# COMPARATIVE STUDY ON PHYSICOCHEMICAL CHARACTERISTICS OF CASSAVA ROOTS FROM THREE LOCAL CULTIVARS IN CÔTE D'IVOIRE

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**Abstract**

This study was aimed to characterize three local cassava cultivars (*Akaman*, *Yace* and *Zoklo*) commonly used and to compare their physicochemical characteristics in order to choose the right roots for the suitable usages. For this purpose, the moisture, ash, starch, protein, lipid, titratable acidity, pH, cyanide, total sugar, carbohydrate, caloric energy, minerals (Ca, Mg, Zn, Fe and P) contents and the Ca/P ratio of roots were evaluated. Data obtained were subjected to chemometric methods (Analysis of variance, Multidimensional Analysis of variance and Cluster analysis). The results showed that roots analyzed had the same general characteristics, whatever the cassava cultivar. Their moisture (60.36-62.18%), energy (385.93-388.63 kcal/100 g), starch (75.36-77.70%) and carbohydrate (92.52-93.65%) contents were high while the protein (1.95-2.27%), lipid (0.58-1.04%), ash (2.29-2.67%) and total sugar (2.10-2.64%) contents were low. The significant differences ($p<0.05$) between the three cassava cultivars were on the physicochemical parameters such as pH, titratable acidity, lipid, cyanide, total sugar and carbohydrate contents. The roots from *Yace* cultivar are toxic variety and must be processed into various products before consumption. They were characterized by high titratable acidity and carbohydrate, low pH value and total sugar content. The roots from *Zoklo* cultivar are non-toxic and can be eaten directly, either raw or boiled, or can be processed into various products before consumption. The *Akaman* roots, characterized by their relatively high lipid content, were intermediate variety and must be processed in order to avoid farther poisoning. Attention must be focused on their utilization form, avoiding consumption as raw.

**Keywords:** Characterization, local variety, cassava, cluster analysis, roots

## Introduction

Cassava (**Manihot esculenta** Crantz), a perennial of the dicotyledonous family Euphorbiaceae, is a worldwide cultivated crop (Perera et al., 2014). It is an important staple food in world, particularly in Africa (Faostat, 2013). In some countries, cassava is consumed daily and sometimes more than once a day (Nweke, 2004). Cassava was found to be the cheapest source of calories among all food crops (Tonukari, 2004). It is estimated to provide over 12% of the daily per capita calorie needs for the people of Sub-Saharan Africa (Faostat, 2005). Farmers in Africa grow several cassava varieties included local varieties and improved ones. The local cassava varieties have low productivity and are subjected to diseases and pests contamination. Due to its importance, many breeding programs are on-going in Africa and other parts of the world, to improve the traits of end user preference, such as high tuber yield, pest and diseases resistance, tolerance to abiotic stresses, micronutrients, starch quality, dry matter content, etc. Thus, new better performing cassava varieties were obtained (Megnanou et al., 2009). The proximate composition and the mineral profiles of some improved cassava roots have been assessed (Adeniji et al., 2007; Kouassi et al., 2010; Doue et al., 2014). Their sensory properties and those of the product manufactured were also evaluated (Tanya et al., 2006; Assanvo, 2008; Megnanou et al., 2009). When following instructions, the agronomic characteristics of improved varieties were satisfactory. They presented higher roots yields and were reported to be more resistant to diseases and pests than existing local varieties (N'zue et al., 2004).

In Côte d'Ivoire, about 2.5 million tons/ year are produced in 360,000 ha (Faostat, 2013). That leads to a yield of 6.9 tons/ha instead of more than 36 tons/ha obtained with improved varieties (Bakayoko et al., 2012). It is a clear indication that the adoption of improved technologies by farmers encountered meaningful problems. In general, they argue that the reasons for why improved technologies are not transferred are (i) their unsuitability and (ii) the difficult access conditions (Kaboré, 2011). Therefore, local cassava varieties are still used in multiple areas of the country. They are currently used in cassava products preparation (e.g., *placali*, flour, *attieke*, *attoupkou*, foutou, *gari*, konkondé…). The physicochemical characteristics of some local varieties have been assessed (Aboua, 1995; Zoumenou et al., 1999). Besides, the physicochemical and sensory properties of the products manufactured from local varieties were also evaluated (Aboua, 1995; Zoumenou et al., 1999; Koffi-Nevry et al., 2007; Nimaga et al., 2012). Nevertheless, it was observed that, since the development of improved technologies, work is focused on improved cassava varieties, regardless of the local varieties. However, the local varieties are still used in meaningful preparations. It is therefore necessary to investigate on the physicochemical characteristics of these local varieties in order to choose the right roots for suitable uses.

