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# Biochemical characterization of new varieties of yellow colored pulp cassava flours from Côte d'Ivoire

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## ABSTRACT

*Objective*: The present study aimed to evaluate the new cassava flours varieties (V4, V23, V52, V53, V54, V55, V69, V71 and V73) for the best characteristics in order to promote them. Indeed, the use of cassava flour is on the increase throughout the world, but its utilization is under the control of many standard regulators.

*Methodology and Results:* Physicochemical and biochemical characteristic of nine new cassava varieties flours (8 yellow and 1 white colored pulp) were determined, and statistical analyses (PCA, HAC, DFA and ANOVA) were performed on the data. Three distinct clusters C1 (V4, V52, V55, V71 and V73), C2 (V23 and V53) and C3 (V54 and V69) were identified. All varieties showed very low moisture content (4.21±0.10 to 5.85±0.44g/100g), but high starch (74.65±0.90 to 78.27±0.63 g/100), carbohydrate (87.74±0.30 to 89.26±0.34 g/100g) and energy values (384.93±1.80 to 393.95±3.03 g/100g). Their proteins and fat amounts ranged respectively from 1.10±0.60 to 3.00±0.46 g/100g and 3.40±0.70 to 3.50±0.45 g/100g. The cyanide content of varieties V4 (2.13±0.76 mg/100g), V55 (1.78±0.76 mg/100g) and V23 (1.61±0.31 mg/100g) were very high compared to those of the others varieties V52 (1.06±0.03 mg/100g), V53 (1.06±0.03 mg/100g), V54 (0.54±0.03 mg/100g), V69 (0.54±0.03 mg/100g), V71 (0.53±0.03 mg/100g) and V73 (0.53±0.03 mg/100g) and the Codex-Alimentarius standard (1 mg/100g). Moreover, varieties V52, V53 and V73 recorded relatively neutral pH (6.67±0.1, 7.03±0.1 and 6.41±0.1, respectively) and high reducing and total sugars (1.43±0.01 and 2.02±0.03 g/100g, 3.38±0.01 and 9.07±0.03 g/100g, 2.76±0.01 and 5.67±0.03 g/100g, respectively). About acidity, varieties V54 (93.17±0.03 meq/100g), V71 (71.10±0.03 meq/100g) and V73 (75.34±0.03) registered important contents.

*Conclusions and application of findings:* Varieties V52, V53, V54, V69, V71 and V73, recorded the best characteristics (high caloric and starch amount, very weak moisture and cyanide contents). Hence, they could be used either in animal feeds and non-food purpose or be exploited for direct house feeding and food industries (composite flours, pastry, gelatinized products, and candies). Precisely, varieties V52, V53 and V73 could easily be used in pastry because of their relatively neutral pH and sugar amounts. Varieties V54, V71 and V73 could be introduced in composite flours for infant weaning because of their high acidity and their weak cyanide content. As for V4, V23 and V55, their cyanide amount was higher than Codex-Alimentarius standard for edible cassava flours, so they can be limited to animal feeding.

**Key words: New** Cassava flour, yellow colored pulps, characteristics, standard regulator

## INTRODUCTION

Cassava (*Manihot esculenta* Crantz), a very caloric raw material, is an important source of energy involved in the FAO program to assure food security and fight against famine through the world (Fiagan, 2007). Moreover, it constitutes an increasing resource for several billion of farmers, traders and industry (Amani *et al*., 2005; Akoroda, 2007). That precious raw material is grown for its edible roots, which serves as a staple food in many tropical countries (FAO, 2008) But it is perishable and requires rapid utilization (Poulter, 1995; Amoa-Awua *et al*., 1996; Brauman *et al*., 1996) and so it is transformed into flour, starch and several other (chips, flakes, biofuel, textile, glue) exploitable products (food and non-food) (Akoroda, 2007; FAO, 2008). Indeed, concerning cassava flour, it is either involved in composite flours for pastry, infant weaning meal, gelatinized products, or directly consumed as paste (Aryee *et al*., 2006; Akoroda, 2007; Oluwamukomi *et al*., 2011; Zannou *et al*., 2011). However, thanks to its increasing demand and its wide panel of usage, cassava flour is submitted to several exigencies (Codex-Alimentarius, 1991). In fact, its moisture, ash and cyanide content must respect some standards which vary with the usage. Moreover, several forums had been introduced by the FAO (FAO, 2008) in order to check how to improve either cassava productivity and/or its quality. Many studies also, occurred worldwide to achieve these aims. In Côte d'Ivoire, the level of productivity and resistance to diseases of some local varieties has been increased after some agronomical researches (N'zue *et al*., 2004; Goualo *et al*., 2007). Other researches in Nigeria leaded to β-carotene enriched cassava varieties (Maziya-Dixon, 2005; Howe et Tunamihardjo, 2006; Tunamihardjo, 2008).

