Journal of Applied Biosciences 225: 25032 – 25044
ISSN 1997-5902

Biochemical clustering and the influence of root pulp colour on the starch, Beta-carotene, and Vitamin C content of 51 cassava genotypes in Burkina Faso

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Submitted 10/08/2026, Published online on 31/10/2026 in the https://www.m.elewa.org/journals/journal-of-applied-biosciences-about-jab/ https://doi.org/10.35759/JABs.225.1

ABSTRACT

Objective: To support efforts to improve the nutritional quality of cassava tubers in Burkina Faso.
Methodology and results **:** The plant material used consisted of the fresh pulp roots of 51 cassava genotypes. Data was collected on eight biochemical traits such as : Moisture (MT), Hydrogen ion concentration (pH), Total titratable acidity (TTA), Total sugars (TSR), Reducing sugars (RSR), Vitamin C (VTC), Starch (STC) Beta-carotene (BTA); Analysis of variance revealed highly significant differences among genotypes. Hierarchical cluster analysis (HCA) grouped the 51 genotypes into three clusters. Yellow pulp roots genotypes are rich in beta-carotene (2.41 ± 0.11 mg/g) than white pulp roots (1.05 ± 0.0911 mg/g) and cream pulp roots (0.79 ± 0.0811 mg/g). But white pulp roots contain more vitamin C and starch than beta-carotene. The starch content is highest in white pulp roots (26.87 ± 0.2511 mg/g), than cream (24.44 ± 0.2111 mg/g), and yellow (20.94 ± 0.2811 mg/g) pulp roots.
Conclusion and application of results : This study found that genotypes with white pulp roots are rich in starch, and that genotypes with yellow pulp root are rich in beta-carotene. Starch-rich genotypes can be processed into atiéké. Beta-carotene-rich genotypes can also be processed into food products rich in provitamin A. The genetic diversity observed among cassava genotypes offers opportunities for selecting new cassava varieties with superior nutritional quality in Burkina Faso.

Keywords : Cassava, genotypes, starch, beta-carotene, Vitamin C, Burkina Faso.

INTRODUCTION

Agriculture is a major historical regional resource that contributes to human well-being by producing, among other things, food, raw materials, and employment (Abou *et al*., 2018 ; Millogo *et al.*, 2018). Cassava (*Manihot esculenta* Crantz) is one of the most important food crops grown and consumed worldwide (Djinadou *et al*., 2018). Both humans and animals consume the tuberous roots and leaves of cassava. According to Diallo *et al*., (2013) and Kouadjo *et al.,* (2019). In West Africa, the cassava root is used primarily in the human diet in a variety of dishes. It serves as a source of calories for rural populations (Biratu *et al*., 2018 ; Adunoye *et al.,* 2022). The pulp colour of the tuberous roots of improved cassava varieties in Burkina Faso is white and rich in carbohydrates primarily starch but very low in protein (Guira, 2016). These varieties, as well as the cultivars currently in use, are also low in vitamin A. Cassava leaves are rich in protein (30%) and vitamins B1, B2, and C (Mabossy-Mobouna and Malaisse, 2021). The processed food products from cassava are widely consumed in Burkina Faso, so it is essential that the roots contain high levels of vitamin A to meet the ongoing needs of children and pregnant women. However, it must be noted that cassava tubers contain relatively low levels of beta-carotene, with the exception of fortified varieties with carotenoids, which can reach levels of over 11.03 µg/g (Djinadou *et al*., 2018). It is to meet this enormous demand for cassava of good nutritional quality that new genotypes obtained through open and controlled hybridization are being introduced from Nigeria and Burkina Faso. The objective of this study is to contribute to improving the nutritional value of cassava roots tubers in Burkina Faso.

MATERIAL AND METHODS

Plant Material: The plant material used in this study consisted of fresh pulp of the tuberous roots of 51 cassava genotypes. It included 29 genotypes from the Institute of Environment and Agricultural Research (INERA) in Burkina Faso and 22 genotypes from the International Institute of Tropical Agriculture (IITA) in Nigeria.

Methods

Preparation of cassava tuber samples: Healthy tubers were selected during harvest for analysis. The weight of a fresh cassava root sample was 150 g. The roots were carefully washed, then peeled, crushed, and ground to obtain a fine, homogeneous paste. Centrifuge tubes were used to hold the paste from each sample for the various assays.