The aim of this study was to characterize and compare the physicochemical properties of roots from three local cassava varieties commonly used in order to suggest their suitable usages. It is also expected that the database obtained will served as a guide for future research.

## Materials and methods

### Raw materials

Fresh cassava roots from three local varieties (*Akaman*, *Yace* and *Zoklo*) were used in this study. These roots were harvested 12 months after cultivation in five regions of Côte d'Ivoire, *i.e. Belier*, *Lôh-djiboua*, *Marahoue*, *Nzi* and *Haut-sassandra*. In each region, three samples of roots were extracted per cultivar.

### Physicochemical analyses

The following analyses were conducted to characterize the cassava roots from three local cultivars. Moisture, ash, starch, protein and lipid contents were evaluated using BIPEA (1976) methods. Titratable acidity and pH were determined according to method described by Dufour et al. (1996). Cyanide and total sugar contents were carried out following FAO (1956) and Dubois et al. (1956) methods respectively. Total carbohydrate contents were evaluated using method described by Bertrand (1913). Caloric energy was calculated according to Atwater general factor system (FAO, 2003). The system uses a single factor for each of the energy-yielding substrates (protein, fat, carbohydrate) regardless of the food in which it is found. The energy values are 4.0 kcal/g for protein, 9.0 kcal/g for fat and 4.0 kcal/g for carbohydrates. Minerals such as calcium (Ca), magnesium (Mg), zinc (Zn), iron (Fe) and phosphorus (P) were quantified by Atomic Absorption Spectrometer (Varian AA 20, Australia) and Spectrophotometer (UV/Visible Jasco V 530i) respectively, after digestion of samples following IITA (1981) method. The Ca/P ratio was evaluated by calculation.

**Statistical analyses**

Data obtained were subjected to statistical analyses using STATISTICA 7.1 software package. Analysis of variance (ANOVA) was done. If necessary, Tukey HSD multiple comparison tests were done to determine significant differences at 5% probability between means. Multidimensional analysis of variance (MANOVA) was also done. Cluster analysis was done to define a class as a group in which the variance between members is relatively small. The Squared Euclidean distance was the chosen metric as recommended by Johnson and Wichern (2002). The quality of the typology was evaluated by the proportion (%) of total sum of squares explained. This proportion is calculated using agglomeration schedule obtained from SPSS 17.0 software package according to Tenenhaus (2010).

**Results**

**Difference between cassava roots**

The physicochemical characteristics of cassava roots from three local cultivars were subjected to MANOVA. The results are presented in Table 1. As shown, the physicochemical characteristics of roots varied significantly ($p<0.05$) between cultivars. Besides, the roots were grouped into clusters. The hierarchical trees obtained in *Belier*, *Nzi*, *Marahoue*, *Haut-sassandra and Lôh-djiboua* regions are presented in Figures 1, 2, 3, 4 and 5, respectively. It was observed that three clusters of roots can be distinguished clearly, whatever the region. Otherwise, each cluster is composed by the cassava roots from only one cultivar. There was a cluster, constituted by the roots from *Akaman* cultivar. The second one grouped the roots of *Zoklo* cultivar while the last cluster was for *Yace* cultivar. The quality of typology in three clusters was evaluated by the proportion of total sum of squares explained. Table 2 presents the proportions of total sum of squares explained by the typology in three clusters. The values ranged from 87.53 to 92.97%. The recorded values in *Belier*, *Lôh-djiboua* and *Marahoue* regions were 87.53, 89.69 and 92.07% respectively. In addition, it was observed the proportion values of 92.75 and 92.97% in *Haut-sassandra* and *Nzi* regions respectively. These values were high.

**Table 1.** MANOVA table from physicochemical characteristics of cassava roots of three cultivars in Côte d'Ivoire.

| Error source | Test | Value | F | Degree of freedom | p |
|---|---|---|---|---|---|
| Intercept | Wilk | 0.000015 | 101789.1 | 17 | 0.00 |
| Cultivars | Wilk | 0.007394 | 16.3 | 34 | 0.00 |

Effect is significant at $p<0.05$.