A few numbers of these β-carotene enriched varieties have been provided to the National Center of Agronomical Research (CNRA) by the International Institute of Tropical Agriculture (IITA) and have showed interesting agronomical aptitudes such as high productivity and resistance to many diseases (N'zue *et al*., 2007). Fifteen of these new varieties have also been characterized as far as their pastes and their couscous (atiéké) are concerned, and three of them showed best characteristics compared to others (Megnanou *et al*, 2009; Kouassi *et al*, 2010). The present study aimed to check varieties with best characteristics (high caloric and starchy content, very slight moisture and cyanide amount and presence of fat and protein). Thus, flours were extracted from nine cassava root varieties (eight yellow and one white colored pulp) and their physicochemical (pH, acidity, cyanide, oxalic acid, dry matter, moisture, ash) and biochemical (starch, carbohydrate, energy value, fat, proteins, reducing and total sugar contents) characteristics were determined. Then statistical methods such as principal component, hierarchical ascendants and discriminated factors analyses and ANOVA were performed to identify performing varieties.

## MATERIAL AND METHODS

**Samples :** Flours were extracted following Aryee *et al*. (2006) process from nine different varieties of cassava roots (V4, V23, V52, V53, V54, V55, V69, V71, V73), and stored at 55°C . These flours were from roots of eleven months old which were kindly provided by the National Center of Agronomical Research (CNRA).

**Physicochemical and biochemical characteristics:** Moisture, dry matter and ash contents were determined using the AOAC (1980) methods. The total cyanogen content was carried out by the method of Liebig-Denige (1979), and Rachid (1978) method to get oxalate content. AFNOR (1991) methods lead to pH and total titrable acidity values. BIPEA (1976) methods were used to determine fat and proteins contents. Vitamin C content was obtained with the method of Tillmanns and Hirsch (1932). Reducing and total sugars were evaluated with the methods of Bernfeld (1955) and Dubois *et al*. (1956), respectively. As for carbohydrate and starch contents, they were calculated by difference following the expression recommended by FAO (1947):

Carbohydrate content =
100 – (% Moisture + % Ash + % Fat + % Proteins)
Starch content =
0.9 (% Carbohydrate – %Total sugars).

Energy value was also calculated using the relation described by Atwater and Rosa (1899) concerning starchy foods:
Energy value
= (2.74 × %proteins) + (4.03 × %carbohydrate) + (8.37 × %fat).

**Statistical analysis:** All analyses were performed in triplicate. The data were registered using EXCELL and analyses were carried out on XLSTAT version 2007. Thus, principal component analysis (PCA), hierarchical ascendant classification (HAC) and discriminating factors analysis (DFA) was performed successively. Then, Tukey's test (95% confidence level) of the ANOVA added confirmation. All expressed results per 100 g concerned dry material.

## RESULTS

**Dissimilarity between the different varieties of cassava flours:** Due to the Principal component analysis performed on fifteen physicochemical characteristics of nine varieties of cassava flour (V4, V23, V52, V53, V54, V55, V69, V71 and V73), height components might explain all the variances between these varieties. But the first fourth components cumulated more than 80% of the total variances (Figure 1).