Determination of the moisture content of fresh cassava roots: The moisture content (MC) and dry matter (DM) were determined using the thermogravimetric method specified in the Association of Official Analytical Chemists method (AOAC., 1990). For each sample, the weight of the empty weighing bottle (w_0) was determined, and 5 g (w_s) of ground cassava tuber was added to it. The bottle weighing was then placed in an oven set to 105°C for 24 hours. After removing the bottle from the oven, they were cooled in a hermetically sealed desiccator for 10 minutes, and the baskets were weighed again to obtain a final weight (w_f). The dry residue constituted the dry matter (DM). The moisture content was determined using the following formula.

$$MC = \frac{(w_0 + mw_s) - w_f}{w_s} x100$$

Where w_0 = weight of the empty weighing bottle in grams ; w_s = weigh of the sample in grams

w_f = weigh of the weighing bottle plus the weight of the sample in grams after heating to 105°C

The dry matter content was calculated from the moisture content using the following formula

$$DM = \frac{m_f - wm_s}{w_s} x100$$

Where w_0 = weigh of the empty weighing bottle in grams ; w_s = weigh of the sample in grams

w_f = weigh in grams of the weighing bottle plus the mass of the sample after heating to 105°C

Determination of the pH of fresh cassava roots: The pH of the extract from fresh cassava tubers was determined using a digital pH-meter with a glass electrode according to the AOAC method (1990). pH buffers of 4.0, 7.0, and 10.0 were used to calibrate the pH-meter. The pH was determined by immersing the pre-calibrated glass electrode of the pH-meter in 10 mL of the supernatant obtained after macerating 10 g of the sample in 75 mL of distilled water. The pH value displayed on the pH-meter's screen was recorded and represents the pH of the sample.

Determination of total sugars in fresh cassava roots: The determination of soluble sugars was performed using the phenol-sulfuric acid method described by Dubois *et al*. (1956). In the presence of concentrated sulfuric acid, the sugars are dehydrated to form compounds belonging to the furfural derivative family ($C_5H_6O_2$). These products condense with phenol to form orange-yellow complexes. The formation of these complexes is monitored by measuring the increase in optical density. The reaction mixture consists of 70 µL of extract, 35 µL of 5% phenol, and 175 µL of concentrated sulfuric acid. The reading is taken against a blank consisting of 35 µL of 5% phenol, 175 µL of concentrated sulfuric acid, and 70 µL of 80% ethanol. After 15 minutes of incubation in a water bath at room temperature, the absorbances were measured at 490 nm. The soluble sugar contents were expressed in micrograms of glucose equivalent per 100 grams of powder (µg GE/100 g), calculated using the following formula :

$$\mathbf{X = \frac{C * D}{Ci} * 100}$$

Where X = concentration of soluble sugars in the sample, expressed in mg EG/100 mg of powder

C = concentration of the sample, expressed in mg EG/mL ; D = dilution factor

Ci = initial concentration of the sample (mg/g).

Determination of reducing sugars in fresh cassava roots: Reducing sugars were quantified using the 3,5-dinitrosalicylic acid (DNS) method described by Lam *et al*. (2021). 0.25 g of cassava pulp was dissolved in distilled water to a final volume of 25.0 mL, and 2.0 mL of this solution was diluted to 10.0 mL. After filtration, 2.0 mL of the diluted solution was mixed with 1.5 mL of DNS solution (1.00 g of DNS in 20.0 mL of 2.0 N NaOH solution and 50.0 mL of distilled water ; 30.0 g of potassium sodium tartrate was heated in a water bath until completely dissolved, then diluted to 100.0 mL with distilled water) and 6.5 mL of distilled water for one (01) minute, then heated to 80 °C in a water bath for 10 minutes and cooled by immersion in water for 20 minutes. The resulting solution was analysed by UV-visible spectrophotometry at a wavelength of 546 nm. The values obtained were directly extrapolated to a glucose calibration curve using the same preparation procedures described above. A blank sample was prepared using the same procedure.

Determination of the titratable acidity of fresh cassava roots: Titratable acidity is the sum of free inorganic and organic acids (Berrah and Boudaoud, 2017). This method is based on titrating the acidity of an aqueous solution with a sodium hydroxide solution in the presence of phenolphthalein as a color indicator.

$CH_3\text{-}COOH + NaOH \rightleftharpoons CH_3\text{-}COONa + H_2O$

The titratable acidity is determined according to method NF V 05-101 (1974) described by AFNOR (1986) and applicable to products of plant origin. To perform this test, 10 mL of cassava root juice was placed in a beaker, and then 500 µL of phenolphthalein was added. Next, titrate the solution with a burette using 0.1 N NaOH until a persistent pink coloration was observed for 30 seconds, and read the volume of NaOH that decolorized the solution on the graduated burette. The titratable acidity was expressed as a percentage of citric acid; the determinations were performed in three (03) replicates, and the total titratable acidity (TTA) was calculated using the following formula.

$$\textbf{Rate of TTA Eq. citric acid} = \frac{\mathbf{w(NaOH) * N(NaOH) * 0,07}}{\textbf{extrat volume}} * \mathbf{100}$$

Where : w(NaOH)= 40g/mol ;
N(NaOH) = [NaOH] *V(NaOH) ;
0,07 milliequivalent of citric acid

Determination of vitamin C content in fresh cassava roots: The method used to measure vitamin C levels is the one proposed by Mehta *et al*., (2018). It is also the method for determining ascorbic acid, which is based on its ability to decolorize 2,6-dichlorophenolindophenol (DCPIP). To do this, 50 µL of extract was added to 150 µL of DCPIP (0.2 mM). Absorbance was measured at 515 nm against a blank consisting of 150 µL of DCPIP and 50 µL of distilled water. A calibration curve was established using ascorbic acid at concentrations ranging from 10 µg/mL to 100 µg/mL. Vitamin C content is expressed in mg of ascorbic acid equivalent per 100 g of dry matter (mg AEE/100 g).

