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# Physico-chemical Characterization Leaves from Five Genotypes of Cassava (*Manihot esculenta* Crantz) Consumed in the Far North Region (Cameroon)

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**Abstract** Leaves from five cassava (*Manihot esculanta*) genotypes including local and improved were evaluated for their physicochemical and antioxidant properties. Results showed a significant ($p<0.05$) variations with the different analysed parameters. Leaves from the improved genotype *92/0326* exhibited the highest ash content (2.34 mg/g fresh weight). Mineral elements were more present in *IRAD4115* and *92/0326* cassava leaves. Leaves from *IRAD4115* exhibited the highest carbohydrates content meanwhile those from local genotype *EN* presented a high protein content (6.64%). The improved variety *IRAD4115* detained the highest total phenolic compounds as well as ascorbic acid (40.51 µg /g) and the highest total antioxidant activity. Cassava leaves are a very important source of macronutrient, micronutrient minerals and antioxidant compounds that can contribute in the strive against chronic malnutrition leading to a better state of health in rural and urban population.

***Keywords:*** *Cassava genotypes, leaves, nutritional qualities, Far North Region*

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## 1. Introduction

Micronutrient malnutrition is a global public health problem, particularly in developing countries [1] where, every year, more than five million children less than five year old die. Nowadays, particularly in Cameroon, the Far North Region faces the problem of food insecurity because of accelerated climate change. The proportion of the malnourished population has remained within the range of 33 to 35% for children below five years [2]. Projections show that there will be an increase in this tendency unless preventive measures are taken. Rural populations are having challenges resulting from the provision of adequate food. Vegetable are essential for a well-balanced diet and can contribute to the prevention of malnutritional disorder [3].

Cassava (*Manihot esculenta*) belongs to the family of *Eupobiaceae* and it is believed to be a native of South America [4]. Cassava has the ability to grow and produce starchy storage roots and leaves. In addition to this, it tolerates even long prolonged drought, high temperature and other adverse environmental conditions following the initial establishment period after planting, to marginal soil and reliable yields in areas where other crops such as maize, sorghum, beans and soybeans die or do not perform well [5]. Its production worldwide has increased and is expected to increase further due to the tremendous demand for good quality food, animal feeds, raw industrial materials as well its antioxidant potential (anticarcinogen, antidiabetic, antitumor) [5,6,7].

A lot of efforts have been made in order to identify compounds that can act as a suitable antioxidant in other to replace synthetic ones which have been questioned, due to their potential health risks and toxicity [7]. Cassava leaves are largely consumed in Africa and are found to be among the top three African indigenous vegetables rich in nutrients [8,9]. Indeed, cassava leaves are an excellent source of proteins (21 - 39%), minerals, antioxidant compounds and vitamins for the human diet [5,10]. Recent findings in plant biochemistry have proved that the proteins embedded in cassava leaves are equal in quality to those in eggs [11].

The natural dietary antioxidant contents in food has been the focus of much investigation recently due to its contribution in protection against diseases. Unfortunately in the Far North Region of Cameroon, the cultivation of cassava is almost unknown or limited in certain villages because it is not one of the stable food. Yet the cassava leaves are greatly appreciated in this area particularly to make different kinds of food like *soup, magani and* *groundnut pellet*. Aregheore [12] noted that pregnant women in some African countries consume cassava leaves to increase breast milk production. Indeed, the high-protein content and nutritive value of cassava leaves can reduce or eradicate nutritional deficiency in poor population and also fight against micronutrients malnourishment. Knowing the nutritional and therapeutic value or importance of cassava leaves, this study will characterize physicochemical proprieties from five cassava genotypes that will enable the determination of the leaves with a higher nutritional value and the best antioxidant activity.

The aim of this study is to determine the physico-chemical and antioxidant properties of leaves from five genotypes of cassava in the Far North Region of Cameroun.