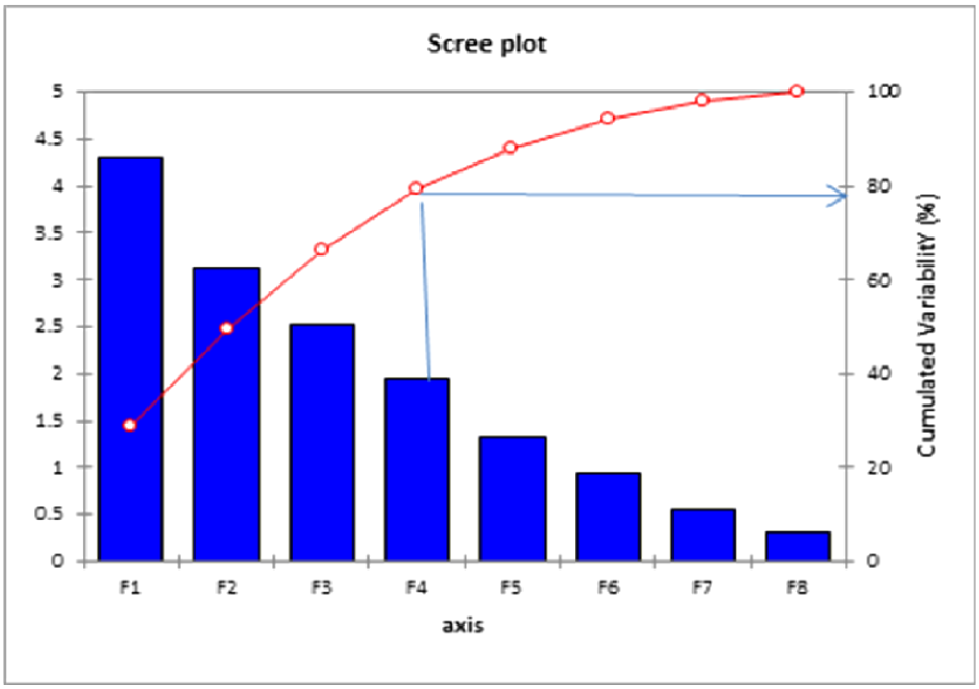


**Figure 1:** Principal components cumulating

The first component (CP1) involved three characteristics (Moisture, dry matter and energy value), the second one (CP2) represented two characteristics (Total and reducing sugars) while the third (CP3) were attributed to acidity and fat. As for the fourth component (CP4), it was characterized by the proteins content. Thus, height parameters could lead to a clear discrimination of the nine varieties of cassava flours (Table 1).

**Table 1:** Cosine squares of physicochemical and biochemical characteristics of cassava flours

| | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 | PC7 | PC8 |
|---|---|---|---|---|---|---|---|---|
| **Acidity** | 0.025 | 0.056 | **0.606** | 0.004 | 0.265 | 0.012 | 0.003 | 0.028 |
| **Fat** | 0.029 | 0.009 | **0.639** | 0.012 | 0.128 | 0.009 | 0.172 | 0.002 |
| Ash | 0.225 | 0.495 | 0.037 | 0.052 | 0.004 | 0.121 | 0.033 | 0.033 |
| **Proteins** | 0.007 | 0.007 | 0.046 | **0.873** | 0.034 | 0.030 | 0.000 | 0.002 |
| Carbohydrate | 0.466 | 0.153 | 0.096 | 0.159 | 0.022 | 0.060 | 0.001 | 0.042 |
| Starch | 0.014 | 0.120 | 0.365 | 0.036 | 0.345 | 0.073 | 0.044 | 0.003 |
| **Energy value** | **0.818** | 0.087 | 0.000 | 0.064 | 0.006 | 0.020 | 0.005 | 0.000 |
| **Moisture content** | **0.530** | 0.002 | 0.000 | 0.390 | 0.003 | 0.071 | 0.001 | 0.003 |
| **Dry matter** | **0.884** | 0.000 | 0.009 | 0.079 | 0.004 | 0.000 | 0.024 | 0.001 |
| **Total sugar** | 0.048 | **0.732** | 0.038 | 0.023 | 0.004 | 0.131 | 0.002 | 0.023 |
| Vitamin C | 0.004 | 0.373 | 0.212 | 0.023 | 0.112 | 0.221 | 0.046 | 0.009 |
| **Reducing sugar** | 0.275 | **0.525** | 0.001 | 0.007 | 0.180 | 0.011 | 0.001 | 0.000 |
| Cyanide | 0.463 | 0.001 | 0.079 | 0.094 | 0.184 | 0.002 | 0.015 | 0.161 |
| pH | 0.130 | 0.135 | 0.397 | 0.091 | 0.009 | 0.062 | 0.177 | 0.000 |
| Oxalic acid | 0.378 | 0.430 | 0.010 | 0.034 | 0010 | 0.120 | 0.014 | 0.005 |

**Legend**: The discriminated characteristics are **in bold**

On the basis of these height characteristics (parameters) which are moisture, dry matter, acidity, energy value, fat, proteins, total and reducing sugars, three clusters of cassava flours were identified by the HAC (Figure 2 and Table 2). DFA results confirmed these clusters and their contents (Figure 3) and gave characteristics of each cluster (Table 3). Indeed, the first cluster was composed by varieties V4, 52, V55, V71 and V73 when the second contained varieties V23 and V53. The third cluster was represented by varieties V54 and V69.

