Assessment of Chemical Composition and Nutritional Value of Some Varieties of Okra Available in the Market of Daloa (Côte d'Ivoire)

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ABSTRACT— *Six okra varieties (F1 Yodana, Kirikou, Volta, Yeleen, Kousko and Local) sold and consumed in Daloa (Côte d'Ivoire) were evaluated with regards to the nutritional, antioxidant and mineral contents. The result of the study revealed that the proximate composition in dry weight basis was significantly (P < 0.05) varied and ranged: dry matter 87.83-92.33%, crude protein 13.65-22.63%, crude fat 2.78-3.94%, crude fiber 21.08-26.70%, crude ash 7.16-10.59%, carbohydrate 39.28-54.25%, and energy value 274.78-297.97 kcal/100 g. Volta had the highest content in both protein and fat. Yeleen had the highest ash content, Local had the highest fiber content, while Kirikou presented the highest content in both carbohydrate and energy values. The phenolic content ranges from 111.42 to 156.00 mg/100 g while the vitamin C ranges from 25.30 to 49.60 mg/100 g in dry weight basis. Volta had the highest content in both phenolic and vitamin C. The mineral contents (mg/100 g) in dry weight basis were also significantly (P < 0.05) varied. Potassium was the most abundant macro-element (1642.71-2519.84) followed by calcium (460.80-767.72), magnesium (345.46-432.70) and Iron (0.42-3.18) in all the varieties. Interrelationships between the parameters analysed and the different okra varieties were investigated by principal component analysis (PCA). PCA revealed differences between the okra varieties and classified them into three groups on the basis of the measured parameters: Group 1 (F1 Yodana, Volta and Local), Group 2 (Kirikou and Kousko) and Group 3 (Yeleen). This study provided important information about the nutritional composition of okra from Daloa, which can help to increase production and consumption of these nutrient-rich vegetables and will help reduce the nutrition-related disorders in Africa.*

Keywords— Okra, proximate composition, nutrients constituents, Côte d'Ivoire
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1. INTRODUCTION

Vegetables have long been part of diets in communities worldwide and contribute substantially to food security [1]. Vegetables are valuable sources of nutrients, with some having important medicinal properties [2, 3, 4].

Okra (*Abelmoschus esculentus* L.) is one of the oldest cultivated crops and presently grown in many countries and is widely distributed from Africa to Asia, southern Europe and America [5]. It is one of the most widely known and utilized species of the family Malvaceae. The nutritional potential of okra (mineral elements, protein, fiber, antioxidants and vitamins) has been reported by many researchers [6, 7, 8]. In addition, this plant has a wide range of medicinal values and has been used to treat many diseases. Some authors reported that okra owns the antioxidation and anti-diabetes activities, cures ulcers and relief from hemorrhoids, and reduces blood lipid [9, 10, 11].

In West Africa, okra is in second place in vegetable production behind tomatoes [12]. It is mainly cultivated for its immature fruits which are eaten after cooking. The plant is also cultivated because the leaves can be consumed and the stem used for fiber and rope. In Côte d'Ivoire, okra occupies an important place in the diet. With 5.5 kg of fresh fruit per inhabitant

/ year, okra comes first ahead of the eggplant (3.7 kg / inhabitant) and the tomato (1.4 kg / inhabitant), among the vegetables of great consumption in Côte d'Ivoire [13]. The fruits are used in both fresh and dried forms. It represents 24% of the vegetables consumed fresh and 41% of vegetables consumed dried [14]. Despite the exceptional characteristics of okra, it remains a marginalized, minor crop and an essentially feminine activity. Several varieties exist on the Ivorian market with different forms and different production cycles. But little is known about their nutritional quality. Assessing the nutritional importance of these varieties can lead to a better understanding of the value of these plants. Therefore, this work aims to evaluate the nutritional characteristics of the different okra varieties sold and consumed in Daloa (Côte d'Ivoire) to increase the uptake/promotion of these vegetables.