## 2. Materials and Methods

### 2.1. Trial Site and Experimental Design

The study was conducted in the Soudano-sahelian transitional zone in the subdivision of Tokombéré (Far North of Cameroon). The soil is a sandy clay and the area is characterized by a transient equatorial climate with a long dry season (October to April) and short rainy season (May to September). There is an annual precipitation of 1000 mm and a mean annual temperature of 27 °C.

The field experiment was a randomized complete block design with four repetitions. Each repetition measured 25 $m^2$ with 25 cassava plant feet spaced at 1 m. Five genotypes of cassava (*Manihot esculanta*) were considered in this study. Three improved genotypes (*92/0326*; 96*/1414* and *IRAD4115*) from IITA (International Institute of Tropical Agriculture) in Adamawa Region where they were tested and two local genotypes (*EN* and *AD*) highly appreciated by the population respectively in the Far North and Adamawa Regions. They were allowed to grow for 12 months before their leaves were harvested early in the morning.

### 2.2. Physicochemical Analysis

The dry matter and the ash content of the different cassava (*Manihot esculanta*) leaves were determined using the standard AOAC [13] method. A slurry of fresh samples was made [14] and their pH was measured using a pH meter (HI 8424 Microcomputer Hanna instruments). Ash from the different leaves were used to determine the minerals content (calcium, magnesium, potassium, sodium, zinc, manganese, cupper and iron). About 100 mg of ash was diluted in 5 mL of $HCl/HNO_3$ (3/1) and left boiling for 2 hour. The obtained solution was filtered and it volume adjusted with deionized water to 50 mL in a volumetric flask. Using atomic absorption spectroscopy method, minerals content was determined as performed by Jones & Case [15].

The Ninhydrin colorimetric method [16] was used to determine the free amino acids content of the samples. One hundred milligrams of dried sample was introduced in a beaker containing 10 mL of distilled water. The mixture was stirred from time to time for 24 hour at 4°C and then filtered. The obtained solution was used for analysis. The total proteins content of the dried samples was determined using acetyl acetone/formaldehyde method proposed by Devani *et al*. [17]. Samples were first mineralized using Kjeldahl method [18]. The nitrogen content of the mineralisate was evaluated after a reaction with ammonia ($NH_3$) and acetyl acetone/formaldehyde. The resulting yellow complexe (3,5-diacetyl-1,4-dihydrolutidin) had a maximum absorption at 412 nm. A conversion factor of 6.25 was used to determine the proteins content of the samples.

Free sugars and carbohydrates content of cassava leaves were determined by Orcinol colorimetric method [19]. Free sugars were obtained after stirring dried sample in an 80% ethanol solution. Concerning the total carbohydrates, samples were first hydrolysed with 13M $H_2SO_4$ (30 min, 25°C) after heating at 100°C for 2 h [20]. Regarding their solubility in petroleum ether, lipids content of the samples were determined according to the standard AOAC [13] method. According to the standard AOAC [13] method, the crude fiber content of the sample was determined. Dried samples were hydrolysed with $H_2SO_4$ 0.26N (100°C/30 mn) and washed three times before hydrolysing with KOH 0.23N and also washed successively with distilled water, ethanol and acetone. The dried residue was then put in a furnace (550°C) in order to remove the ash.

### 2.3. Evaluation of Antioxidant Capacities

Vitamin C was extracted by stirring 100 mg of samples in 25 mL oxalic acid solution 0.5%. This was filtered and the extract volume was completed to 50 ml with oxalic acid solution. The extract was titrated against a standard solution of vitamin C using the N-Bromosuccinimid titrimetric method [21].

Methanolic extract of cassava leaves were analyzed for their total phenolics content, total antioxidant potential and DPPH radical-scavenging. Folin method performed by Singleton *et al*. [22] was used for total phenolics content. Results were expressed in terms of milligram gallic acid equivalent per gram of sample. The ferric reducing antioxydant potential (FRAP) of leaves was determined according to their ability to reduce Fe (III)-2,4,6-Tri(2-pyridyl)-s-triazine (TPTZ) complex to Fe (II)-TPTZ presenting a maximum absorption at 593 nm [23]. The free radical scavenging activities (FRSA) of the samples were determined by using DPPH (2,2-diphenyl-1-picrylhydrazyl) free radicals as performed by Sun *et al.* [24]. Results of FRAP and FRSA) were expressed in terms of milli mole of Trolox per mg of sample.

