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Physico-chemical and biochemical characteristics of improved cassava varieties in Cote d'Ivoire

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Cassava, characteristics, valorization.

1 SUMMARY

Cassava (*Manihot esculenta* Crantz) has large potential as a food and industrial crop. The National Center of Agronomic Research proposed nine varieties (V4, V23, V60, V61, V62, V63, V64, V65 and V66) that have good yield and are resistant to many diseases (cassava common mosaic, bacterial wilt, blight leaf spot, etc.), for release to farmers. Physicochemical and biochemical characteristics of the roots and sensorial characteristics of their *attiéké* (a fermented cassava couscous) were performed, in order to identify the most suitable varieties as far as nutritional and industrial uses are concerned.

ANOVA revealed significant difference between varietal characteristics. Varieties V4 and V62 presented the highest energy value (183.96 and 168.16 kcal/100g), carbohydrate (40.14 and 38.09 g/100g), starch (23.17 and 23.24 g/100g) and dry matter (43.59 and 40.40 g/100g) while their moisture (56.41 and 59.16 g/100g), acidity (44.46 and 73.03 meq/100g) and reducing sugar (0.48 and 0.86 g/100g) were low. In contrast, varieties V23 and V60 registered the least energy value (122.70 kcal/100g), carbohydrate (22.45 g/100g), starch (3.83 g/100g) and dry matter (26.94 g/100g) while their moisture (73.05 g/100g) and reducing sugar (1.5 g/100g) were the highest. Varieties V61, V63, V64, V65 and V66 presented intermediate values of carbohydrate (30.32 g/100), starch (11.50 g/100g), dry matter (32.97 g/100g), energy value (136.95 kcal/100g), reducing sugar (1.090 g/100g) and moisture (67.03 g/100g); and high content of ash (0.52 g/100g), acidity (95.89 meq/100g), cyanide (10.93 mg/100g) and vitamin C (8.28 mg/100g). Sensorial characteristics (taste, texture and fiber) of the *attiéké* were on the whole, acceptable by consumers. Varieties V62 and V4 presented superior characteristics in comparison to the other varieties.

2 INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is among the most important root crops in the world and it provides food for one billion people (Bokanga, 2001; FAO, 2008). It contributes significantly to the economy of most tropical countries (Cock, 1985; Bokanga, 2001; Kawano *et al*., 2003; Amani *et al.,* 2005) through processing into various products (Abu *et al*., 2006; Assanvo, 2008; Apea-Bah *et al.,* 2009). Due to its importance research has been undertaken to improve cassava productivity and to produce superior varieties that not only guarantee food security but also provide good quality raw material for several industries (FAO, 2008).

In Côte d'Ivoire, new cassava varieties are regularly being bred, assessed and selected by the National Center of Agronomic Research (CNRA) for their high yield and resistance to pests and diseases (N'zué *et al.,* 20004). Results obtained from these research efforts have been satisfactory. Thus, new better performing cassava varieties (resistant to diseases and good yield productivity) were obtained after several crosses between a local variety V4 (IAC, white color) and an imported variety V23 (Anango agba, yellow color).

However, before any dissemination, it is important to determine the physicochemical, biochemical and sensorial characteristics of the varieties. Therefore, this study aimed to identify, among the improved varieties, those which present superior properties in order to valuate and popularize them.

3 MATERIALS AND METHODS

3.1 Samples preparation: The roots of seven improved cassava varieties (V60, V61, V62, V63, V64, V65 and V66) and two original local varieties V4 (white flesh) and V23 (yellow flesh) were obtained from eleven months old plants grown at the CNRA experimental plot (Adiopodoumé, Côte d'Ivoire). The fresh roots were washed, peeled manually and cut into small pieces with a knife. The pieces were thoroughly washed and grated finely with a kitchen chopper. The paste obtained was homogenized and stored in portions of 250 g in aseptic polyethylene bags at -18°C until analyses. All reagents used were of analytical grade.

3.2 Physico-chemical and biochemical characterisation: Moisture, dry matter and ash contents were determined using the AOAC (1980) methods. Total cyanogen content was determined by the method of Liebig-Deniges (1971) while pH was directly read with a pH-meter (Roucaire, Metr Ohm 632), and the total titrable acidity evaluated on cassava juice obtained from 40 g of paste.