Determining the starch content of fresh cassava roots: To determine the starch content, 0.1 g of fresh cassava root paste is added to 5 mL of KOH (1N). The solution is thoroughly mixed at room temperature and then neutralized with 5 mL of HCl (1N). The mixture is then boiled in a water bath for 15 minutes. The volume is adjusted to 10 mL. After centrifugation (at 4,000 rpm for 15 minutes), the supernatant is collected and filtered if necessary. For the assay, 0.05 mL of this solution was added to 4.85 mL of distilled water and 0.1 mL of iodine reagent (I_2/KI), then incubated for 10 minutes before measuring the optical densities at 580 nm. The starch content is determined using a calibration curve with a 5 mg/mL starch solution as the reference sugar (Thivend *et al*., 1965).

Determination of beta-Carotene in fresh cassava roots: The beta-carotene content of cassava pastes was determined using the method described by Nagata *et al.* (1992) with a few minor modifications. 1.0 g of cassava root paste samples was weighed, then 10 mL of acetone-hexane solvent (4 :6) was added and homogenized, followed by centrifugation at 6,000 rpm for 5 minutes. This resulted in phase separation (precipitate and supernatant). The optical density of the supernatant was then measured using an Epoch spectrophotometer simultaneously at 663 nm, 645 nm, 505 nm, and 453 nm. Based on these values, the beta-carotene content was estimated using the equations below. The beta-carotene content was determined using the following formula.

$$\textbf{β-carotène } (\frac{\mathbf{mg}}{\mathbf{100mL}}) = \mathbf{0,216A_{663} - 0,30A_{505} + 0,452A_{453}}$$

β-carotène = β-carotène content in mg/g
A_{663} = absorbance at 663 nm ;
A_{645} = absorbance at 645 nm ;
A_{505} = absorbance at 505 nm ;
A_{453} = absorbance at 453 nm.

Data analysis: All analyses were performed using R software version 4.5.1. Analysis of variance (ANOVA) followed by the Newman-Keuls test for comparing means at the 5% significance level was conducted. Pearson's correlation matrix was calculated to establish relationships among the biochemical variables studied. Principal Component Analysis (PCA) was performed to determine the main

associations among the traits and to identify those most representative for grouping genotypes via H**ierarchical cluster analysis** (HCA) using Ward's aggregation method and Euclidean distance. The same R software was used for Discriminant Factor Analysis (DFA) to characterize the groups resulting from the HCA.

RESULTS

Variance of biochemical traits: All genotypes showed highly significant differences for all traits evaluated. Table 1 below presents details on the performance of the genotypes studied. The moisture content (MT) of fresh cassava roots ranged from 22.86% to 85.71%, with an average of 70.25%. The pH of the various solutions prepared from fresh cassava tuber roots ranged from 5.52 to 6.75, with an average of 6.25 for all genotypes. The total titratable acidity (TTA) ranged from 1.23% to 6.83%, with an average of 3.24%. The total sugar content (TSR) ranged from 0.19 mg to 20.89 mg, with an average of 5.59 mg. The reducing sugar content (RSR) ranged from 1.17 mg to 14 mg, with an average of 6.27 mg. Vitamin C (VTC) ranged from 0.10 mg to 2.80 mg, with an average of 1.82 mg. Unlike vitamin C, fresh cassava tubers have a high starch content (STC). It ranged from 0.11 mg to 82 mg, with an average of 24.63 mg per unit of fresh cassava root. As for beta-carotene (BTA), it ranged from 0.01 mg to 5.80 mg, with an average of 1.29 mg.

Table 1: Genotypes performances based on biochemical traits

Caractères	Min	Max	AVG	CV (%)	F-value	Pr (> F)	Significant
MT (%)	51.43	85.71	70.95	8.60	3.04	9.36e-07	***
pH	5.52	6.75	6.25	4.91	68.18	<2e-16	***
TTA (%)	1.26	6.83	3.25	33.41	5.227	<2e-16	***
TSR (mg/100g)	0.19	20.89	5.59	75.61	68.04	<2e-16	***
RSR (mg/100g)	0.12	0.97	0.62	16.63	6.58	<2e-16	***
VTC (mg/100g)	0.10	2.80	1.81	21.09	25.76	<2e-16	***
STC (mg/100g)	0.11	82.00	24.63	81.08	56.88	<2e-16	***
BTA (mg/100g)	0.01	5.80	1.29	106.45	10.79	<2e-16	***

Legend: MT: Moisture; pH: Hydrogen ion concentration; TTA : Total titratable acidity; TSR: Total sugars; RSR: Reducing sugars; VTC : Vitamin C; STC: Starch; BTA: Beta-carotene; Min : Minimum; Max : Maximum; AVG: Average; CV : Coefficient of Variation; F-Value: Fisher's F-value; Pr (>F): Factor probability; (***): Very highly significant.