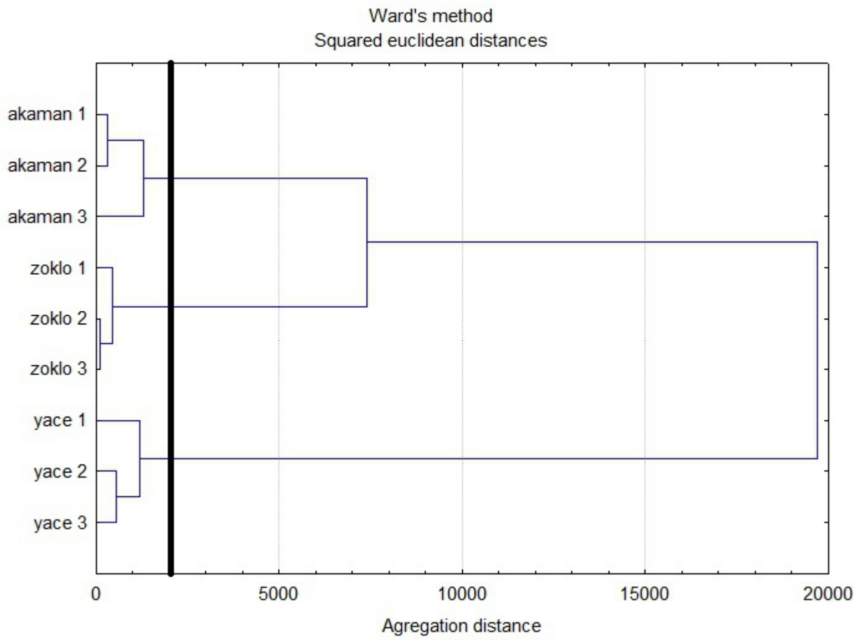


**Figure 1.** Hierarchical tree of cassava roots from *Belier* region

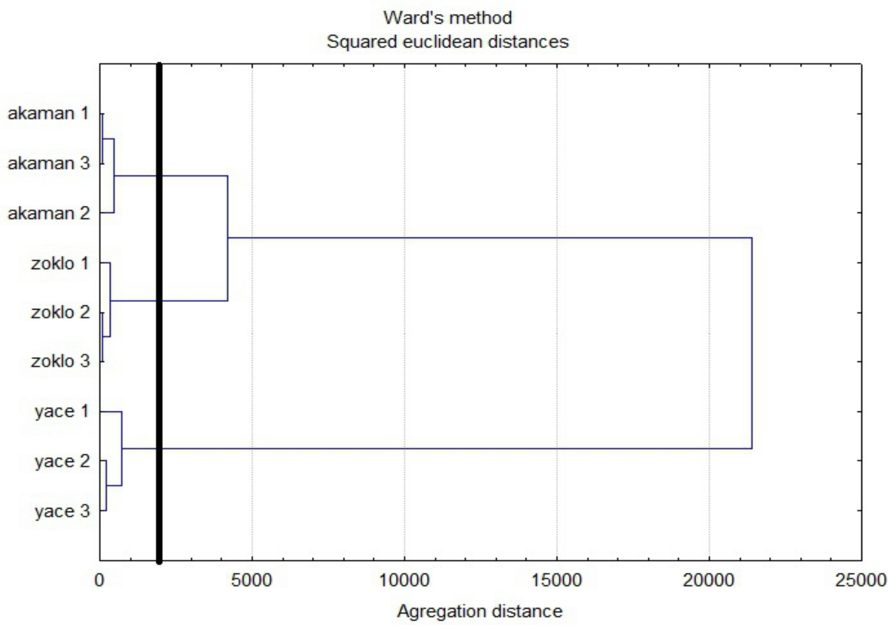


**Figure 2.** Hierarchical tree of cassava roots from *Nzi* region

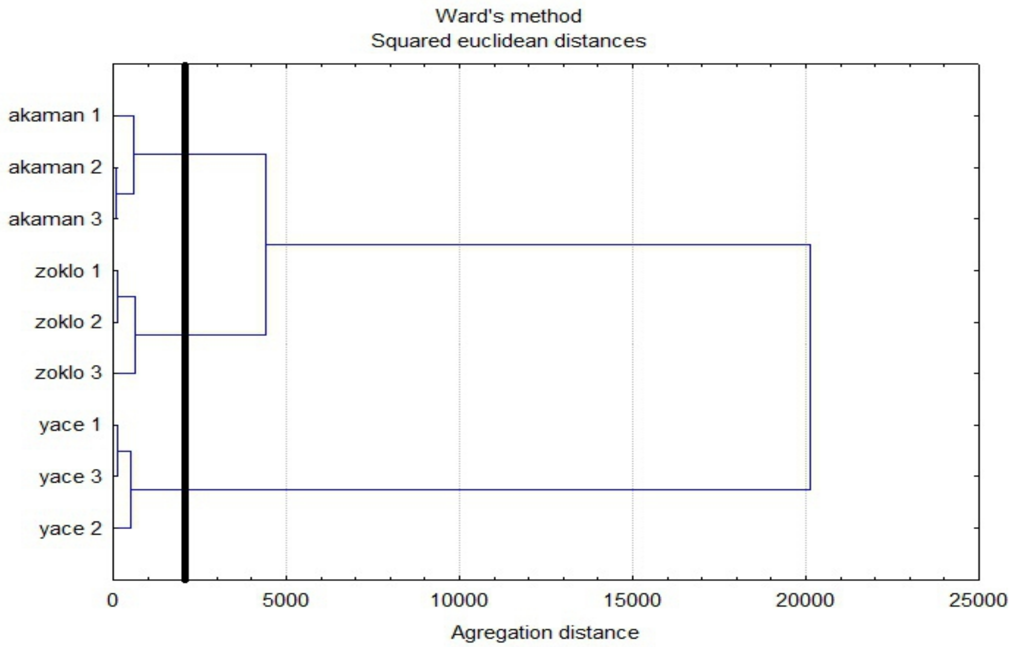


**Figure 3.** Hierarchical tree of cassava roots from *Marahoue* region

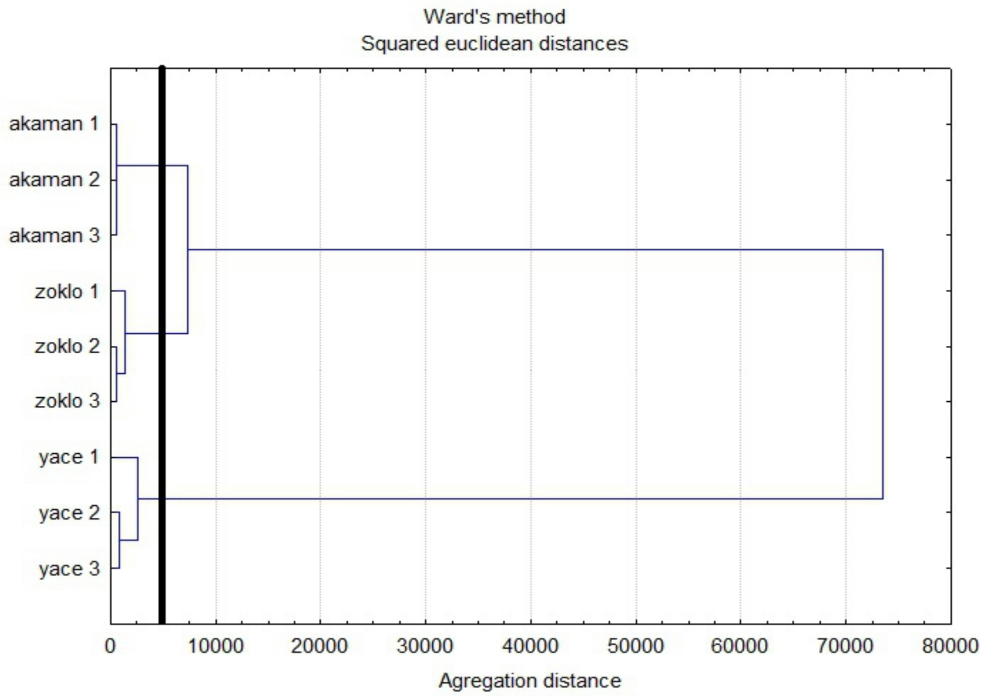


**Figure 4.** Hierarchical tree of cassava roots from *Haut-sassandra* region

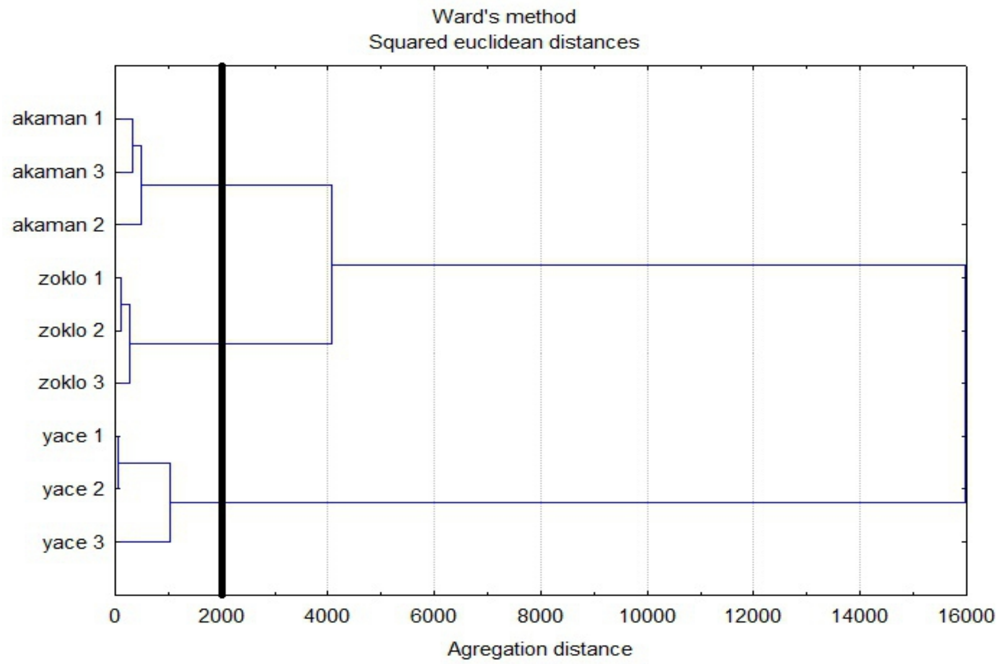


**Figure 5.** Hierarchical tree of cassava roots from *Lôh-djiboua* region

**Table 2.** Quality of the typology in three clusters in each region.

| Regions | Total sum of squares | Sum of squares within-groups of the typology | Proportion (%) of total sum of squares explained |
|---|---|---|---|
| Belier | 15480.431 | 1929.129 | 87.53 |
| Nzi | 13761.891 | 967.171 | 92.97 |
| Lôh-djiboua | 11177.344 | 1151.313 | 89.69 |
| Marahoue | 13308.327 | 1054.585 | 92.07 |
| Haut-sassandra | 43573.553 | 3156.060 | 92.75 |

**Physicochemical characteristics of roots from the three cassava cultivars.**

Table 3 presents the results of physicochemical characterization of roots from the three cassava cultivars. It was observed that the moisture content of cassava roots varied from 60.36±3.09 (*Zoklo* cultivar) to 62.18±2.41% (*Yace* cultivar). The moisture content of *Akaman* roots was 61.92±2.18%. The protein content of roots ranged from 1.95±0.31 (*Zoklo* variety) to 2.27±0.35% (*Akaman* variety). A value of 2.19±0.50% was recorded in *Yace* roots. The pH values of roots are located between 6.54±0.11 (*Yace* cultivar) and 6.74±0.05 (*Zoklo* cultivar) whereas the titratable acidity ranged from 2.57±1.13 (*Zoklo* cultivar) to 4.73±1.69 meq/100 g (*Yace* cultivar). The acidity and pH values of the roots from *Akaman* variety were 3.40±1.51 meq/100 g and 6.70±0.06, respectively. The lipid content ranged from 0.58±0.10 (*Yace* variety) to 1.04±0.43% (*Akaman* variety) with 0.77±0.13% for the *Zoklo* variety. The ash content of the roots varied from 2.29±0.49 (*Yace* variety) to 2.67±0.54% (*Zoklo* variety) with 2.64±0.36% for *Akaman* cultivar. The total sugar contents of cassava roots ranged from 2.10±0.41 (*Yace* variety) to 2.64±0.15% (*Zoklo* variety) while cyanide contents varied from 20.00±6.54 (*Zoklo* variety) to 106.00±12.13 mg/kg (*Yace* variety). In *Akaman* roots, the cyanide and total sugar contents were 54.33±7.03 mg/kg and 2.43±0.26% respectively. The carbohydrate contents of the roots varied from 92.52±0.77 (*Akaman* variety) to 93.65±0.92% (*Yace* variety). Starch contents ranged from 75.36±2.75 (*Akaman* variety) to 77.70±2.71% (*Yace* variety). The recorded values of carbohydrate and starch for *Zoklo* variety were 92.77±1.24% and 75.36±2.75% respectively. The energy values varied from 385.93±5.31 (*Zoklo* variety) to 388.63±3.04 kcal/100 g (*Yace* variety) with 388.62±2.94 kcal/100 g for the *Akaman* variety. The phosphorus and calcium contents ranged from 111.78±29.84 (*Yace* variety) to 140.43±69.15 mg/100 g (*Akaman* variety) and from 97.41±42.06 (Yace variety) to 115.67±70.54 mg/100 g (*Akaman* variety), respectively. The values of 127.96±59.87 and 112.16±60.75 mg/100 g were recorded in *Zoklo* variety for phosphorus and calcium, respectively. The Ca/P ratio of cassava roots varied from 0.79±0.09 (*Akaman* variety) to 0.85±0.17 (*Yace* variety) with 0.85±0.08 for *Zoklo* variety. It was observed that the magnesium and iron contents of the roots varied from 65.81±47.46 (*Akaman* cultivar) to 72.92±43.96 mg/100 g (*Zoklo* cultivar) and from 6.94±1.87 (*Akaman* cultivar) to 10.41±7.55 mg/100 g (*Zoklo* cultivar), respectively. The values of 68.39±36.10 and 8.71±5.82 mg/100 g were recorded in *Yace* variety for magnesium and iron contents, respectively. The zinc content of roots ranged from 2.51±1.42 (*Akaman* cultivar) to 2.81±1.57 mg/100 g (*Zoklo* cultivar) with 2.52±1.43 mg/100 g for *Yace* cultivar. In total, the moisture, starch, carbohydrate and energy contents of the roots were much higher than those for ash, total sugar, protein and lipid.