BIPEA (1976) methods were used to determine fat and protein contents. Vitamin A and carotenoids contents were evaluated using the spectronic method of Rougereau (1981); Vitamin C content was obtained using Tillmanns and Hirsch (1932) method. Reducing and total sugars were evaluated by the methods of Bernfeld (1955) and Dubois *et al.* (1956), respectively.

Carbohydrate and starch contents were calculated by difference following the equation of Coulibaly (2008). Energy value was calculated using the equation described by Atwater and Rosa (1899).

3.3 Sensory analysis of "attiéké" from each variety: *Attiéké* of each variety was prepared following the process described by Assanvo (2008). Fermented cassava roots were added to peeled fresh cassava and together they were grated with a commercial mechanical grater. The paste obtained, was fermented for about fifteen (15) hours after which, it was squeezed. The dehydrated paste was sifted, granulated and sun-dried for about one (1) hour. The attiéké resulted from the steaming the granules. The sensorial analysis of the attiéké was part of the hedonic analysis. A panel of 24 assessors (14 females, 10 males aged between 15 and 40 years) were trained following international standards (ISO, 1993) to appreciate sensorial characteristics of the *attiéké*. Each assessor received a list on an index card of tasting on which were mentioned evaluating criteria on taste, texture, and presence or absent of fibers. These criteria were assigned a score ranging from 1 to 5, with 1 corresponding to very bad, 2 - bad, 3 - acceptable, 4 - good and 5 - very good (Sauvageot, 1980).

3.4 Statistical analysis: All analyses were performed in triplicate. The data analysis was conducted using EXCELL and XLSTAT version 2007. For physico-chemical and biochemical

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parameters, Simple Statistic Analysis was used to get means and standard deviations. Then, Principal Component Analysis (PCA) leading to the principal component and the Hierarchical Ascendant Classification (HAC) was brought in to get different clusters of cassava varieties based on their characteristics. The sensorial data were treated by Analyses of Variances (one way ANOVA) in order to detect eventual variation among sensorial annotations. Duncan's test at 95% confidence level was used to determine significant differences among the varieties.

4 RESULTS

4.1 Physicochemical and biochemical characteristic: Varieties V4, V60, V61, V62, V63, V64, V65 and V66, registered 142.48 kcal/100g as mean of the energy value (Table 1). This characteristic is correlated to the carbohydrate (r= + 0.924, p=0.05), starch (r= + 0.692, p=0.05), dry matter (r= + 0.971, p=0.05) and moisture content (r= -0.971, p=0.05), as shown in table 2. The cyanide content was relatively high (10.15 mg/100g), as well as the acidity (82.19 meq/100g) (Table 1).

Table 1: Physico-chemical and biochemical characteristics of nine cassava varieties in Cote d'Ivoire.

Parameter	**Mean ± SD**
Cyanide (mg/100g)	10.15 ± 4.36
Dry matter (g/100g)	33.70 ± 5.85
Moisture (g/100g)	66.31 ± 5.83
Carbohydrate (g/100g)	30.53 ± 6.16
Starch (g/100g)	12.40 ± 8.357
Energy value(kcal/100g)	142.48± 22.60
Reducing sugar (g/100g)	1.09 ± 0.48
Ash (g/100g)	0.44± 0.18
Acidity (meq/100)	82.19 ± 21.33
Total sugar (g/100g)	16.75± 6.08
Fat (g/100g)	1.55 ± 1.11
pH	5.95 ± 0.12
Carotenoid m(g/100g)	0.11± 0.06
Vitamin A (mg/100g)	17.89 ± 15.42
Protein (mg/100g)	1.61 ± 0.70
Vitamin C (g/100g)	6.89 ± 2.17

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Table 2: Pearson's correlation between physico-chemical and biochemical characteristics of cassava Varieties evaluated in Cote d'Ivoire.