Relationship among the biochemical traits : The Pearson correlation matrix revealed correlations among the various biochemical traits studied. Positive correlations were observed among the biochemical traits. In fact, a strong positive correlation was found between reducing sugar content and vitamin C ($r = 0.79$). A weak positive correlation was found between moisture content and pH in fresh tuberous roots ($r = 0.21$). However, negative correlations were observed between certain traits, namely: pH and total titratable acidity ($r = -0.50$), beta-carotene content and reducing sugar content ($r = -0.48$), and beta-carotene and vitamin C ($r = -0.31$). Figure 1 below shows the correlations among the biochemical traits studied.

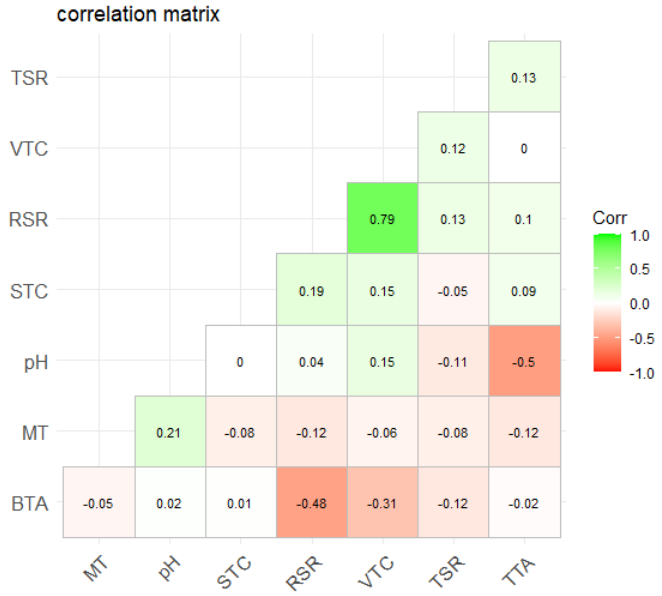


Figure 1: Correlation matrix between biochemical traits

Representation of the traits on the axes: The total variability explained by the first two axes is 83.97% (Table 2). The plane formed by Dim 1 and Dim 2 accounted for 83.97% of the total variability. Two traits contributed most to Dim 1, accounting for 50.32% of the total inertia. The most significant contributors to Dim 1 were reducing sugars (50.45%) and beta-carotene (43.24%). Dim 2 accounts for 33.65% of the total inertia. Starch alone contributes the most to this value.

Table 2 : T**raits contribution to the axis achievement**

	Dim 1	**Dim 2**
Eigenvalues	1,51	1,01
Variance (%) of var.	50,32	33,65
Cumulative (%) of var.	50,32	83,97
RSR (mg/g)	50,45	0,04
STC (mg/g)	6,32	85,90
BTA (mg/g)	43,24	14,07

Legend : RSR : Reducing sugars ; STC : Starch; BTA : Beta-carotene; var : variance ; Dim 1 : Dimension 1 ; Dim 2 : Dimension 2

Grouping of genotypes:

H**ierarchical cluster analysis** (HCA) was performed based on the following biochemical traits : starch; reducing sugars; and beta-carotene. The dendrogram generated by the HCA analysis grouped the 51 genotypes into three (03) groups. Figure 2 below shows the dendrogram that grouped the genotypes into three groups.

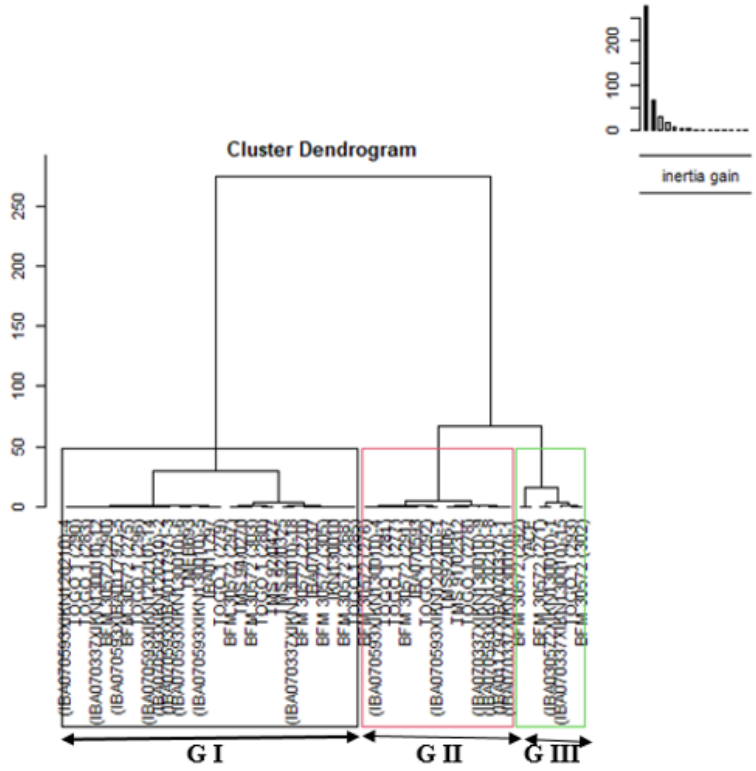


Figure 2: Dendrogram generated by HCA of the 51 genotypes

Characterization of groups: Discriminant Factor Analysis was used to characterize the three (03) biochemical groups identified (Figure 3). Group I consists of 27 genotypes with low levels of starch, reducing sugars, and beta-carotene. Group II comprises 17 genotypes with low starch content, moderate beta-carotene content, and high reducing sugar content. Group III consists of 7 genotypes with high starch content and low levels of reducing sugars and beta-carotene.