### 2.4. Statistical Analysis

All analyses were performed in triplicate and results were given by the means ± standard deviation. Analysis of variance ($p<0.05$) was used to analyze statistically experimental data. Correlation between the FRAP, the phenolic content and the DPPH scavenging activity of the cassava leaves was studied by Pearson correlations ($p < 0.05$).

## 3. Results

### 3.1. Variation of Proximate Composition of Leaves from Five Cassava Genotypes.

#### 3.1.1. pH, Dry matter, Ash and Minerals Content

The variation of dry matter contents of leaves from five cassava genotypes is presented in Table 1. Results showed that the local variety *EN* exhibits the highest value (35.26 %). Nevertheless, the local genotype *AD* showed significantly ($p < 0.05$) the lowest value (26.86 %) which was very far from the other values of dry matter content. It is noticed that there is no significant difference ($p < 0.05$) among the improved genotypes (*IRAD4115*, *96/1414*, *92/0326*).

**Table 1. pH, dry matter (DM), ash, crude fibres and lipids content of cassava leaves obtained from five different genotypes. Values are giving in mg or g per 100 g of fresh weight**

| | Cassava leaves | | | | |
|---|---|---|---|---|---|
| | 92/0326* | 96/1414* | IRAD4115* | AD** | EN** |
| pH | 6.24 ± 0.03$^{ab}$ | 6.29 ± 0.04$^{a}$ | 6.18 ± 0.02$^{c}$ | 6.28 ± 0.04$^{a}$ | 6.20 ± 0.03$^{bc}$ |
| DM (%) | 33.28 ±0.25$^{bc}$ | 33.67 ± 0.17$^{b}$ | 33.10 ±0.19$^{c}$ | 26.86 ± 0.23$^{d}$ | 35.26 ± 0.16$^{a}$ |
| Ash (mg/g) | 23.37 ± 0.75$^{a}$ | 16.95 ± 0.89$^{c}$ | 22.35 ± 0.88$^{a}$ | 21.48 ± 0.41$^{b}$ | 17.98 ± 0.81$^{c}$ |
| Crude Fibres (%) | 4.56 ± 0.09$^{b}$ | 5.36 ± 0.18$^{a}$ | 3.91 ± 0.18$^{c}$ | 3.18 ± 0.15$^{d}$ | 3.46 ± 0.19$^{d}$ |
| Lipids (%) | 5.34 ± 0.33$^{c}$ | 6.91 ± 0.26$^{a}$ | 7.03 ± 0.16$^{a}$ | 6.44 ± 0.23$^{b}$ | 6.02 ± 0.27$^{b}$ |

Values are means from triplicate measurements ± standard deviation. Values in the same line followed by different letters are significantly different (p <0.05).
* = Improved genotype; ** = Local genotype.

Table 1 also shows that the pH of the leaves also varies according to the cassava genotypes. The ash content of the various cassava leaves varies from 16.95 to 23.37 mg/g fresh weight. Results in Table 1 shows that leaves from the improved varieties *92/0326* and *IRAD4115* exhibited significantly ($p < 0.05$) the highest value while those from the improved *96 /1414* and local *EN* genotype recorded the lowest value of ash content.