2. MATERIALS AND METHODS

2.1. Materials

The biological material used in this study consisted of six varieties of okra, namely F1 Yodana, Kirikou, Volta, Yeleen, Kousko and Local (Fig. 1). The samples of okra were collected in the region of Daloa (Côte d'Ivoire). They were fresh and without infections or wounds.

Figure 1: Varieties of Okra studied: A) F1 Yodana; B) Local; C) Kirikou; D) Kousko; E) Volta; F) Yeleen

2.2. Sample Preparation

The okra fruits were sorted, washed, stumps trimmed off (with stainless steel knife) and then consumable parts were cut longitudinally into portions of equal size. The samples were oven-dried at 70 °C for 24 h. The dried material obtained was ground to a fine powder and finally packed into airtight polyethylene plastic bottles and stored in the desiccator until required for analysis. The dry samples were analysed for proximate composition, minerals (Ca, Mg, Fe and K), vitamin C and total phenolic content. Determinations were carried out by duplicate. The results are expressed as g per one hundred (100) g of dry weight (g/100 g DW).

2.3. Determination of Proximate Composition

Okra samples were analyzed for their pH and dry matter [15]. One hundred (100) mL of distilled water was homogenized with 10 g of sample, and the pH was measured with a combined glass electrode pH-meter (Hanna Instruments, Romania). Dry matter was determined by hot oven (Memmert, Schwabach, Germany) drying at 105 °C for 24 h to constant weight. Crude fat determination was carried out by Soxhlet extraction of a 10 g sample, with hexane as solvent [16]. Ash content was determined using the muffle furnace at 550 °C during 24 h according to the AOAC method [17]. Crude protein was determined by using Kjeldahl method in which percent nitrogen (N) was multiplied by 6.25 to convert the percent N into percent crude protein [18]. Crude fiber was determined by digestion method [19]. Two (2) g of sample was accurately weighed and transferred into beaker containing 50 mL of H_2SO_4 (0.25 N). After boiling for 30 min under reflux refrigerant, 50 mL of NaOH (0.31 N) was added and boiled. After 30 min, the solution was filtered. Residues were washed with hot water and transferred to crucible. Crucible containing residue was dried at 105 °C for 8 h to a constant weight. The crucible was then cooled in a desiccator and weighed. The residues were placed in muffle furnace at 550 °C for 3 h and then the sample was cooled in a desiccator and weighed. Results were expressed as shown in equation 1:

$$Crude\ fiber\ (\%) = \frac{Weight\ of\ residue\ -\ Weight\ of\ ash}{Weight\ of\ sample\ \times\ Dry\ weight} \times 100$$

(1)

Total carbohydrate content was calculated adding the total values of crude protein, crude fat, crude fiber and total ash contents of the sample and subtracting it from 100% according to the equation 2 [20].

$$Total\ carbohydrate\ (\%) = 100 - (\%\ protein + \%\ ash + \%\ fat + \%\ crude\ fiber)$$ (2)

The energy value was calculated from the total carbohydrate content, crude protein and crude fat using the conversion factors for energy (Atwater factors such as 4 kcal per 1 g of carbohydrate, 9 kcal per 1 g lipid and 4 kcal per 1 g of protein) [21].

2.4. Determination of Mineral Content

The mineral content (Ca, Mg, K and Fe) was determined using an atomic absorption spectrophotometer (Thermo Scientific iCE 3000 Series) according to the procedure reported by Kouassi et al. [22]. Ashing of the samples was followed by digestion and absorption. The ashed sample (0.25 g) was mixed with 30 mL of 1% nitric acid. The extract obtained was filtered using whatman filter paper, then collected in a 100 mL flask and adjusted with distilled water. The supernatant was puted into clean vials for mineral determination. The absorbance was read on atomic absorption spectrophotometer at different wavelength for each mineral element (Ca-422.7 nm, Fe-248.3 nm, Mg-285.2 nm, and K-766.5 nm). All results were expressed on per 100 g of dry weight basis.