Variables	Cyanide	Dry matter	Moisture	Carbohydrate	Starch	Energy value	Red.* sugar	Ash	Acidity
Dry mater	-0.107								
moisture	0.106	**-1.000**							
Carbohydrate	-0.119	**0.985**	**-0.985**						
Starch	0.007	**0.733**	**-0.733**	**0.762**					
Energy value	-0.189	**0.971**	**-0.971**	**0.924**	**0.692**				
Red. sugar	0.468	-0.530	0.529	-0.607	**-0.750**	-0.503			
Ash	**0.698**	0.043	-0.043	0.022	-0.033	0.002	0.281		
Acidity	0.541	-0.341	0.339	-0.292	-0.455	-0.442	0.518	0.643	
Vitamin C	-0.001	0.037	-0.038	0.200	0.135	-0.167	-0.352	0.078	0.377

NB: Significant correlations are marked bold; *red. Sugar = reducing sugar.

Principal Component Analysis revealed ten (10) principal components represented by cyanide, acidity, energy value, carbohydrate, starch, dry matter, moisture, ash, vitamin C and reducing sugar (data not shown). ANOVA performed on these ten characteristics showed significant variation between varieties (Table 3).

Varieties V4 and V62 presented the highest energy value (183.96 and 168.16 kcal/100g), carbohydrate (40.14 and 38.09 g/100g), starch (23.17 and 23.24 g/100g) and dry matter (43.59 and 40.84 g/100g), while their moisture content (56.41 and 59.16 g/100g) and reducing sugar (0.48 and 0.86 g/100g) were low. As for acidity, ash and cyanide content, the values ranged from 44.46 to 116.68 meq/100g, 0.25 to 0.86 g/100g and 5.1 to 20.4 mg/100g, respectively, for variety V4 and V62. The highest values were presented by variety V61 and the lowest for varieties V4, V60 and V23. Variety V23 showed the least vitamin C content (2.6 g/100g).

Table 3: Physico-chemical and biochemical characteristics of nine cassava varieties evaluated in Cote d'Ivoire.

Variety	Acidity (meq/100g)	Vitamin C (g/100g)	Cyanide (mg/100g)	Reducing sugar (g/100g)	Moisture (g/100g)	Dry matter (g/100g)	Carbohydrate (g/100g)	Starch (g/100g)	Energy value (kcal/100g)	Ash (g/100g)
V61	**116.68a**	6.16**d**	**20.4a**	1.6**b**	68.32**d**	31.68**f**	27.83**g**	11.5**d**	133.83**g**	**0.86a**
V63	105.42**b**	8.18**c**	10.02**d**	**1.67a**	64.85**g**	35.15**c**	32.02**d**	1.82**h**	142.7d	0.51**b**
V66	91.41**c**	9.22**b**	7.91**g**	0.86**d**	65.21**f**	34.79**d**	32.72**c**	13.09**c**	145.97**c**	0.4**cd**
V64	89.43**d**	**9.53a**	7.65**h**	0.51**f**	69.88**c**	30.12**g**	28.51**f**	10.84**e**	124.63**h**	0.4**cd**
V65	76.5**e**	8.34**c**	8.67**e**	0.81**e**	66.88**e**	33.12**e**	30.54**e**	20.28**b**	137.63**f**	0.45**bc**
V62	73.03**f**	6.12**d**	10.97**c**	0.86**d**	59.16**h**	**40.4b**	38.09**b**	**23.24a**	168.16**b**	0.27**e**
V23	72.42**g**	2.6f	5.1i	1.41**c**	70.7**b**	29.3**h**	24.03**h**	3.32g	138.45**e**	0.35**d**
V60	70.4**h**	6.16**d**	12.24**b**	1.59**b**	**75.41a**	24.59i	20.87i	4.34**f**	107i	0.25e
V4	44.46i	5.7**e**	8.42**f**	0.48f	56.41i	**43.59a**	**40.14a**	**23.17a**	**183.96a**	0.45**c**

NB: In each column, means followed by different letters (a, b, c, etc.) are significantly different; the lowest values are underlined and the highest are marked in bold.

In summary, results of the Hierarchical Ascendant Analysis led to three clusters with variable characteristics (Table 4). Cluster 1 was formed by variety V4 and V62, and it presented the highest energy (176.06 kcal/100g), carbohydrate (39.11 g/100g), starch (23.20 g/100g) and dry matter (42.26 g/100g) value while their acidity (58.75 meq/100g), reducing sugar (0.67 g/100g) and moisture content (57.78 g/100g) were the lowest. In contrast, the second cluster comprised of variety V23 and V60, and had the highest reducing sugar content (1.5 g/100g) and the lowest values for energy (122.70 kcal /100g), carbohydrate (22.45 g/100g), starch (3.83 g/100g) and dry matter (26.94 g/100g). Varieties V23 and V60 also contained little cyanide (8.67 mg/100g) and vitamin C (4.38 g/100g). Cluster 3 (V61, V63, V64, V65 and 66) presented intermediary values for all the characteristics, except they had the highest cyanide (10.93 mg/100g), acidity (95.89 meq/100g) and vitamin C content (8.28 g/100g) (Table 4).