Results showed that calcium (Ca) followed by potassium (K) and magnesium (Mg) are the main minerals found in cassava leaves (Figure 1). Ca represents more than 60% of minerals in the cassava leaves from the improved *IRAD4115* and local *AD* genotype. But with the improved genotypes (*96/1414* and *92/0326*), K and Mg exhibit the same distribution patterns (Figure 1). Table 2 shows that the improved genotype *IRAD4115* exhibits significantly ($p < 0.05$) the highest value of calcium (5.92 mg/g fresh weight) and zinc (29.51 µg/g). We also notice that, whatever the mineral, the highest value is exhibited by the leaves from improved genotypes (*96/1414*, *92/0326* or *IRAD4115).*

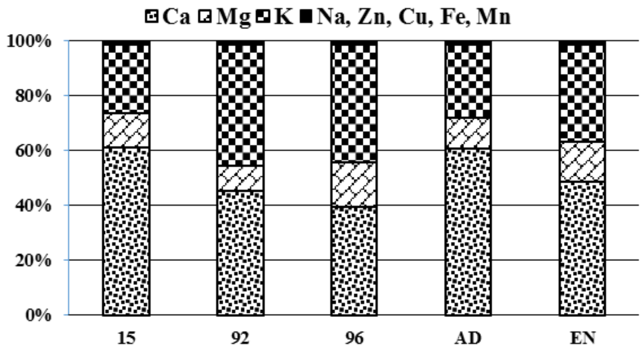


**Figure 1.** Distribution patterns of minerals of different cassava leaves from five genotypes. IRAD4115 (15) *, 92/0326 (92) *, 96/1414 (96) *, AD (AD) ** and EN (EN) ** are the five genotypes. * = Improved genotype, ** = Local genotype

**Table 2. Mineral content of five cassava leaves obtained from different genotypes. Values are giving in µg or mg per g of fresh matter**

| Minerals | Cassava leaves | | | | |
|---|---|---|---|---|---|
| | 92/0326* | 96/1414* | IRAD4115* | AD** | EN** |
| Ca (mg/g) | 4.076 ± 0.021$^{c}$ | 3.303 ± 0.028$^{d}$ | 5.923 ± 0.028$^{a}$ | 4.578 ± 0.013$^{b}$ | 4.180 ± 0.022$^{c}$ |
| Mg(mg/g) | 0.822 ± 0.024$^{c}$ | 1.340 ± 0.014$^{a}$ | 1.221 ± 0.014$^{b}$ | 0.842 ± 0.025$^{c}$ | 1.243 ± 0.022$^{b}$ |
| K (mg/g) | 3.963 ± 0.048$^{a}$ | 3.586 ± 0.026$^{b}$ | 2.444 ± 0.026$^{d}$ | 2.020 ± 0.023$^{e}$ | 3.043 ± 0.020$^{c}$ |
| Na(µg/g) | 8.092 ± 0.048$^{a}$ | 6.490 ± 0.028$^{c}$ | 5.219 ± 0.087$^{d}$ | 4.457 ± 0.063$^{e}$ | 6.824 ± 0.037$^{b}$ |
| Zn(µg/g) | 15.667 ± 0.226$^{c}$ | 13.117 ± 0.172$^{d}$ | 29.509 ± 0.151$^{a}$ | 12.181 ± 0.135$^{e}$ | 16.536 ± 0.048$^{b}$ |
| Mn(µg/g) | 23.891 ± 0.263$^{d}$ | 25.112 ± 0.339$^{c}$ | 38.588 ± 0.489$^{a}$ | 32.357 ± 0.197$^{b}$ | 25.102 ± 0.400$^{c}$ |
| Fe (µg/g) | 76.194 ± 0.821$^{a}$ | 69.227 ± 0.390$^{c}$ | 59.934 ± 0.890$^{d}$ | 56.668 ± 0.380$^{e}$ | 74.141 ± 0.354$^{b}$ |
| Cu(µg/g) | 3.714 ± 0.024$^{a}$ | 1.662 ± 0.028$^{c}$ | 1.669 ± 0.300$^{c}$ | 1.350 ± 0.010$^{d}$ | 3.540 ± 0.030$^{b}$ |

Values are means from triplicate measurements ± standard deviation. Values in the same line followed by different letters are significantly different (p <0.05). * = Improved genotype; ** = Local genotype.
Cu: Copper; Zn: Zinc; Mn: Magnesium; Fe: Iron; Ca: Calcium; Mg: Manganese; K: Potassium; Na: Sodium.