2.5. Determination of Antioxidants

The amount of total phenolic content in the okra was determined using the Folin-Ciocalteu reagent and gallic acid as standard [23]. Methanolic extracts of okra (1 mL) were transferred into different test tubes, and then mixed with 1 mL of Folin–Ciocalteu reagent. After 3 min for allowing the reaction to take place, 1 mL of 20% sodium carbonate (Na_2CO_3) was added. The test tubes were placed in the dark for 30 min at ambient temperature, and the absorption was measured at 725 nm using spectrophotometer (DR 3900) against a blank, which contained methanol in place of sample. Gallic acid was used as calibration standard, and the total phenolic content was expressed as gallic acid equivalent in mg/100 g dry weight (mg GAE/100 g DW).

The amount of ascorbic acid (Vitamin C) was determined according to the 2, 6-dichlorophenol – indophenols dye method of Pongracz et al. [24]. Ten (10) g of each sample (powdered okra) was mixed with 40 mL of 2% metaphosphoric acid at room temperature. The mixture obtained was centrifuged at 3000 rpm for 20 min. The supernatant was introduced into a 50 mL (V_1) flask and adjusted with distilled water. Test sample (10 mL, V_2) of the diluted sample was titrated with 2,6-dichloroindophenol (2,6-DCPIP, 0.5 g/L) until it turns pale pink. Percentage of vitamin C content was calculated by using the equation 3:

$$Vitamin\ C\ (\%) = \frac{(C \times V) \times V_1}{W \times V_2 \times DW} \times 100$$

(3)

Where, V = Volume (mL) of 2,6-DCPIP required to titrate sample, V_2 = Volume (mL) of test sample, C = Concentration (g/L) of 2,6-DCPIP, V_1 = Volume (mL) of diluted sample, W = weight of sample (g), DW = dry weight

2.6. Statistical Analysis

The statistical processing of the data consisted of an analysis of variance (ANOVA) with a classification criterion using the SPSS software (SPSS 20.0 for Windows, SPSS Inc.). Means were compared by the Duncan test at the 5% significance level. A principal component analysis (PCA) was also carried out using R software (version 3.5.0) in order to structure the variability between okra and nutritive content.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition

The proximate and nutrient analyses of okra play a crucial role in assessing its nutritional significance. The proximate composition for the mean dry weight, pH, ash, crude fat, crude protein, crude fiber, total carbohydrate and energy values found in the present work are shown in Table 1. The result shows that the pH values of the different okra varieties were not significantly different (P < 0.05). It varied respectively from 5.80 to 6.06. These findings are consistent with those of Nair and Fahsa [25] who reported pH values with a range of 5.2-6.4 for five varieties of okra.

Table 1: Proximate Composition of Okra Varieties (on dry weight basis).

Composition (%)	F1 Yodana	Local	Kirikou	Kousko	Volta	Yeleen
pH	5.84[a] ± 0.01	5.80[a] ± 0.01	5.87[a] ± 0.02	5.82[a] ± 0.09	6.06[a] ± 0.99	5.96[a] ± 0.40
DM	91.94[d] ± 0.15	87.83[a] ± 0.20	90.39[c] ± 0.39	88.61[b] ± 0.31	90.00[c] ± 0.02	92.33[d] ± 0.02
Crude protein	21.41[cd] ± 0.70	21.92[de] ± 0.28	13.65[a] ± 0.59	20.48[c] ± 0.28	22.63[e] ± 0.34	14.77[b] ± 0.34
Crude fat	2.98[a] ± 0.08	2.78[a] ± 0.09	2.92[a] ± 0.22	3.30[a] ± 0.04	3.94[a] ± 0.08	3.19[a] ± 0.69
Ash	7.84[b] ± 0.29	8.09[bc] ± 0.04	8.08[bc] ± 0.07	7.16[a] ± 0.03	8.44[c] ± 0.01	10.59[d] ± 0.27
Crude fiber	23.48[bc] ± 0.61	26.70[e] ± 0.37	21.08[a] ± 1.26	24.09[cd] ± 0.64	25.71[de] ± 0.38	22.03[ab] ± 0.75
Total carbohy.	44.29[b] ± 1.11	40.50[a] ± 0.22	54.25[d] ± 1.56	44.96[b] ± 0.92	39.24[a] ± 0.66	49.41[c] ± 1.50
EV (kcal/ 100 g)	289.61[bc] ± 0.91	274.78[a] ± ± 1.18	297.97[d] ± 5.89	291.53[cd] ± 2.24	283.08[b] ± ± 1.97	285.47[bc] ± ± 1.55

