staple food. *Sci J Anal Chem*, 7(4), 83-91. <https://doi.org/10.11648/j.sjac.20190704.12>
- Brighenti, F., Casiraghi, M. C., & Baggio, C. (1998). Resistant starch in the Italian diet. *Br J Nutr*, 80(4), 333-341. <https://doi.org/10.1079/096582198388283>
- Cardoso, A. P., Mirione, E., Ernesto, M., Massaza, F., Cliff, J., Haque, M. R., & Bradbury, J. H. (2005). Processing of cassava roots to remove cyanogens. *Journal of Food Composition and Analysis*, 18(5), 451-460. <https://doi.org/10.1016/j.jfca.2004.04.002>
- Charles, A. L., Chang, Y. H., Ko, W. C., Sriroth, K., Huang, T. C., & Lin, H. H. (2005). Some physical and chemical properties of starch isolates of cassava genotypes. *Starch/Stärke*, 57(2), 76-83. <https://doi.org/10.1002/star.200400332>
- Chavez, A. L., Sánchez, T., Jaramillo, G., Bedoya, J., Echeverry, J., Bolaños, E., Ceballos, H., & Iglesias, C. (2005). Variation of quality traits in cassava roots evaluated in landraces and improved clones. *Euphytica*, 143(1), 125-133. <https://doi.org/10.1007/s10681-005-3057-2>
- De Souza Fernandes, D., dos Santos, T. P. R., Fernandes, A. M., & Leonel, M. (2019). Harvest time optimization leads to the production of native cassava starches with different properties. *International journal of biological macromolecules*, 132, 710-721. <https://doi.org/10.1016/j.ijbiomac.2019.03.245>
- Diallo, Y., Gueye, M. T., Sakho, M., Darboux, P. B., Kane, A., Barthélémy, J.-P., & Lognay, G. (2013). Importance nutritionnelle du manioc et perspectives pour l'alimentation de base au Sénégal — Synthèse bibliographique. *Biotechnology, Agronomy, Society and Environment*, 17(4), 634-643.
- Diallo, Y., Gueye, M. T., Sakho, M., Darboux, P. G., Kane, A., Barthélemy, J.-P., & Lognay, G. (2013). Importance nutritionnelle du manioc et perspectives pour l'alimentation de base au Sénégal (synthèse bibliographique). *Biotechnologie, Agronomie, Société et Environnement*, 17(4), 563-575.
- Ebah-Djedji, B. C., Djè, K. M., N'Zué, B., Zohouri, G. P., & Amani, N. g. G. (2012). Effect of Harvest Period on Starch Yield and Dry Matter Content from the Tuberous Roots of Improved Cassava (*Manihot esculenta* Crantz) Varieties. *Pakistan Journal of Nutrition*, 11, 414-418. <https://doi.org/10.3923/pjn.2012.414.418>
- FAOSTAT. (2023). *Crops and livestock products production*. Retrieved from <https://www.fao.org/faostat/en/#data/QA>
- Gómez, G., Valdivieso, M., & Noma, A. T. (1985). The influence of cultivar and plant age on the chemical composition of field-grown cassava leaves and roots. *Plant Foods for Human Nutrition*, 35(2), 109-119. <https://doi.org/10.1007/BF01092126>

- Hongbete, F., Mestres, C., H.N, A., Pons, B., Hounhouigan, D., Cornet, D., & Nago, C. M. (2011). Effects of cultivar and harvesting conditions (age, season) on the texture and taste of boiled cassava roots. *Food Chemistry*, 126, 127-133. <https://doi.org/10.1016/j.foodchem.2010.10.088>
- Kouadio, K. K., Kouamé, P. L., & Assanvo, J. B. (2020). Évaluation de la qualité physicochimique et technologique des farines de manioc traditionnelles et améliorées en Côte d'Ivoire. *African Journal of Food, Agriculture, Nutrition and Development*, 20(5), 16534-16552. <https://doi.org/https://doi.org/10.18697/ajfand.93.19329>
- Laya Alphonse, Benoît Bargui Koubala, Habiba Kouninki, & Nukenine, E. N. (2018). Effect of Harvest Period on the Proximate Composition and Functional and Sensory Properties of Gari Produced from Local and Improved Cassava (*Manihot esculenta*) Varieties. *International Journal of Food Science*. <https://doi.org/10.1155/2018/6241035>
- Montagnac, J. A., Davis, C. R., & Tanumihardjo, S. A. (2009). Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement. *Compr Rev Food Sci Food Saf*, 8(3), 181-194. <https://doi.org/10.1111/j.1541-4337.2009.00077.x>
- N'Zue, B., Sangare, A., Letourmy, P., Zohouri, G., & Vernier, P. (2009). Morphological characterization of the national cassava (*Manihot esculenta* Crantz) collection in Côte d'Ivoire. *African Journal of Root and Tuber Crops*, 7(1), 32.