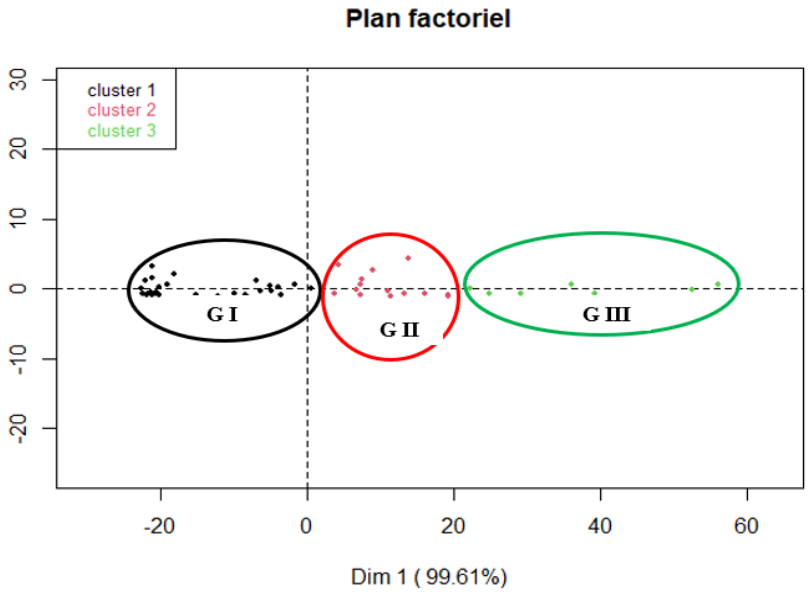


Figure 3 : Projection of the groups onto the plane formed by the first two dimensions of the AFD.

Variation of biochemical traits according to roots pulp colour: The analysis of variance for genotypes according to roots pulp colour did not reveal a significant difference for the tuber root moisture content trait (P = 0.63). The total sugars trait got a P-value = 0.026, indicating a marginally significant difference among genotypes for this trait. However, the titratable acidity and vitamin C traits showed P-values = 0.0078 and 0.0020, respectively, indicating a highly significant difference across all genotypes. Finally, the traits pH, reducing sugars, starch, and beta-carotene showed very low P-values, well below 0.05; these results reveal a highly significant difference among the genotypes in terms of cassava pulp colour (Table 3).

Table 3: Genotypes performance based on root pulp color

RPC / Traits	White	Creamy	Yellow	F-value	Pr (> F)	Significant
MT (%)	71.29±4.53a	71.06 ±6.70a	70.35±6.78a	0.47	0.63	**NS**
pH	6.34±0.39a	6.225± 0.24b	6.23±0.29b	53.58	<2e-16	***
TTA (%)	2.99±0.81b	3.38±1.24a	3.36±1.08a	5.10	0.0078	**
TSR (mg/g)	5.70±0.12a	5.71±0.11a	5.26±0.14b	3.78	0.026	*
RSR (mg/g)	0.61±0.11b	0.64±0.07a	0.59±0.13b	9.53	0.00016	***
VTC (mg/g)	1.82±0.45a	1.84±0.20a	1.75±0.51b	6.60	0.0020	**
STC (mg/g)	26.87±0.25a	24.44±0.21b	20.94±0.28c	128.50	<2e-16	***
BTA (mg/g)	1.05±0.09b	0.79±0.08c	2.41±0.11a	79.82	<2e-16	***

Legend : RPC : Root pulp color ; MT : Moisture; pH: Hydrogen ion concentration; TTA : Total titratable acidity; TSR: Total sugars; RSR: Reducing sugars; VTC: Vitamin C; STC: Starch; BTA: Beta-carotene;; F-Value : Fisher value; Pr (>F): Factor probability; (***): Very highly significant; (**): Highly significant; (*): Significant; (NS): Not significant.

The results are the means of the parameters for each pulp color group, and those with the same letter or a shared letter in the same row are not statistically different according to the Newman-Keuls test for comparison of means at the 5% significance level.