Values are averages ± standard deviation of replicate determinations (n = 2). Means not followed by the same superscript letters in the same row are significantly different (P < 0.05). DM = Dry matter, Total carbohy = Total carbohydrate, EV = Energy value.

The dry matter content of a sample corresponds to its mass after complete evaporation of free water. These rates range from 87.83 to 92.33% for the six varieties of okra. The results show significant differences (P < 0.05) between dry matter content of the sample. Indeed, these low water contents reflect the high solids content of the samples. This facilitates their preservation. Yeleen variety was observed to have the highest content while Local variety had the least. These values are in agreement with high dry matter content in okra pods at 86.67-90.31% as previously reported [8].

Proteins play a particularly important role in human nutrition. The amino acid contents, proportions, and their digestibility by humans characterize a protein's biological value [26]. The protein content of the studied okra varieties ranged between 13.65-22.63% on dry weight basis. These values were in the same range of the protein values (10.25-26.12%) reported for okra varieties [8]. Kirikou variety had the least protein content while Volta variety had the highest; this could be due to genetic factor. Okra can be considered as a high protein vegetable. Thus, a diet containing these varieties of okra would be beneficial to health, knowing the important role played by proteins in the body.

The fat content in the studied okra varieties is reported in Table 1. It varied from 2.78-3.94% on dry weight basis. Volta variety had the highest content of fat which was not significantly different from all other varieties. The fat content in these

okra varieties is low in comparison with the range of fat (4.34-4.52%) reported by Sami et al. [27]. This difference may be due to the genetic factor of the varieties.

The ash content is the total quantity of minerals present in the sample. The ash content in the okra varieties varied from 7.16-10.59% on dry weight basis. These results were approximate to those reported by other researchers [6]. These results indicate that these okra varieties would provide essential valuable and useful minerals needed for body development.

Interest in fiber evaluation has increased due to the potential role of dietary fiber in human nutrition [28]. Dietary fiber helps to stabilize blood sugar by regulating the rate at which sugar is absorbed from the intestinal tract [29]. Fiber also promotes the growth and protects the beneficial intestinal flora. Moreover, high intake of fiber reduces the risk of colon cancer [30]. Crude fiber in all the samples differed significantly and ranged from 21.08 to 26.70% on dry weight basis. Adetuyi et al. [6] reported that the fiber content of Okra pod ranges from 10.15 to 11.63 g/100 g which is lower than the crude fiber obtained in the present study. The crude fiber contents were however, within the range of the crude fiber content (11.97-29.93%) of okra reported previously [8]. The high value of fiber reported for okra fruit can improve its digestibility and absorption processes in large intestine, helping to stimulate peristalsis, thereby preventing constipation [31].

Carbohydrate is essential for energy production in the human body [32]. The total carbohydrate contents of the six varieties of okra used in this study are shown in Table 1. Total carbohydrates ranged from 39.28 to 54.25% on dry weight basis. Similar results have also been found [8]. The high levels were observed in Kirikou, Yeleen, Kousko and F1 Yodana varieties; indicating that these varieties contain more mucilage and this implies that these okra can serve as a good source of carbohydrate or polysaccharide. Researchers [33] have shown that okra polysaccharides are particularly effective at inhibiting the adhesion of *Helicobacter pylori* bacteria on gastric tissues, preventing the spread of these bacteria. Therefore, eating more okra can keep the stomach clean and create an environment that prevents destructive cultures from flourishing.