#### 3.1.2. Crude Fibres and Total Lipids Content

The crude fibres content of leaves from the five cassava genotypes significantly ($p<0.05$) varies from 3.18 to 5.36 % (fresh matter). From Table 1, it was realised that the improved genotypes (*96/1414*, *92/0326*, *IRAD4115)* have the highest value fibres content compared to the local genotypes. This suggests that the improved genotypes especially that of the 96*/1414* are good source of dietary of fibres. It is noted that there is no significant difference ($p < 0.05$) of crude fibres content between the local genotypes.

Table 1 shows that the total lipids content of cassava leaves also varies according to the genotype (5.34 - 7.03 %). Cassava leaves from the improved genotypes *96/1414* and *IRAD4115* exhibited the highest lipids content. This suggest that these leaves have more cuticle and chlorophyll than the others.

#### 3.1.3. Free Sugars, Free Amino Acid, Total Carbohydrates and Total Proteins Content

The values of free sugars content of cassava leaves also varies significantly (p <0.05) from one genotype to another (Figure 2). The improved variety *96/1414* exhibits the highest value (8.16 mg/g fresh weight) while, the local variety *AD* shows the lowest (5.06) value of free sugars content. Generally leaves from the improved genotypes are sweeter than those from the local genotypes. The total carbohydrates content of cassava leaves fluctuates from 7.48 to 11.50 % (fresh weight). As results in Figure 2, it was found that the total carbohydrates content of the improved genotype *IRAD4115* was the highest. There is no significant difference between the value of the improved genotype *96/1414* and the local genotype *AD*.

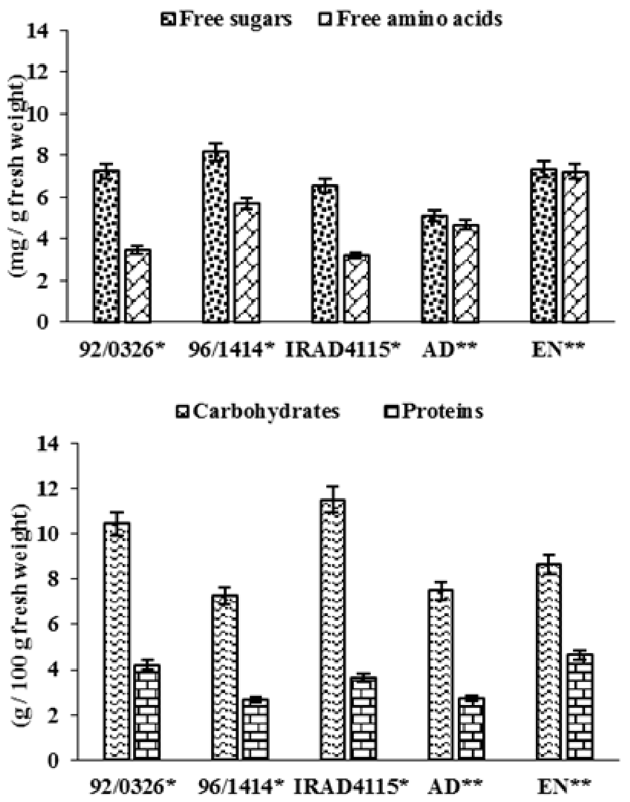


**Figure 2.** Free sugars, free amino acids, total proteins and carbohydrates contents of five cassava genotype leaves. Values are giving on the fresh matter basis; IRAD4115, 92/0326, 96/1414, AD and EN are the five genotypes. * = Improved genotype, ** = Local genotype

Figure 2 shows that the free amino acids content of cassava leaves vary from local to improved genotype. These values ranged from 3.19 to 7.21 mg/g with the improved genotype *96/1414* exhibiting the lowest and the local genotype *EN* the highest. It is also noticed that the proteins content of cassava leaves significantly vary according to the studied genotypes (Figure 2). It is clear that leaves from the local genotype *EN* is richer in protein (4.64 %) than those from the other genotypes. These results showed that all the five cassava leaves tested were important source of proteins.