DISCUSSION

The analysis of variance for genotypes revealed a highly significant difference for all traits studied. This variability among genotypes reflects the high heterozygosity of cassava (Aleves, 2002). Remarkable variations were observed in the starch content of fresh cassava tubers, ranging from 0.21 mg/g to 82 mg/g. This variation in starch content is primarily genetic and secondarily physiological. In fact, starch content increases with the age of the tuberous root until the root reaches physiological maturity and decreases when the root begins to lignify and subsequently deteriorate. This variation in starch content is also observed in potatoes. According to Guilao *et al*., 2023, cassava contains approximately 20% to 80% starch, compared to 23% to 77% for potatoes and 25% to 75% for corn. It should be noted that starch content varies by species. Principal Component Analysis (PCA) applied to the 51 genotypes based on the biochemical traits studied revealed significant variability (83.97%) among the genotypes along the first two dimensions. The levels of starch, reducing sugars, and beta-carotene were the most discriminating traits among the genotypes. Indeed, starch is a major biochemical compound in cassava and other root or tuber crops. Starch is the primary carbohydrate reserve synthesized by higher plants from solar energy. It constitutes a predominant fraction, ranging from 60% to 90% in tubers (Sidibé *et al.,* 2007). The genotypes had average reducing sugar and total sugar contents of 0.62 mg/g and 5.59 mg/g, respectively. These values are lower than those reported by Guira (2016), who found reducing sugar and total sugar contents of 1.48 mg/g and 7.62 mg/g, respectively, in fresh cassava tubers. This discrepancy may be attributed to the genetic potential of the genotypes used in the present study and to physiological factors such as the age of the tuber. Wireko-Manu *et al*. (2013) demonstrated that the degree of maturity of the yam tuber has a significant influence on the physicochemical quality of the food product for which it serves as the raw material. A negative correlation was observed between pH and total titratable acidity (r = -0.50). Indeed, pH and titratable acidity are two characteristics that are inversely related in the physicochemical composition of foods. This result is similar to that reported by Degnon *et al*. (2018), who found, in cassava chip samples, pH values ranging from 5.01 to 6.50 (low pH) and titratable acidity ranging from 8.01 to 13.44 (high acidity). In an aqueous medium containing cassava, fermentation is triggered, which would explain a decrease in pH and an increase in titratable acidity. Similar results were reported by Ajifolokun (2018) in comparable studies. Furthermore, Rebouças *et al*. (2016) ; Alphonce and Kaalé (2020) ; and Boli *et al*. (2023) reported that acidity levels increase during the fermentation of cassava roots. This finding supports our result showing a negative correlation between hydrogen ion concentration and the titratable acidity of cassava tubers. This increase in acidity in the fermented samples studied could be linked to the accumulation of organic acids, particularly lactic, acetic, and succinic acids, which acidify the medium (Oduah *et al*., 2015). Hierarchical cluster analysis (HCA) divided the genotypes into three groups. Discriminant Factor Analysis characterized these three groups derived from the HCA based on starch, reducing sugar, and beta-carotene content, which were the main characteristics of cassava. The colour of the cassava pulp is a determining factor in total starch and sugar content. In fact, white pulp contains higher levels of starch and sugar than cream coloured and yellow pulp. The results revealed that the tuberous roots of cassava with yellow pulp have a higher beta-carotene content than those with white and cream pulp. The beta-carotene content of the yellow pulp ranged from 0.28 to 5.80 mg/g, with an average of 2.41 mg/g. These values are

higher than those obtained by Mahungu *et al*. (2022), who achieved a content of 9.5 µg/g (measured using an iCheck Carotene device) after biofortifying the genotypes with carotenoids. This discrepancy can be explained, on the one hand, by the genetic effects of cassava genotypes and, on the other hand, by the method used to determine beta-carotene levels. In contrast, orange-fleshed sweet potatoes contain more beta-carotene than cassava, according to the results of Somé's 2012 study, which showed that beta-carotene levels in orange-fleshed sweet potatoes reached 10.85 mg per 100 g of fresh sweet potato root. Similarly, concentrations of 11.03 µg/g were observed by Djinadou *et al.,* 2018 in a study evaluating the performance of improved beta-carotene-rich cassava varieties in southern Benin; this result supports our finding that carotenoid-enriched cassava may contain vitamin A. The evaluation of the genotypes' biochemical traits showed that white-coloured roots contain more vitamin C than yellow-coloured ones. In fact, according to Ayata *et al.* (2010), cassava contains more vitamin C per 50 mg of fresh weight than certain root and tuber crops such as yams, orange-fleshed sweet potatoes, and taro, which contain 25 mg, 35 mg, and 10 mg, respectively, per 50 g of fresh weight. However, the vitamin A content of these species exceeds that of cassava (Ayata *et al*., 2010). In fact, they contain higher levels of vitamin A: 117 mg for yams, 900 mg for orange-fleshed sweet potatoes, and 0 to 42 mg for taro per 100 g of fresh matter of each of the aforementioned species (Ayata *et al*., 2010). As a result, the levels of beta-carotene (provitamin A) and vitamin C are inversely proportional in these tubers or roots. Creating a cassava ideotype that combines both high levels of beta-carotene and vitamin C would be difficult through hybridization.