The results of the energy values showed significant differences (P < 0.05) between varieties. The average energy values content range from 274.78 kcal/100 g to 297.97 kcal/100 g. Kirikou variety had the highest energy value while Local variety had the least. These energy values indicate that these okra varieties can serve as a good source of energy for the body.

These chemical composition values confirmed that okra is an excellent food source, justifying its direct use in human nutrition.

3.2. Antioxidant Contents

Table 2 shows the total phenolic and vitamin C contents of the six studied okra varieties. The result of the total phenolic content of the present investigation was expressed as mg gallic acid equivalent (GAE) per 100 g sample on dry weight basis. Significant difference was found between the varieties (P < 0.05). Phenolic compounds were considered as a major group of compounds that contributed to the antioxidant activity of okra. It varied between 111.42 mg GAE/100 g and 156.00 mg GAE/100 g. The order of total phenolic contents was as follow: Volta > F1 Yodana > Local > Yeleen > Kousko > Kirikou. The total phenolic contents of the varieties of okra were comparable with those of common vegetables such as celery leaves (113.0 mg GAE/100 g), red pepper (173.20 mg GAE/100 g), salad (116.20 mg GAE/100 g), lettuce (124.50 mg GAE/100 g), broccoli (101.70 mg GAE/100 g), red onion (154.10 mg GAE/100 g) [34]. Plants rich in phenolics are being used in the food industry because they retard oxidative degradation of lipids and improve the quality and nutritional value of food [35].

Table 2: Antioxidant Contents of Okra Varieties

Varieties	Total phenolics (mg GAE/100 g DW)	Vitamin C (mg/100 g DW)
F1 Yodana	146.20[c]±4.05	47.00[d]±0.90
Local	126.54[b]±5.03	34.73[b]±1.30
Kirikou	111.42[a]±6.43	40.87[c]±0.40
Kousko	116.73[ab]±2.32	42.11[c]±0.15
Volta	156.01[d]±2.34	49.60[d]±1.76
Yeleen	123.55[b]±1.54	25.30[a]±2.32

Values are averages ± standard deviation of replicate determinations (n = 2). Means not followed by the same superscript letters in the same column are significantly different (P < 0.05). GAE: Gallic acid equivalent, DW: Dry weight.

The vitamin C or ascorbic acid is a water soluble vitamin and possesses a good antioxidant property [36]. The results showed that there were significantly differences (P < 0.05) between the okra varieties. The vitamin C content of theses okra varieties ranged from 25.30 mg/100 g to 49.60 mg/100 g on dry weight basis (Table 2). These values were lower to those reported for fresh okra (71.30 mg/100 g DW) [37]. The reduction of the vitamin C content in okra is the result of the drying processes which is known to accelerate oxidation of ascorbic acid [38].

3.3. Mineral Composition

The minerals present in vegetables are essential for the functioning of the organism and its development [39]. Four different minerals were analyzed for their concentration in dry weight basis (mg/100 g DW). According to the results of minerals quantification, the major element found were potassium (K: 1642.71-2519.84 mg/100 g) followed by calcium (Ca: 460.80-767.72 mg/100 g), magnesium (Mg: 345.46-432.70 mg/100 g) and iron (Fe: 0.42-3.18 mg/100 g) in all varieties (Table 3). Researchers [40] have pointed out that in okra fruits, the mineral contents were in the order of P > K > Ca > Mg > Na > Fe, which also signifies their relative functional importance in growth and metabolism. Table 3 also revealed that there was a significant (P < 0.05) difference in the mineral compositions of okra varieties.