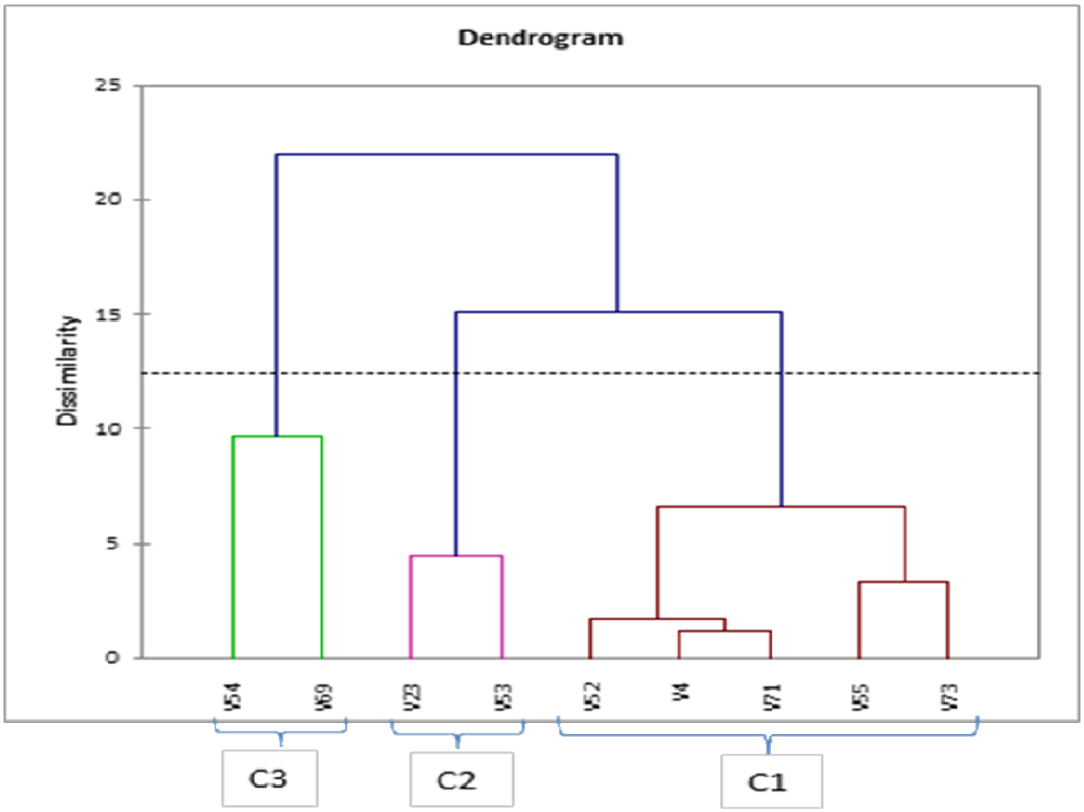


**Figure 2:** Dendogram of cassava flours dissimilarity
**Legend**: V4 to V73 represent cassava varieties which composed clusters C1 to C3.

**Table 2**: Composition of the different clusters of cassava flours

| Clusters | C1 | C2 | C3 |
|---|---|---|---|
| | V4 | V23 | V54 |
| | V52 | V53 | V69 |
| Varieties | V55 | | |
| | V71 | | |
| | V73 | | |

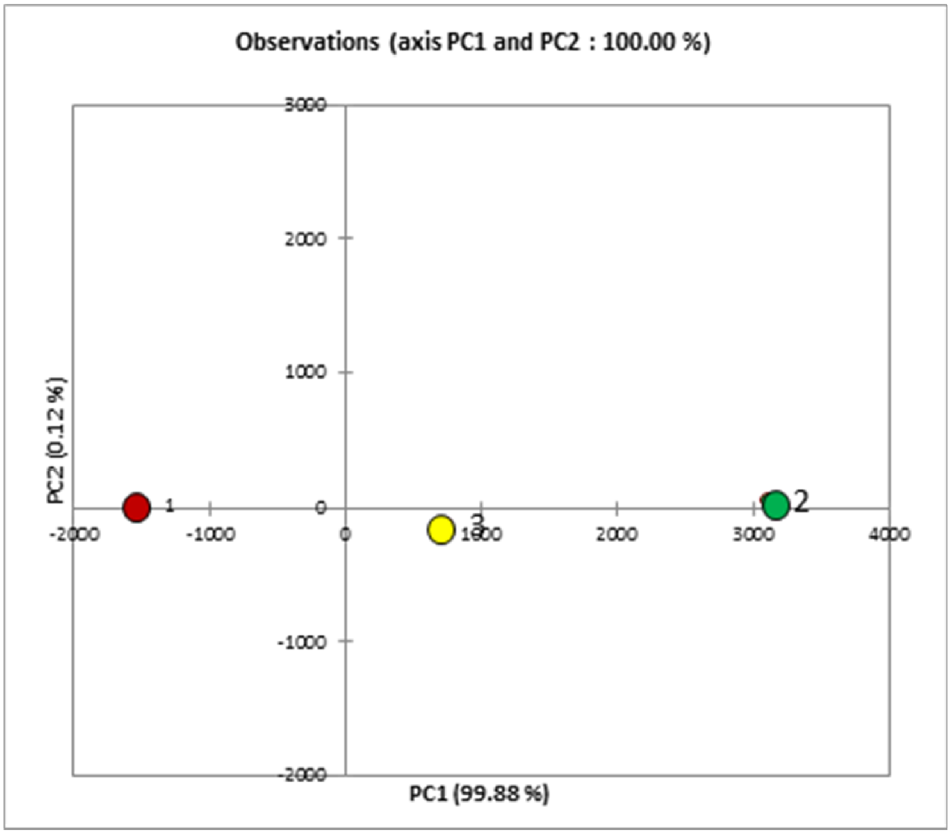


**Figure 3:** discriminating factors analysis of clusters of cassava flours.
**Legend: -** PCI and PC2 represent Principal Components one (1) and two (2)
- ● Cluster 1 ● Cluster 2 ○ Cluster 3