**Comparison of the physicochemical characteristics of the cassava roots from three cultivars**

Analyses of variance results are shown in Table 3. It was observed that, the following parameters of the roots did not vary significantly ($p>0.05$): moisture, protein, ash, starch, energy, minerals (P, Mg, Fe, Zn and Ca) and Ca/P ratios. In contrary, the values of pH and acidity, lipids, total sugars, cyanide and carbohydrate varied significantly ($p<0.05$) between the cultivars. The *Yace* cultivar roots recorded the highest values of acidity (4.73±1.69 meq/100 g), cyanide (106.00±12.13 mg/kg) and carbohydrate (93.65±0.92%), and the lowest values of pH (6.54±0.11), lipids (0.58±0.10%) and total sugars (2.10±0.41%). The *Akaman* cultivar recorded the highest value of lipid (1.04±0.43%) while the lowest cyanide content of the roots was recorded in *Zoklo* cultivar (20.00±6.54 mg/kg). Otherwise, the pH, acidity and total sugar values of *Akaman* and *Zoklo* roots were not statistically different (p>0.05). In addition, the carbohydrate content of *Zoklo* cultivar was not significantly different (p>0.05) to those of *Akaman* and *Yace*.

**Table 3**. Physicochemical characteristics of cassava roots from three local cultivars in Côte d'Ivoire

| | Cultivars | | |
|---|---|---|---|
| Parameters | Akaman | Zoklo | Yace |
| Moisture (%)* | 61.92±2.18a | 60.36±3.09a | 62.18±2.41a |
| Proteins (%) | 2.27±0.35a | 1.95±0.31a | 2.19±0.50a |
| pH | 6.70±0.06a | 6.74±0.05a | 6.54±0.11b |
| Acidity (meq/100g) | 3.40±1.51a | 2.57±1.13a | 4.73±1.69b |
| Lipids (%) | 1.04±0.43a | 0.77±0.13b | 0.58±0.10b |
| Ash (%) | 2.64±0.36a | 2.67±0.54a | 2.29±0.49a |
| Total sugars (%) | 2.43±0.26a | 2.64±0.15a | 2.10±0.41b |
| Cyanide (mg/kg)* | 54.33±7.03a | 20.00±6.54b | 106.00±12.13c |
| Starch (%) | 77.37±2.78a | 75.36±2.75a | 77.70±2.71a |
| Carbohydrates (%) | 92.52±0.77a | 92.77±1.24ab | 93.65±0.92b |
| Energy (kcal/100 g) | 388.62±2.94a | 385.93±5.31a | 388.63±3.04a |
| P (mg/100 g) | 140.43±69.15a | 127.96±59.87a | 111.78±29.84a |
| Mg (mg/100 g) | 65.81±47.46a | 72.92±43.96a | 68.39±36.10a |
| Fe (mg/100g) | 6.94±1.87a | 10.41±7.55a | 8.71±5.82a |
| Zn (mg/100 g) | 2.51±1.42a | 2.81±1.57a | 2.52±1.43a |
| Ca (mg/100g) | 115.67±70.54a | 112.16±60.75a | 97.41±42.06a |
| Ca/P | 0.79±0.09a | 0.85±0.08a | 0.85±0.17a |