Table 3: Mineral Contents of Okra Varieties (mg/100 g on dry weight basis)

Varieties	K	Ca	Mg	Fe
F1 Yodana	2519.84[e]±33.16	703.21[bc]±83.90	423.52[e]±0.81	1.67[b]±0.08
Local	2326.16[c]±31.79	732.76[bc]±6.88	400.89[d]±3.21	3.18[e]±0.14
Kirikou	1903.53[b]±4.19	574.68[ab]±30.57	345.46[a]±4.80	2.03[c]±0.18
Kousko	1642.71[a]±18.03	505.73[a]±14.29	359.40[c]±1.10	0.42[a]±0.12
Volta	2462.55[d]±5.33	460.80[a]±11.71	352.38[b]±0.96	2.64[d]±0.15
Yeleen	2414.30[d]±13.87	767.72[c]±157.33	432.70[f]±0.91	2.53[d]±0.16

Values are averages ± standard deviation of replicate determinations (n = 2). Means not followed by the same superscript letters in the same column are significantly different (P < 0.05).

Result of potassium content appeared to be far higher than the potassium contents of okra varieties, varying between 122.59 mg/100 g to 318.20 mg/100 g [8]. High amount of potassium in the body was reported to increase iron utilization [41] and beneficial to people taking diuretics to control hypertension and suffer from excessive excretion of potassium through the body fluid [42].

The content of calcium in the studied okra varieties was comparable to the values of calcium (515.22-564.84 mg/100 g) previously reported [43]. A similar result concerning magnesium content was also found [43]. Calcium and magnesium play a significant role in photosynthesis, carbohydrate metabolism and nucleic acids. Magnesium is essential mineral for enzyme activity, like calcium and chloride; magnesium also plays a role in regulating the acid-alkaline balance in the body. High magnesium levels in drinking water have been linked to resistance to heart disease [44].

The iron content found in the present study was lower than the value (14.98 mg/100 g and 17.40 mg/100 g) reported [39] for two varieties of okra, but higher than the iron contents (0.87-0.96 mg/100 g) of the local okra varieties from Nigeria [6]. The main role of iron is the transport of oxygen to the tissues which is the active constituent of hemoglobin in red blood cells. Iron also enhances the body's immune system thus reducing infections and fostering proper functioning of other organs of the body [45].

3.4. Results of the Principal Component Analysis.

In the principal component analysis (PCA) the F1 axis (Factor 1) alone represents 39.29% of the total inertia while the F2 axis (Factor 2) has 34.18% of the inertia (Figure 2a). The F1 and F2 axes therefore explained 73.47% of the total information. The level of connection between the parameters, represented by the geometric angles between the arrows, explains their correlation. Observation of the correlation circle (Figure 2a) showed that most of the parameters studied were well represented. Apart from lipids parameter, the other parameters are close to the circle. The point cloud of the six varieties of okra from the PCA revealed the presence of three groups according to their similarity criteria (Figure 2b).

The first group consisted of three okra varieties i.e. F1 Yodana, Local and Volta located in the center part of the PCA plot. The second group composed by Kirikou and Kousko was observable in the lower part. The third group composed by Yeleen