**Physicochemical and biochemical characteristics of cassava flours:** The characteristics of each cluster appeared in table 4. Dry matter (94.30 to 95.68 g/100g), energy value (386.23 to 391.99 cal/100g) and the acidity (57.86 to 66.01 meq/100g) presented relatively high values, when the moisture were relatively weak (4.32 to 5.71 g/100g). The cluster C1 recorded the highest dry matter (95.68 g/100g), proteins (2.48 g/100g) and energy value (391.99 cal/100g); its moisture (4.32 g/100g) was the lowest. Cluster C3, as for it, topped the highest moisture (5.71 g/100g) and the slightest energy value (386.23 cal/100g). The second cluster C2 registered intermediary values of dry matter (95.34 g/100g), calorie (389.45 cal/100g) and moisture (5.17 g/100), but it had the most important amount of acid, reducing (2.98 g/100g) and total sugars (6.34 g/100g). Considering the whole characteristics (Moisture, dry matter, Ash, pH, acidity, cyanide, Oxalic acid, reducing sugar, total sugar, starch, carbohydrate, energy value, fat, vitamin C and proteins), it appeared some significant differences (95%) between varieties of each cluster (Tables 4a and 4b) so did varieties all together (Tables 5a and 5b).

**Table 3:** Physicochemical and biochemical discriminant characteristic means of clusters.

| Clusters | Acidity (meq) | Fat (g) | Proteins (mg) | Energy value (cal) | Moisture content (g) | Dry matter (g) | Reducing sugar (g) | Total sugar (g) |
|---|---|---|---|---|---|---|---|---|
| C1 | 59.37±12.10 | 3.45±0.21 | 2.48±0.45 | 391.99±2.05 | 4.32±0.10 | 95.68±0.10 | 1.81±0.51 | 3.95±1.75 |
| C2 | 66.01±1.39 | 3.50±0.45 | 1.30±0.28 | 389.45±3.17 | 5.17±0.36 | 95.34±0.21 | 2.98±0.44 | 6.34±3.02 |
| C3 | 57.86±42.96 | 3.45±0.35 | 2.10±0.39 | 386.23±1.64 | 5.71±0.16 | 94.30±0.16 | 0.60±0.55 | 2.77±0.84 |

**Legend:** Value were expressed per 100g of dry matter

**Table 4a:** Physicochemical characteristic means of varieties of each cluster

| Clusters | Varieties | Dry matter | Moisture | Ash | pH | Acidity | Cyanide | Oxalic acid |
|---|---|---|---|---|---|---|---|---|
| C1 | V4 | 95.64±0.06b | 4.36±0.03a | 1.50±0.10a | 6.50±0.10a | 50.19±0.03d | **2.13±0.03a** | 220.60±0.30b |
| | V52 | **95.79±0.06a** | 4.21±0.03b | 1.10±0.10b | **6.67**±0.10**a** | 45.93±0.03e | 1.06±0.03c | 112.70±0.30d |
| | V55 | **95.79±0.06a** | 4.21±0.03b | 1.30±0.10ab | 5.83±0.10b | 54.28±0.03c | 1.78±0.03b | 206.70±0.30c |
| | V71 | 95.64±0.06b | 4.36±0.03a | 1.**60**±0.10**a** | 5.70±0.10b | 71.10±0.03b | 0;53±0.03d | 112.51±0.30d |
| | V73 | 95.56±0.06b | **4.44±0.03a** | 1.40±0.10ab | 6.41±0.10a | **75.34±0.03a** | 0.53±0.03d | **244.51**±0.30**a** |
| C2 | V23 | **95.53±0.06a** | **5.14±0.03a** | 1.00±0.10b | 5.78±0.10b | 64.74±0.03b | **1.61±0.03a** | **247.50**±0.30**a** |
| | V53 | 95.14±0.06b | 4.86±0.03a | 2.10±0.10a | 7.03±0.10a | **67.27±0.03a** | 1.06±0.03b | 227.00±0.30b |
| C3 | V54 | **94.44±0.06a** | 5.56±0.03b | 1.30±0.10a | 5.90±0.10b | **93.17±0.03a** | 0.54±0.03a | 95.27±0.30b |
| | V69 | 94.15±0.06b | **5.85±0.03a** | 1.70±0.10a | 6.81±0.10a | 15.87±0.03b | 0.54±0.03a | **95.70**±0.30**a** |