Tabulated values are means of fifteen determinations ± Standard Deviation (SD)
(*) Fresh matter basis.
Values with different letters in each row are significantly different (p<0.05)

## Discussion

The cassava roots from the three cultivars were subjected to MANOVA, in order to show if they are equal trough their whole physicochemical characteristics. For this purpose, it was observed that the characteristics of the roots varied significantly (p<0.05) between the cultivars. Therefore, some physicochemical parameters of *Akaman* roots differed significantly (p>0.05) from those of *Yace* and *Zoklo*. This result is in agreement with earlier report that mentioned the influence of cultivar on the physicochemical characteristics of cassava roots (Manusset, 2006). Differences between the physicochemical characteristics of roots from some cultivars have already been reported by Asiedu (1991). The hierarchical tree obtained in each region showed clearly this difference. Indeed, the quality of the typology in three clusters like *Akaman*, *Yace* and *Zoklo* is quite relevant as shown by the range (87.53-92.97%) of total sum of squares explained. It was observed that the values of total sum of squares explained by this typology were high. It means that the typology (3-clusters) has a high quality. In addition, the statistical analyses revealed that cluster formed by *Akaman* roots, was characterized by the relatively high lipid content. The other one composed by *Yace* roots, was characterized by high acidity, cyanide and carbohydrate contents. The members of this cluster were also characterized by the low pH and total sugar values. Concerning the roots of the last cluster formed by *Zoklo* cultivar, statistical analyses showed clearly that they were characterized by their low cyanide content. Otherwise, the physicochemical characterization revealed that the cassava roots assessed had high moisture content. The moisture content of cassava roots is found to be 54-73% (Bakayako et al., 2012). The values recorded in this study were within this range. Besides, statistical analyses revealed that there was no significant difference ($p<0.05$) between the moisture content of the roots evaluated. Then, no variety is more perishable than another. The high moisture content found in the three cultivars of the roots could explain their rapid deterioration once harvested. Indeed, a relationship between the moisture content of foods and the proliferation of microorganisms that cause deterioration has been mentioned (Ladeira et al., 2013). In addition, there was no significant difference ($p>0.05$) between the protein values recorded in the roots, whatever the cultivar. It is well-known that cassava roots from local varieties have low protein content (Nassar & Ortiz, 2010). The results obtained in this study confirmed this statement. The protein value reported in some improved cassava varieties was much higher than those recorded in the present study. It is the case of the improved variety V63 which protein value was found to be 8.18% on dry matter basis (Megnanou et al., 2009). The analyses of variance showed that the pH values of cassava roots varied significantly ($p<0.05$) from a cultivar to another. The roots from *Yace* variety recorded the lowest value. It is certainly due to their high acidity while comparing to *Akaman* and *Zoklo* varieties. Indeed, a significant and negative correlation between acidity and pH value has already been reported in cassava roots (Koko, 2012). The pH values of cassava roots were close to 6.7 recorded with an improved variety (TMS 55752) by Karim et al. (2009). Despite the significant difference between the pH values, all of the roots assessed were low-acid foods (pH>4.5). The lipid contents recorded in the present study varied significantly ($p<0.05$) between the cultivars. The highest value was recorded in *Akaman* roots while the lowest one was in *Yace* variety. The relatively high lipid content of roots from *Akaman* cultivar could be due to the presence of carotenoid compounds at relevant level than the other cultivars. Indeed, the relatively yellow color of the *Akaman* roots may be a sign of the presence of such carotenoid compounds. Despite this significant difference, all the values of lipid were low. It is well-know that cassava roots have low lipid content (Ladeira et al., 2013). The statistical analyses revealed that the ash content did not vary significantly ($p>0.05$) between the three cassava cultivars. The ash content of improved cassava variety was found to be 0.92-2.6% on dry matter basis (Megnanou et al., 2009). In this study, the values recorded were close to this range. The total sugar content of roots varied significantly ($p<0.05$) from a cultivar to a cultivar. The lowest value belongs to *Yace* variety as expected because of their bitter taste. Unfortunately, all the values of total sugar were low. The total sugar contents recorded in this study were much