CONCLUSION AND APPLICATION OF RESULTS

This study revealed significant biochemical variability among the 51 genotypes studied. Analysis of variance showed highly significant differences among genotypes for all biochemical traits. A strong, positive correlation was observed between reducing sugar content and vitamin C. However, negative correlations were noted between pH and total titratable acidity, and between beta-carotene content and reducing sugar content. This study revealed significant biochemical variability among the 51 genotypes studied. Analysis of variance showed highly significant differences among genotypes for all biochemical traits. A strong, positive correlation was observed between reducing sugar content and vitamin C. However, negative correlations were noted between pH and total titratable acidity, and between beta-carotene content and reducing sugar content. The HCA grouped the 51 genotypes into three (03) classes based on discriminating traits such as starch content, reducing sugar content, and beta-carotene content. Yellow-fleshed genotypes are richer in beta-carotene than white- and cream-fleshed ones. In contrast, white pulp root tubers contain more vitamin C and starch than beta-carotene. Starch content is highest in white pulp root tubers, followed by cream pulp root, and finally yellow pulp root. These results should be validated through tests of hydrogen cyanide content in the tuberous roots to identify genotypes with low levels that can be consumed raw without processing. Starch-rich genotypes will be used for processing into attiéké. Furthermore, beta-carotene-rich genotypes will be used for processing into fruits and organic foods fortified with vitamin A for children, especially those who are malnourished.

ACKNOWLEDGMENTS

The authors would like to express their sincere thanks to the team at the Laboratory of Biochemistry, Biotechnology, Food Technology, and Nutrition (LABIOTAN) at Joseph KI-ZERBO University, as well as to the Institute of Environment and Agricultural Research (INERA)/CNRST in Burkina Faso.

REFERRENCES

Abou M, Yabi I, Yolou I, Ogouwale E, 2018. Caractérisation des systèmes de production sur les sites d'aménagements hydro-agricoles dans le doublet DangboAdjohoun au sud du Bénin. International Journal of Biological and Chemical Sciences, 12(1) : pp. 462-478. DOI : : https://dx.doi.org/10.4314/ijbcs.v12i1.36

Adunoye OV, Olanrewaju E, Adesanya O Okechukwu R, Ngozi N, 2022. Manuel de formation sur la production et la transformation du manioc, IITA/Nigeria, 97p.

Agré A, Dansi A., Rabbi I., Battachargee R, Dansi M, Melaku G, 2015. Agromorphological characterization of elite cassava (*Manihot esculenta* Crantz) cultivars collected in Benin. *Int. J. Curr. Res. Biosci. Plant Biol.,* 2(2): pp. 1-14.

AFNOR 1986. Recueil de normes francaises, produits dérivés des fruits et légumes, jus de fruits. 2e Edition.

Ajifolokun OM, 2018. Physico-Chemical Characteristics and Storage Stability of Breadfruit and cassava co-fermented into gari analogue. *Journal of Food, Nutrition* and population health,2(1) : pp. 1-5. DOI : https://doi.org/10.21767/2577-0586.100034

Alves AAC, 2002. Cassava botany and physiology. In : R. J. Hillocks JMT and ACB, ed. Cassava : Biology, Production and Utilization. CAB International : Oxford, UK, pp. 67–89.

Alphonce S, Kaale LD, 2020. Assessment of Biochemical Changes during Fermentation Process for production of Traditional Fermented Cassava Meal "Mchuchume". *Tanz. J. Sci.* **46**(2) : pp. 228-240. DOI : https://dx.doi.org/10.4314/tjs.v46i2.4

Ayata SD, Loeillet D, Bréhinier G, 2010. Racine et tubercules Contenu publié par l'Observatoire des marcés du CIRAD, n°182 52p.

Biratu GK, Elias E, Ntawuruhunga P, Nhamo N, 2018. Effect of Chicken Manure Application on cassava Biomass and Root Yields in Two Agro-Ecologies of Zambia. Agriculture, **8**(45): pp. 1–15. DOI: https://doi.org/10.3390/agriculture8040045

Boli ZBIA, Goly KRC, N'sa KMC, Kouacou YSSH, Koffi-Nevry R, 2023. Variation des caractéristiques physico-chimiques et microbiologiques au cours de la production du ferment traditionnel des racines de manioc (*Manihot esculenta* Crantz) bouillies avec la pelure. *Int. J. Biol. Chem. Sci.* **17**(3) : pp. 1163-1179, DOI : https://dx.doi.org/10.4314/ijbcs.v17i3.31

Degnon GR, Konfo TRCS, Adjou E, Ahoussi DE, 2018. Evaluation des conditions de production de la qualité physico-chimique et microbiologique des cossettes de manioc (*Manihot esculanta* Crantz) dans la commune de Bassila (Nord-Bénin). *Int. J. Biol. Chem. Sci.* 12(3) : pp 1528-1541. DOI :

https://dx.doi.org/10.4314/ijbcs.v12i3.36

Diallo Y, Gueye MT, Sakho M, Darboux PG, Kane A, Barthelemy GP Lognay G, 2013. Importance nutritionnelle du manioc et perspectives pour l'alimentation de base au Sénégal. Biotechnologies Agronomie Société et Environnement, 17, pp. 634-643.