- Nauluvula, P., Webber, B. L., Gleadow, R. M., Aalbersberg, W., Hargreaves, J. N. G., Das, B. T., Antille, D. L., & Crimp, S. J. (2025). Time Series Dataset of Phenology, Biomass, and Chemical Composition of Cassava (*Manihot esculenta* Crantz) as Affected by Time of Planting and Variety Interactions in Field Trials at Koronivia, Fiji. *Data*, 10(8), 120. <https://doi.org/10.3390/data10080120>
- Nweke, I. A., Nsofor, C. I., & Mbah, G. O. (2015). Effect of genotype and maturity on mineral composition of cassava roots. *Nigerian Food Journal*, 33(1), 55-62. <https://doi.org/10.1016/j.nifo.2015.04.005>
- Nzola, M., Ndonga, A., Bidiaka, S., Gwanyebit Kehbila, A., Tata-Hangy, W., Tambu, E., & Binzunga, M. (2022, Jun). Screening cassava for time of maturity to respond to various market needs: Case study in African sub-tropical zones. *J Sci Food Agric*, 102(8), 3169-3178. <https://doi.org/10.1002/jsfa.11660>
- N'Zue, B., Okoma, B., Okoma, M., Amani, M. K., Dibi, M., Dibi, K., Goli, B., Essis, P., Essis, B., & Dansi, A. (2014). Morphological characterization of cassava (*Manihot esculenta* Crantz) accessions collected in the centre-west, south-west and west of Côte d'Ivoire. *Greener Journal of Agricultural Sciences*, 4(10), 480-490. <https://doi.org/10.15580/GJAS.2014.6.050614224>
- Oladunmoye, O. O., Aworh, O. C., Maziya-Dixon, B., Erukainure, O. L., & Elemo, G. N. (2014). Chemical and functional properties of cassava starch, durum wheat semolina flour, and their blends. *Food Sci Nutr*, 2(2), 132-138. <https://doi.org/10.1002/fsn3.83>
- Oluwaniyi, O., & Oladipo, J. (2017). Comparative Studies on the Phytochemicals, Nutrients and Antinutrients Content of Cassava Varieties. *Journal of the Turkish Chemical Society, Section A: Chemistry*, 4, 661-661. <https://doi.org/10.18596/jotcsa.306496>
- Ospina Portilla, M., Tran, T., Pizarro, M., Luna, J., Salazar, S., Londoño, L., Ceballos, H., Becerra Lopez-Lavalle, L., & Dominique, D. (2024). Content and distribution of cyanogenic compounds in cassava roots and leaves in association with physiological age. *Journal of the Science of Food and Agriculture*, 104. <https://doi.org/10.1002/jsfa.13123>
- Otekunrin, O. A. (2024). Cassava (*Manihot esculenta* Crantz): a global scientific footprint—production, trade, and bibliometric insights. *Discover Agriculture*. <https://doi.org/10.1007/s44279-024-00121-3>
- Oyeyinka, S., Adeloye, A. A., Smith, S., Adesina, B., & Akinwande, F. (2019). Physicochemical properties of flour and starch from two cassava varieties. *Agrosearch*, 19(1), 28-45. <https://doi.org/10.4314/agrosh.v19i1.3>
- Roux, J.-L. (1994). *Conserver les aliments: Comparaison des méthodes et des technologies*. Technique et Documentation – Lavoisier, Paris. pp. 436-456.
- Scaria, S., Balasubramanian, B., Arun, M., Jaison, J., Gangwar, J., Kurian, J., Pappuswamy, M., pusparaj, K., Park, S., & K S, J. (2024). Cassava (*Manihot esculenta* Crantz)—A potential source of phytochemicals, food, and nutrition—An updated review. *eFood*, 5. <https://doi.org/10.1002/efd2.127>
- Wang, X., Chang, L., Tong, Z., Wang, D., Yin, Q., Wang, D., Jin, X., Yang, Q., Wang, L., Sun, Y., Huang, Q., Guo,

- A., & Peng, M. (2016). Proteomics Profiling Reveals Carbohydrate Metabolic Enzymes and 14-3-3 Proteins Play Important Roles for Starch Accumulation during Cassava Root Tuberization. *Sci Rep*, 6, 19643. <https://doi.org/10.1038/srep19643>
- Williams, G. C., Ansah, K. O., Agbenorhevi, J. K., Oduro, I. N., & Bobobee, E. Y. H. (2019). *Characterization of Starch from New Cassava Accessions at Different Maturity*.
- Zidenga, T., & Sayre, R. (2017). Cyanogen Metabolism in Cassava Roots: Impact on Protein Synthesis and Root Development. *Frontiers in Plant Science*, 8. <https://doi.org/10.3389/fpls.2017.00220>