**Legend**: **In bold**, highest values; underlined, the weakest

**Table 4b**: Biochemical characteristic means of varieties of each cluster.

| Clusters | Varieties | Reducing sugar | Total sugar | Starch | Carbohydrate | Energy value | Fat | Proteins | Vitamin C |
|---|---|---|---|---|---|---|---|---|---|
| C1 | V4 | 1.82±0.01b | 2.78±0.03d | 76.85±0.03b | 88.17±0.03b | 391.11±0.11a | 3.45±0.05a | 2.52±0.02ab | 0.55±0.00d |
| | V52 | 1.43±0.01d | 2.02±0.03e | **78.27±0.03a** | 89.00±0.57a | 393.95±0.11a | 3.50±0.05a | 2.20±0.02ab | **2.08±0.00a** |
| | V55 | 1.54±0.01c | **6.15±0.03a** | 74.65±0.03e | **89.09±0.57a** | 392.97±0.11a | 3.40±0.05a | 2.00±0.02b | 1.42±0.00b |
| | V71 | 1.51c±0.01d | 3.13±0.03c | 76.33±0 .03d | 87.94±0.04c | 390.25±0.11a | 3.40±0.05a | 2.70±0.02ab | 1.09±0.00c |
| | V73 | **2.76±0.01a** | 5.67±0.03b | 76.60±0.03c | 87.76±0.04c | 390.35±0.11a | 3.40±0.05a | **3.00±0.02a** | 0.55±0.00d |
| C2 | V23 | 2.57±0.01b | 3.56±0.03b | **77.13±0.03a** | **89.26±0.04a** | 392.04±0.11a | 3.50±0.05a | 1.10±0.02a | **0.89±0.00a** |
| | V53 | **3.38±0.01a** | **9.07±0.03a** | 76.19±0.03b | 88.04±0.04b | 388.21±0.11a | 3.50±0.05a | 1.50±0.02a | 0.77±0.00b |
| C3 | V54 | **1.10±0.01a** | **3.54±0.03a** | 75.78±0.03b | 87.74±0.04b | **387.53±0.11a** | 3.40±0.05a | 2.00±0.02a | **2.32±0.00a** |
| | V69 | 0.10±0.01b | 2.00±0.03b | **76.28±0.03a** | **87.94±0.04a** | 384.93±0.11b | 3.50±0.05a | 2.20±0.02a | 0.56±0.00b |

**Legend**: **In bold**, highest values; underlined, the weakest

**Table 5a:** Physicochemical characteristic means of cassava variety flours

| Varieties | Dry matter | Moisture | Ash | Acidity | pH | Cyanide | Oxalic acid |
|---|---|---|---|---|---|---|---|
| **V4** | 95.64±0.06b | 4.36±0.03de | 1.50±0.10bcd | 50.19 ± 0.03d | 6.5±0.10cd | **2.13±0.03a** | 220.6±0.30d |
| **V23** | 95.53±0.06c | 5.14±0.03bc | 1.00±0.10d | 64.74±0.03bc | 5.78±0.10e | 1.61±0.30c | **247.5±0.30a** |
| **V52** | **95.79±0.06a** | 4.21±0.03e | 1.10±0.10cd | 45.93±0.03d | 6.67±0.10b | 1.06±0.30d | 112.70±0.30 |
| **V53** | 95.14±0.06d | 4.86±0.03cd | **2.10±0.10a** | 67.27±0.03b | **7.03±0.10a** | 1.06±0.03d | 227.00±0.30c |
| **V54** | 94.44±0.06e | 5.56±0.03ab | 1.30±0.10bcd | **93.17±0.03a** | 5.90±0.10e | 0.54±0.03e | 95.70±0.30g |
| **V55** | **95.79**±0.06**a** | 4.21±0.03e | 1.30±0.10bcd | 54.28±0.03cd | 5.83±0.10e | 1.78±0.03b | 206.70±0.30e |
| **V69** | 94.15±0.06f | **5.85±0.03a** | 1.70±0.10ab | 15.87±0.03e | 6.81±0.10ab | 0.54±0.03e | 95.70±0.30g |
| **V71** | 95.64±0.06b | 4.36±0.03de | 1.69±0.10abc | 71.10±0.03b | 5.70±0.03 | 0.53±0.03e | 112.51±0.30f |
| **V73** | 95.56±0.06bc | 4.44±0.03de | 1.40±0.10bcd | 75.34±0.03b | 6.41±0.10d | 0.53±0.03e | 244.51±0.30b |