### 3.2. Antioxidant Potential of Leaves from Five Cassava Genotypes

#### 3.2.1. Vitamin C and Phenolics Content

Local cassava leaves are significantly (p<0.05) poor in vitamin C (21.18 - 23.15 µg / g fresh weight) than those from improved genotypes (28.74 - 40.51 µg / g). Leaves from *IRAD4115* genotype exhibit an important quantities of vitamin C (Table 3). Results show that the amount of total phenolic contents, measured by Folin-Ciocalteu method, vary widely amongst the five cassava leaves. Values ranged from 6.20 to 15.06 mg equivalent gallic acid / 100 g of fresh leaves. The highest amount of total phenolic is found in leaves from improved cassava genotype *IRAD4115*, while the lowest value is exhibited by the local genotype *AD*. These results bring out the fact that all the five studied cassava leaves could be an excellent source of phenolic compounds. Phenolic compounds derived from the secondary metabolites of plants that affect sensorial and nutritional qualities of foods [25].

#### 3.2.2. Ferric Reducing Antioxidant Potential (FRAP) and DPPH Scavenging Activity (DSA)

Table 3 shows that the FRAP of the five cassava leaves varies from 2.30 to 3.73 µg equivalent vitamin C / g of fresh weight. There is significant (p < 0.05) differences between values obtained from the leaves except the improved genotypes *IRAD4115* and *96/1414* whose values are similar and higher. A significant (p<0.05) positive correlation (r=0.832) was noticed between FRAP and the total phenolic compounds. Leaves from the improved genotype *96/1414* exhibited the highest DSA followed by the improved genotype *IRAD4115* (Table 3). The DPPH Scavenging Activity of the *C. melo* fractions fluctuates from 28 to 308 µmol equivalent Trolox / g (fresh weight). A significant positive correlation (p < 0.05) was also noticed between DSA and phenolic compounds content (r = 0.955) and between FRAP and DSA (0.999). These results showed that cassava leaves possess strong antioxidant activity and can be consider as a good source of natural antioxidants.

**Table 3. Ascorbic acid, total phenolic content and antioxidant activities of five leaves cassava from different genotypes. Values are giving on the fresh matter basis**

| Genotypes | Total phenolic content (mg GAE / 100g) | DPPH Scavenging assay (µmol TE / g) | FRAP (µg VCE / g) | Ascorbic acid (µg / g) |
|---|---|---|---|---|
| 92/0326* | 11.04 ± 0.04$^{d}$ | 120.62 ± 1.84$^{d}$ | 2.30 ± 0.04$^{d}$ | 28.74 ± 0.59$^{c}$ |
| 96/1414* | 14.78 ± 0.11$^{b}$ | 308.32 ± 1.16$^{a}$ | 3.62 ± 0.06$^{a}$ | 31.90 ± 0.60$^{b}$ |
| IRAD4115* | 15.06 ± 0.06$^{a}$ | 301.59 ± 3.03$^{b}$ | 3.73 ± 0.02$^{a}$ | 40.51 ± 1.19$^{a}$ |
| AD** | 6.20 ± 0.07$^{e}$ | 27.72 ± 3.19$^{e}$ | 2.53 ± 0.01$^{c}$ | 21.18 ± 0.48$^{e}$ |
| EN** | 11.69 ± 0.09$^{c}$ | 132.61 ± 0.37$^{c}$ | 3.35 ± 0.02$^{b}$ | 23.15 ± 0.06$^{d}$ |

Values are means from triplicate measurements ± standard deviation. Values in the same column followed by different letters are significantly different (p<0.05). * = Improved genotype; ** = Local genotype. GAE: Gallic acid equivalents, TE: Trolox equivalents, VCE: Vitamin C equivalents, FRAP: Ferric Reducing Antioxydant Potential.