Table 4: Characteristics of cassava varieties evaluated in Cote d'Ivoire, organized into clusters by Hierarchical Ascendant Analysis.

Cluster	Cyanide (mg/100g)	Dry matter (g/100g)	Moisture (g/100g)	Carbohydrate (g/100g)	Starch (g/100g)	Energy value (/100g)	Reducing sugar (g/100g)	Ash (g/100g)	Acidity (g/100g)	Vitamin C (g/100g)
1	9.695	42.265	57.785	39.115	23.205	176.060	0.670	0.360	58.745	5.910
2	8.670	26.945	73.055	22.450	3.830	122.705	1.500	0.300	71.410	4.380
3	10.930	32.972	67.028	30.324	11.506	136.950	1.090	0.524	95.888	8.286

NB: varieties in cluster 1 are V4 and V62; cluster 2 has V23 and V60; and cluster 3 has V61, V63, V64, V65 and V66.

4.2 Nutritional characteristics: In all the varieties the nutritional characteristics were between: fat (0.43 to 4.25 g/100g), protein (0.78 to 2.7 g/100g), minerals (0.25 to 0.86), carotenoid (0.06 to 0.25 mg/100g), vitamin A (8.5 to 57.32 mg/100g) and vitamin C (2.6 to 9.53 /g100g). ANOVA revealed significant differences between the varieties (Table 5). The highest content were registered by varieties V23 for fat (4.25 g/100g), V63 for protein (2.7 mg/100g) and minerals (0.86 g/100g), V61 for carotenoid (0.25 mg/100g), V60 for vitamin A (57.32 mg/100g) and V64 for vitamin C (9.53 mg/100g).

Table 5: Nutritional characteristics of nine cassava varieties evaluated in Cote d'Ivoire.

Variety	Fat (g/100g)	Carotenoid (mg/100g)	Vitamin A (mg/100g)	Protein (g/100g)	Minerals (g/100g)	Vitamin C (g/100g)
V63	0.43**i**	0.13**b**	13.26**d**	**2.7a**	**0.86a**	6.16**d**
V23	**4.25a**	0.11**c**	20.6**b**	1.02**f**	0.51**b**	8.18**c**
V66	1.36**e**	0.08**d**	11**f**	1.71**d**	0.4**cd**	9.22**b**
V64	0.83**h**	0.12**b**	12.56**e**	0.78**g**	04**cd**	**9.53a**
V60	1.72**c**	0.11**c**	**57.32a**	2**c**	0.45**bc**	8.34**c**
V61	1.43**d**	**0.25a**	9.41**g**	2.42**b**	0.27**e**	6.12**d**
V4	1.92**b**	0.06**f**	19.37**c**	1.53**e**	0.35**d**	2.6**f**
V62	0.96**g**	0.07**e**	8.5**i**	1.79**d**	025**e**	6.16**d**
V65	1.03**f**	0.06**f**	8.97**h**	1.55**e**	0.45**c**	5.7**e**

NB: In each column means followed by different letters (a, b, c, etc.) are significantly different; the lowest values are underlined and the highest are marked bold.

4.3 Sensorial characteristics of *attiéké*: On the whole, all the *attiéké* were acceptable to the consumers. However, the variance analysis performed on each sensorial characteristic (taste, texture and fiber) revealed significant differences between the varieties (Table 6). Variety V62 presented the best taste (score of 3.92), followed by V66 (3.75) and V4 (3.46). Regarding the texture, varieties V66 (score of 3.83), V4 (3.75a, V64 (3.62), V65 (3.5) and V62 (3.33) were more accepted than the others. For the fiber content, varieties V4 (score of 4.29), V66 (3.88), V63 (3.68) and V62 (3.67) registered the best acceptance (Table 6).

Table 6: Scores of sensorial characteristics of nine cassava varieties evaluated in Cote d'Ivoire.