Legend: **In bold**, highest values; underlined, the weakest

**Table 5b:** Biochemical characteristic means of cassava variety flours

| Varieties | Reducing sugar | Total sugar | Starch | Carbohydrate | Energy value | Fat | Proteins | Vitamin C |
|---|---|---|---|---|---|---|---|---|
| **V4** | 1.82±0.01d | 2.78±003f | 76.85±0.03c | 88.17±0.04bcd | 391.11±0.11abc | 3.45±0.05a | 2.52±0.02ab | 0.55±0.00g |
| **V23** | 2.57±0.01c | 3.56±0.03d | 77.13±0.03b | **89.26±0.04a** | 392.04±0.11abc | 3.50±0.05a | 1.10±0.02d | 0.89±0.00e |
| **V52** | 1.43±0.01f | 2.02±0.03g | **78.27±0.03a** | 89.00±0.04abc | **393.95±0.11a** | 3.50±0.05a | 2.20±0.02abc | 2.07±0.00b |
| **V53** | **3.38±0.01a** | **9.07±0.03a** | 76.19±0.03f | 88.04±0.04cd | 388.21±0.11bcd | 3.50±0.05a | 1.50±0.02cd | 0.77±0.00f |
| **V54** | 1.10±0.01g | 3.54±0.03d | 75.78±0.03g | 87.74±0.04d | 387.53±0.11cd | 3.40±0.05a | 2.00±0.02bc | **2.32±0.00a** |
| **V55** | 1.54±0.01e | 6.15±0.03b | 74.65±0.03h | 89.09±0.04ab | 392.97±0.11ab | 3.40±0.05a | 2.00±0.02bc | 1.42±0.00c |
| **V69** | 0.10±0.01h | 2.00±0.03g | 76.28±0.03ef | 86.75±0.04e | 384.93±0.11d | 3.50±0.05a | 2.20±0.02abc | 0.56±0.00g |
| **V71** | 1.51±0.01e | 3.13±20.03e | 76.33±0.03e | 87.94±0.04d | 390.25±0.11abc | 3.40±0.05a | 2.70±0.02ab | 1.09±0.00d |
| **V73** | 2.76±0.01b | 5.67±0.03c | 76.60±0.03d | 87.76±0.04d | 390.35±0.11abc | 3.40±0.05a | **3.00±0.02a** | 0.55±0.00g |

Legend: **In bold**, highest values; underlined, the weakest.

Varieties at the whole, presented relatively important dry matter (94.15 g/100g to 95.79, respectively for V69, V55 and V52), starch (74.75 to 78.27 g/100g; V55 and V52), carbohydrate (86.75 to 89.26 g/100g; V69 and V23) and energy value (384.93 to 393.95 cal/100g; V69 and V52). Concerning proteins content, varieties V4 (2.52 g/100g), V71 (3.00 g/100g) and V73 (2.70 g/100) which belong to cluster C1, topped the most important amount in opposition to the variety V23 (1.10 g/100g) of cluster C2. As for acidity, the weakest values were recorded by V69 (15.87 meq/100g) whose pH (6.81) value was important. Highest cyanide content were topped by varieties V4 (2.13 mg/100g) and V55 (1.78 mg/100g) from cluster C1 and by V23 (1.60 mg/100g) of Cluster C2. Concerning vitamin C, its higher amounts were obtained *decrescendo*, by V54 (2.32 mg/100g) belonging to cluster C3 and by V52 (2.08 mg/100g) and V55 (1.42 mg/100g) of cluster C1. Ash content did not vary within the clusters, nevertheless when considering varieties altogether, V53 (2.10 g/100g), V69 (1.70 g/100g) and V71 (1.60 g/100g) topped more considerable amounts than the other varieties.

## DISCUSSION

The different clusters of cassava flours presented interesting preservation potential as their moisture content was very weak (4.21 to 5.85 g/100g) (Nout *et al*., 2003). This could be explained by the process (Oven drying at 55°c for three days) proposed by Aryee *et al*. (2006). Indeed, these values were far lower than those recommended by the Codex Alimentarius (1991) for cassava flour as human feeding (13%). These low moisture content of flours might inhibit the multiplication of alteration microorganism; hence be important for their conservation for a relative long period (Nout *et al*., 2003). Moreover, this moisture content were lower than 6% as recommended by Bencini et Waltson (1991), thus, all the varieties could be classified in the category of flour with very good quality. That would allow the different flours to be directly (without pre-heating) used in preparations as partial substitute of maize flour (Yeo, 2007). It is worth noting that the step of pre heating needs enormous amount of energy which might be economized with these flours. Moreover, nutritional components in flours would be preserved from heating alteration. This potential of long shelf life can be increased by the high acidity (Caplice et Fitzgerald (1999). So, with their relatively high acidity, all the varieties, except for V69 (15.87 meq/100) which recorded the lowest acidity, would either present longer shelf life, or be appreciated by adult consumers. Indeed, the acidity might generally be linked to the presence of organic acids (butyric, acetic, and lactic) which might provide sourness to the meal (Brauman *et al*, 1995, Desmazeaud, 1996; Toka et Dago, 2003). Anyway, these varieties of cassava flours could also, be introduced in composite flour for infant weaning as those proposed by Trèche *et al*. (1995) (*vitafort*®) and Zannou *et al*. (2011) (Attiéké flour + soy flour and cassava flour + soy flour). In fact, organic acid might also fight against infant stomach ache according to Lorri et SvaLegenderg (1994).