## 4. Discussion

Leaves from five cassava genotypes (*92/0326*, *96/1414*, *IRAD4115*, *AD* and *EN*) have been analysed for their physicochemical properties and antioxidant potential. This study was done in order to compare nutritional potential of local (*AD* and *EN*) and improved genotype (*92/0326*, *96/1414*, *IRAD4115*). The results presented here show that the evaluated parameters significantly ($p<0.05$) vary from one genotype to another.

It have been noted that the dry matter content of leaves from the five cassava (*92/0326*, *96/1414*, *IRAD4115*, *AD* and *EN*) are significantly ($p <0.05$) different amongst the improved and the local genotypes. These results are attributed to varietal differences such as age of leaves and probably agronomic conditions [26,27]. Ravindran & Ravindran [28] noticed a variation of dry matter content from 11 to 21% between very young, young and mature cassava leaves. Wobeto *et al*. [29] reported similar average dry matter (29.54 ± 1.15 %) of leaves from five cassava cultivar. All the obtained values of cassava leaves such as pH range from 6.18 to 6.29 which are within the range of neutral leaves and vegetables [30]. The ash content of cassava leaves (51 - 80 mg/g dry matter) widely vary amongst the genotypes. Oni *et al.* [31] also noticed significant variation in ash content (65-161) of cassava leaves from four varieties (*MS 6*, *TMS 30555*, *Idileruwa* and *TMS 30572*). The genotypes responded differently to variations in environmental conditions. These variations could be attributed also to different climatic and edaphic conditions at sites [32].

Calcium forms the major part of the minerals found in human bone. In agreement with Wodebo *et al.* [29], calcium is the major macrominerals found in cassava leaves followed by potassium and magnesium. With it high calcium content (5.93 mg/g fresh weight), cassava leaves from *IRAD4115* will be suitable to cover mineral daily requirement. This value is higher than that of cabbage and spinach known as good sources of calcium [8]. The main microminerals of cassava leaves studied are iron followed by manganese. However, Ravindran & Ravindran [28] found that according to the age of the cassava leaves, it can be iron and manganese or zinc and iron. In addition to calcium, leaves from *IRAD4115* cassava genotype has two times more zinc (89.39 mg/kg dry weight) than the other cassava leaves. However, it is the leaves from *92/0326* cassava genotype which exhibited the highest value of iron (230 mg/kg dry weight). Values obtained in the literature ranging from 50 to 120 mg/kg for zinc and from 150 to 450 mg/kg [27,33,34]. Zinc is an essential ion involved in a certain number of physiological functions, such as protein synthesis, digestion and nucleic acid synthesis [35]. Iron plays numerous biochemical roles in the body, including oxygen binding in haemoglobin and acting as an important catalytic centre of many enzymes [36]. The adverse effects of iron deficiency reported have important deleterious effects such as decreased cellular immunity, behaviour and cognitive alterations [37]. The results of this study show that leaves from *IRAD4115* and *92/0326* cassava genotypes are rich in iron and zinc. Thus leaves can be recommended for diets with iron and zinc deficiency.

The higher amount of free sugars observed in the leaves from 96*/1414* improved cassava genotype (8.16 mg/g fresh weight) are attributed to varietal differences. In addition to their functional potential, with their high carbohydrate content, cassava leaves can exhibit a non-negligible energy potential. This varietal difference is observed with the total carbohydrates content of the cassava leaves (28-35 % dry weight). Similar and varietal differences were also observed by Achidi *et al.* [34] when studying leaves from *TMS30572* and *TME1* cassava varieties. The present results shows that leaves from the five cassava genotypes exhibit high amount of free amino acids content. These findings were in agreement with Montagnac *et al.* [6] who reported that cassava leaves are potential sources of amino acid. According to FAO/WHO [38] the aminoacid profile of cassava leaves is well balanced and exceed that of soybean, fish and egg. Gomez *et al.* [26] and Ngudi *et al.* [39] showed that aspartate, glutamate, alanine and leucine are the main amino acid found in cassava leaves. Only leucine is an essential amino acid but tryptophan, isoleucine, valine and histidine found in cassava leaves exhibit high amino acid scores compared to the FAO reference values [39]. The crude protein content of the different cassava leaves was significantly ($p <0.05$) different (7.99-13.16 % dry matter) and higher than that of leaves from four cassava varieties analysed by Fasuyi [33]. According to these findings, the leaves of cassava genotypes tested indicated a potential source of proteins for the reduction of malnutrition. In fact, the health implication of protein consumption include the involvement of its essential and non- essential aminoacids as building blocks for protein synthesis, not only for growth of infants and children, but also for the constant replacement of turnover of the body protein in adult [40].