alone, occupied an isolated location at the upper part of the figure. The similarity of the three varieties of group 1 is due to their high content of proteins, fibers, phenolics and potassium. The similarity of the 2 varieties of group 2 is due to their high energy values and their low potassium and iron contents. The variety of group 3 is distinguished by its high content in ash, calcium and magnesium but also its low vitamin C content.
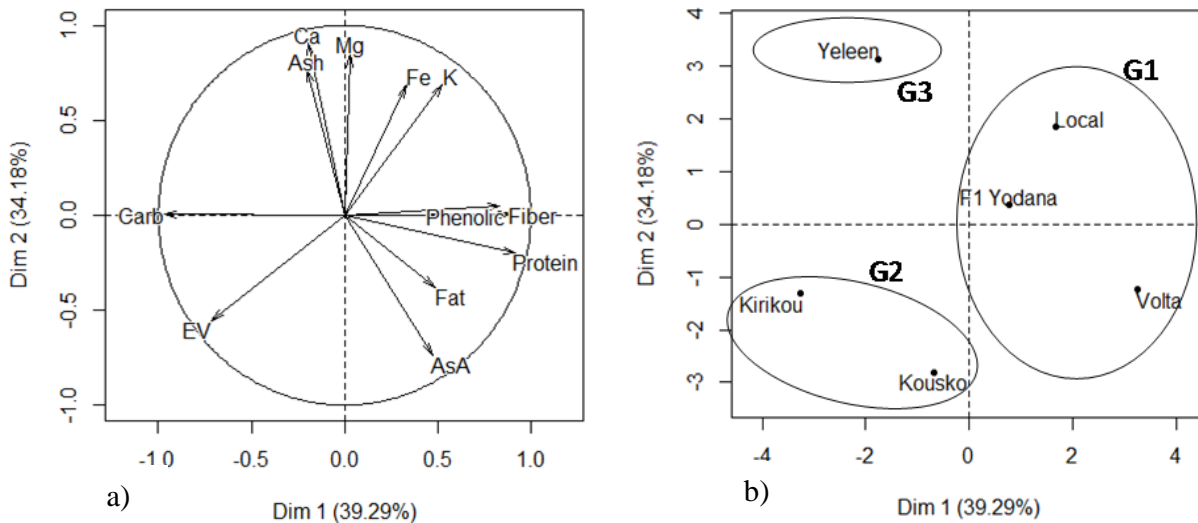

Figure 2: Principal Component Analysis: a) Correlation circle (Carb= carbohydrate, AsA= ascorbic acid, EV= energy value); b) Clustering of okra varieties on the factorial plane (G1= group 1, G2= group 2, G3= group 3)

The result of the hierarchical cluster analysis (HCA) is shown as a dendrogram (Figure 3) in which three well defined clusters (group 1, group 2 and group 3) were visible. Group 1 was composed of F1 Yodana, Volta and Local; Group 2 comprised Kirikou and Kousko and group 3 contained Yeleen alone. This is in agreement with the results of the PCA.
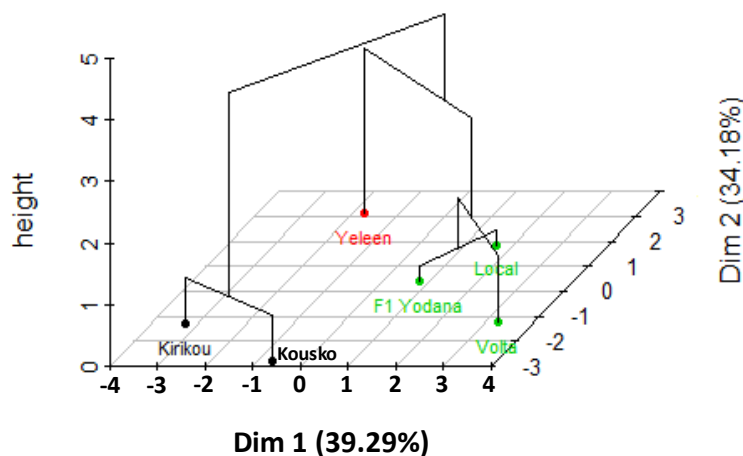

Figure 3: Dendrogram of Hierarchical Clusters of Okra Varieties.

4. CONCLUSION

This study provides information on proximate composition and mineral and antioxidant contents of six varieties of okra growing in Daloa (Côte d'Ivoire). The analyses showed that these varieties of okra can provide nutrient-rich products considering protein, fiber, ash, magnesium, calcium, potassium and iron as quality indices, with slight differences in the quantities of proximate and minerals contents. The results on total phenolics and vitamin C proved that appreciable antioxidants were present in the fruits of the studied okra varieties. Therefore, promoting the consumption of such nutritious vegetables will be beneficial to human health by providing the necessary macro-elements and energy to the body. The results obtained showed also that okra constitutes an important source of antioxidants that could boost immune body system.

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