Variety	Taste	Texture	Fiber
V4	3.46**c**	**3.75a**	**4.29a**
V62	**3.92a**	3.33a	3.67c
V23	3.5**c**	3.17**b**	3.54**e**
V60	3.04**de**	3.17**bc**	3.62**d**
V61	2.92**e**	2.95**d**	3.29f
V63	2.96**e**	3.04**cd**	3.68**c**
V64	2.92**e**	**3.62a**	3.25**f**
V65	3.2**d**	**3.5a**	3.58**de**
V66	3.75**b**	**3.83a**	3.83**b**

In each column, means followed by different letters (a, b, c, etc.) are significantly different; the highest are marked bold

DISCUSSION

The cassava varieties in this study were, on the whole, neither sweet nor bitter (cyanide: > 5 mg and < 10 mg/100g), except for varieties V60, V61, V62 and V63 that had cyanide values over 10 mg/100g (Fortin *et al.,* 1998). Nevertheless, all of them might not be consumed crude, but after cooking or transformation into edible products to reduce cyanide content (Ampe *et al.*, 1994; Desmazeaud, 1996; Assanvo, 2008). The varieties with high acidity could be used to prepare foods such as *placali*, *gar*i and *attiéké*, with the sourness that is appreciated by consumers (Toka & Dago, 2003). This appreciation was also shown by the result of sensorial test (taste) on attiéké of the different varieties.

The presence of Vitamin C should enable prolonged root storage time (Ampe *et al.*, 1994; Brauman *et al.*, 1995; Desmazeaud, 1996), especially for varieties V61, V63, V64 and V6. They are also likely to be less perishable in spite of their high moisture and reducing sugar contents, due to their high acidity and the presence of vitamin C (Brauman *et al.*, 1995; Desmazeaud, 1996).

Concerning dry matter, energy value, carbohydrate and starch content, values obtained in this study are higher than those given by Bokanga (2001) and Nweke *et al.* (2002). Therefore, these varieties would easily assure food and energy security as proposed by FAO (2008); especially owing to their content of some of the most desirable nutritional compounds like fat, protein, carotenoid, minerals, vitamins A and C, in higher proportion than those reported elsewhere previously (Bokanga, 2001; Nweke *et al.*, 2002. They could also be exploited in various industrial products (Kraft paper, plywood, paperboard, textile, bakery, biscuits) made with cassava starch, mainly regarding varieties V4 and V62 (FAO, 2008).

Moreover, with their higher dry matter (and lowest moisture content) these varieties would be suitable for prolonged root storage (Trèche e*t al.*, 1995). According to Meuser and Smolnik (1980), , high dry matter of cassava roots could contribute to increase the yield and the texture of derivative product, such as *attiéke*. This observation is confirmed by the result of sensorial analysis on *attiéké* in the present study, mainly for varieties V4 and V62 which had the highest dry matters. Their texture was more acceptable to consumers, compared to *attiéké* of varieties V23, V60, V61, V63, V64, V65 and V66.

The varieties with relatively high moisture and reducing sugar content could be suitable sources of raw materials for alcohol, lactic bacteria, organic acid (lactic, acetic, formic) and biofuel industries (FAO, 2008). They could also be use for humans and animals feeding, as they contain nutritional elements like fat, protein, carotenoid, minerals, vitamins A and C. Moreover, except for variety V61 and at least V63, the sensorial characteristics of their *attiéké* were quite acceptable.

CONCLUSION

All the cassava varieties (original and improved) evaluated in this study were on the whole energy containing and bitter. Varieties V4 and V62 registered the best carbohydrate, starch, and dry matter content and energy value. These could be widely exploited in several industries (chemical, pharmaceutical, cosmetic and pastry) and constitute a guarantee for food security because they contain energy, protein, fat, minerals, carotenoid, vitamins A and C, in substantial proportions.

Varieties V23, V60, V61, V63, V64, V65 and V66 had less energy than V4 and V62, but some of their nutritional values were higher. Moreover, with their high moisture and reducing sugar contents they would be suitable for fermentation, and could be successfully used as raw material in alcohol, organic acids, lactic bacteria and biofuel industries.

Notably and importantly, *attiéké* of the different cassava varieties evaluated were well accepted by the consumers based on their taste, texture and fiber content.

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