Djinadou AKA, Olodo NI, Adjanohoun A, 2018. Evaluation du comportement de variétés améliorées de manioc riches en bêta-carotène au Sud du Bénin. *Int. J. Biol. Chem. Sci.* **12**(2) : pp 703-715. DOI : https://dx.doi.org/10.4314/ijbcs.v12i2.8

Guilao M, Bah TV, Diallo MST, Camara AK, Diané S, Camara A, Traoré MS, Baldé ES, 2024. Production et caractérisation de l'amidon de manioc et de maïs pour la fabrication de médicaments traditionnels améliorés pp 143-148. *Guinée Médicale.***107**(3*)* : pp. 143-148.

Guira F, 2016. Potentialités technologiques des racines de manioc à travers la production del'*attiéké* : aspects nutritionnels, biochimiques, microbiologiques et moléculaires. Thèse unique de doctorat de l'Université Joseph KI-ZERBO 173 p.

Kouadio KE, Kreman K Bamba KL Kouadja GS, 2019. Effet de la farine d'épluchures de manioc sur les performances zootechniques et économiques du poulet de chair au démarrage en Côte d'Ivoire. *J. Anim. Plant Sci*. 42(2) pp : 7237-7244. DOI: https://doi.org/10.35759/JAnmPlSci.v42-2.5

Lam, HH, Dinh TH, Dang-Bao T, 2021. Quantification des sucres totaux et des sucres réducteurs d'échantillons de sucre dérivés du fruit du dragon par la méthode spectrophotométrique UV-Vis. Dans *la série de conférences IOP : Sciences de la Terre* et de l'environnement 947(1) : pp. 1-6.

Mabossy-Mobouna G, Malaisse F, 2021. Etude socio-économique de la consommation des feuilles de manioc (*Manihot esculenta* Crantz) dans la ville de Brazzaville (République du Congo). *Geo-Eco-Trop*, 45(1) : pp. 9-29

Mahungu NM, Ndonda A, Kendenga T, Bidiaka S, 2022. Amélioration génétique et sélection du manioc en République Démocratique Congo. Dans le Manioc en République Démocratique du Congo. pp.15-64.

Millogo V, Sissao M, Ouédraogo GA, 2018. Qualité nutritionnelle et bactériologique des échantillons de quelques produits laitiers locaux de la chaîne de production au Burkina Faso. *International Journal of Biological and Chemical Sciences*, 12(1) : 244-252. DOI : https://dx.doi.org/10.4314/ijbcs.v12i1.19

Ministère de l'Agriculture, des Ressources Animales et Halieutiques, 2025. Filière manioc plan d'action de 2025-2029. 71 p.

N'zué B, Okana M, Kouakou A, Dibi K, Zouhouri G, Essis B, 2014. Morpholoical 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(6): pp. 220-231. DOI: http://dx.doi.org/10.15580/GJAS.2014.6.050614224

Nagata M, and Yamashita, I, 1992. Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. Nippon shokuhin kogyo gakkaishi, 39(10), pp. 925-928. DOI : https://doi.org/10.3136/nskkk1962.39.925

Oduah NO, Adepoju PA, Longe O, Elemo GN, Oke OV, 2015**.** Effects of fermentation on the quality and composition Of Cassava Mash (Gari). *International Journal of Food Nutrition and Safety,* 6(1) : pp. 30-41. DOI : https://www.researchgate.net/publicatio n/291522343

Rebouças KH, Gomes LP, Leite AMO, Uekane TM, Rezende CM, Inês MBT, Almeida EL, Del AEM, and Paschoalin VMF, 2016. Physicochemical Characteristics Evaluating and Rheological Microbial Community Dynamics during the Natural Fermentation of Cassava Starch. *Journal of Food Technology Processing* 7(4) : pp. 1-9. DOI : https://dx.doi.org/104172/2157-7110.1000578

Sidibé D, Sako A, Agbo NG, 2007. Etude de quelques propriétés physico-chimiques des amidons de cinq variétés de manioc (*Manihot esculenta* Crantz) cultivées en Côte d'Ivoire : Attiéké mossi 1, attiéké Mossi 2, Agbablé 1, Kétévie et TA(8), Rev. Cames, **05** : pp. 92-97.

Somé K, 2012. Genetic Improvement of Sweet potato (Ipomoea batatas [L,] Lam) For beta-carotene and yield in Burkina Faso, PhD Thesis, University of Ghana, Legon, Accra, pp.103-105.

Thivend P, Mercier C, Guilbot A, 1965. Dosage de l'amidon dans les milieux complexes. In Annales de Biologie Animale Biochimie Biophysique 5(4) pp. 513-526). EDP Sciences.

Wireko-Manu, FD, Oduro I, Ellis WO, Asiedu R, Maziya-Dixon B, 2013. Food quality changes in water yam (Dioscorea alata) during growth and storage. Asian. *J. Agric. Food Sci.,* 01, pp. 66–72