lower than those reported by Ladeira et al. (2013). These authors found in fresh cassava roots, values ranging from 3.71 to 4.3% on fresh matter basis. According to the cyanide contents of roots evaluated, the analysis of variance revealed that there was a significant difference ($p<0.05$) between the values recorded. Then, the *Yace* roots which cyanide content is more than 100 mg/kg are toxic variety (Purseglove, 1968). Due to toxicity, attention must be focused on their processing forms in order to reduce cyanide content at safe levels, before used them in human diet. The *Yace* roots could therefore be used in *placali* and *attieke* preparation, both fermented products consumed in Côte d'Ivoire. The role of fermentation in cassava detoxification has been mentioned (Kobawila et al., 2005). These roots could also be used in *gari* preparation and other cassava products that need meaningful unit operations in their processing flow chart. The lowest cyanide content of *Zoklo* roots (less than 50 mg/kg) is an indication of non-toxicity. This kind of roots could be used either in *foutou* preparation that needs slight transformation, or in *placali* and *attieke* production. These roots could also be eaten directly, either raw or boiled. The roots from *Akaman* cultivar which cyanide content is between 50 and 100 mg/kg are classified as intermediate variety (Purseglove, 1968). These roots must be processed before consumption in order to reduce cyanide content. Then, the *Akaman* roots could be processed into various products like *placali*, *attieke*, *foutou*, flour, *fufu*, *gari*, etc. Moreover, the starch content of the cassava roots is found to be 65-91% on dry matter basis (Bradshaw, 2010). In this study, the starch contents of roots from the three cassava cultivars assessed were within this range. In addition, statistical analysis revealed that there was no significant difference ($p<0.05$) between the starch content of the three cultivars. Therefore, the roots are starchy products. Due to their high starch content, the roots from the three local cassava cultivars could be used at small-scale in starch production. Before using them at industrial scale, their starch quality must be first assessed. The *Yace* roots recorded the highest carbohydrate contents while the values obtained in *Akaman* variety seemed to be the lowest. Despite the significant difference ($p<0.05$), all the values of carbohydrate in the three cassava cultivars were high. The high levels of carbohydrate could explain the high-energy values recorded in the roots, whatever the cultivar. Indeed, about one kilogram of the roots from the three cultivars could cover the recommended daily energy value for adult, which is 3050 kcal (FAO, 1985). Then, the roots from the three cultivars are energizing foods. In the present study, it was observed that all the roots from the three cultivars contained minerals (P, Mg, Fe, Zn and Ca). Besides, the analysis of variance revealed that there was no significant difference ($p<0.05$) between these mineral contents. Then, the mineral contents did not vary significantly ($p<0.05$) between the cultivars. Otherwise, a quantity of one kilogram of the roots from the three cassava varieties could cover the daily recommended dietary allowances (RDA) values of P (700 mg), Mg (310-400 mg), Fe (8-18 mg), Zn (8-11 mg) and Ca (1000 mg) for adult males and females (Institute of Medicine, 2002). These results confirm earlier report that cassava has been recognized as a suitable crop for micronutrient intervention in Africa (Oyewole and Asagbara, 2003). The Ca/P ratios of cassava roots were close to 0.7, which is the optimal value for the absorption of the both minerals according to Javillier et al. (1967). It is a clear indication that the minerals in cassava roots are well-balanced.

## Conclusion

The present study has clearly showed that the cassava roots from the three cultivars had high energy, moisture, starch and carbohydrate contents and were poor in protein, total sugar, lipid and ash contents whatever the cultivar. The significant differences ($p<0.05$) between the cultivars were on some physicochemical characteristics (pH, titratable acidity, total sugar, cyanide and carbohydrate contents). *Yace* cultivar, a toxic variety was characterized by high titratable acidity, high carbohydrate, low pH value and low total sugar content. It must be transformed before using it in human consumption. The non-toxic variety was *Zoklo* cultivar. Their roots could be used in human consumption either without any transformations or after processing into the various cassava by-products. The roots from *Akaman* cultivar were intermediate variety and characterized by their relatively high lipid content. They must be processed before consuming them. If not, attention must be focused on its utilization form in order to reduce the cyanide content at safe level.

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