Nevertheless, when taking into account cyanide, only varieties V54, V69, V71; V73 and at least V52 and V53 might be concerned by human feeding because they recorded slightly values (0.53±0.03 to 1.06±0.03 mg/100g) than those of the other varieties V4, V23 and V55 (1.61±0.03 to 2.13±0.03 mg/100g). Moreover, these values complied either with the regulatory standard of not more than1 g/100g (Codex Alimentarius, 1991) for cyanide content or less than 500 mg/100g concerning oxalic acid content (Gontsea *et al*., 1968; Munro *et al.,* 1969). This proposition for human feeding would be justify as all the cassava flours clusters constitute good potential of energy foods due to their high energy values (386.89 to 393.00 cal/100g). In general, the different amounts of calories obtained in this study, were confirmed by those obtained by Ingram (1975) and Aryee *et al*. (2006) about some cassava flours. This quality would be linked to their carbohydrate content, especially to their starch content (Aryee *et al*., 2006). Varieties V52, V53, V69 and V73 could be used in pastry manufacturing because of their interesting pH (6.41 to 7.03) which would indicate appreciable levels of starch safety (absence of breakage) (Aryee *et al*., 2006, Apea-Bah *et al*., 2011). Concerning varieties V54 and V71, they could be used in gelatinized food (frost, soup, ice-cream) and many other feeding products like biscuits, gums and toffee (FAO, 1977). Concerning the previous usages, it is worth to stress the importance of the sugar content (mainly reducing sugar). Indeed, reducing sugar would confer the crispy texture to product such as bread, biscuit resulting from the Maillard's reaction which occurs between amino acids and reducing sugar at high temperature (Clarke, 1997). Also, this sugar content might give the natural sweet taste to products.

So, apart from variety V69 which recorded very weak reducing (0.1 g/100g) and total (2.00 g/100g) sugar, all the varieties could be selected on the basis of their sugar content .

All the varieties contained interesting amounts of nutritional factors such as Ash, proteins, fat and vitamin C. It is also worth recalling that except for variety V4, all varieties are yellow-colored due to their high β-carotene content (Safo-Kantanka *et al*., 1985; Megnanou *et al*., 2009) which provides vitamin A to the flours. Indeed, presence of these nutritional factors might constitute a real advantage for the varieties though they recorded higher amounts than those published by authors like Maziya-Dixon *et al*. (2005) on some β-carotene enriched cassava flour and Apea-Bah *et al*. (2011) as far as proteins are concerned. For the ash content, all the varieties ranged in the standard recommended by Codex Alimentarius (1991) (< 3%).

These edible flours V52, V53, V54, V69, V71 and V73 could also be mixed as desired, in order to increase one or several properties. For instance, variety V73 with V53 in equal amounts might raise the acidity and the vitamin C of V69. V53 might also increase the pH and sugar content of V73 which would enrich the previous in proteins. Therefore, such mixtures could, widen the usages of the different flours. Concerning varieties V4, V23 and V55 with high cyanide (2.13, 1.61 and 1.78 mg/100g, respectively) than the Codex-Alimentarius recommends (≤1mg/100g), they could be very useful in nonfood factories as raw material for starch, dextrin, glucose, alcohol, bio-fuel and plastics. These three varieties showed important dry matter, starch and energy value. Hence, they could also be used in animal feeding.

Finally, as far as the characteristics of the present study are concerned, the flours of varieties V54 and V69 and their pastes maintained the widest possibility of use (households, food and nonfood industries) , following the results of Mégnanou *et al*. (2009) and Kouassi *et al*. (2010). Varieties V52, V53, V71 and V73, would also be apt to a wide range of utilization, compared with variety V4 flour which might be limited to nonfood purpose.

## CONCLUSION

All the varieties of the clusters in this study presented very high energy values, linked to their starch amount. That would confirm the caloric food quality of cassava. Moreover, moisture contents were so low that all varieties could either get long shelf life or be classified as *very good flour* following physical criteria. The flours also contained nutritional factors such as proteins, fat, ash and vitamin C, in relative acceptable amounts. Nevertheless three of them V4, V23 and V55 recorded cyanide amounts higher than the Codex-Alimentarius standard for edible cassava flours. Thus they might be limited to animal feeding and/or nonfood use (non-feeding starch, dextrin, glucose, biofuel and plastic)

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