It was noted that the crude fibres content of cassava leaves were important and largely varied between improved and local studied cassava genotypes. The highest value (5.36%) of the crude fibres content obtained in this study was similar to 4.2 % obtained by Balamurugan & Anbuselvi [10]. This suggests that the leaves from the improved genotype *96/1414* could be a good source of dietary fibres. Indeed, fibres in human diets help to prevent over absorption of water and formation of hard saddle which can lead to constipation. On the other hand, fibres lower the body cholesterol level, thus reducing the risk of cardiovascular diseases [41]. Lipids are vital to the structure and biological functions of cells and are used as alternative energy source. The results observed from the studied cassava leaves show that most of the leaves exhibit more than 6 % of lipids. These values are higher than those (0.1-6%) obtained by Balamurugan & Anbuselvi [10] and Achidi *et al.* [34]. So, genotypes responded differently to variations in environmental conditions. These variations could be attributed to different climatic and edaphic conditions at sites [32]. According to Ravindran & Ravindran [28], the age of the leaves can also have an effect on the lipids content (3.8-6.8%).

Results on Table 3 shows that *IRAD4115* cassava leaves is a good source of vitamin C (0.123 mg / g dry matter). According to the findings of Lui *et al.* [41], highest concentration of ascorbic acid in plant samples might associate with attractive free radical scavenging capacity and health benefit like anti-carcinogenic and antiatherogenic. Kipandula *et al*. [43] found that amongst indigenous vegetables cassava leaves had recovered the highest value of ascorbic acid. Simao *et al*. [44] analysed leaves from four cassava varieties and found highest values of vitamin C content (1.49 - 5.21 mg/g) which vary according to the plant age. It have been reported that reduction in cancer risk is associated with a diet high in vitamin C [45]. Variations of total phenolic compounds of leaves from five cassava genotypes are due to genotype differences, harvest period, age of plant and also environmental influence [46]. It has been also noticed that these could also be due to the maturity of leaves [47]. Values obtained in the present study (expect the *AD* cassava genotype) were lower than those observed by Simao *et al*. [44]. These results are attributed to the influence of cultivars, maturity stage and method of extraction. Phenolic compounds, at low concentration may act as antioxidant and protect food from oxidative deterioration [48]. At high concentration, they may interact with proteins, carbohydrates and minerals [49].

Antioxidants are capable of stabilizing, or deactivating, free radicals before they attack cells. In addition to their high phenolic compounds and ascorbic acid content, leaves from *96/1414* and *IRAD4115* also exhibit higher value of FRAP (3.62 - 3.73 µg vitamin C equivalent / g). This suggest that antioxidant activity could be highly correlated with phenolic content. Simao *et al*. [44] showed a positive significant ($p<0.05$) correlation ($r = 0.70\text{-}0.84$) between antioxidant activities, polyphenols and vitamin C content of leaves from four cassava varieties.

In this present study, the highest correlation was found between FRAP value and total phenolic contents. This finding is in agreement with Sreeramulu *et al*. [50] who found a positive correlation amongst the total phenolic compounds and antioxidant activity. This indicates that the phenolic compounds were the main contributors of antioxidant activity [51]. These observations suggest that the reducing power exhibited by different cassava genotypes is contributed not only by their phenolic compounds content but also by the presence of other constituents as vitamin C.

In the current study, the DPPH scavenging activity of cassava leaves fluctuated significantly among the five cassava genotypes. Factors affecting the antioxidant properties include genetics, growing and environmental conditions, diseases and processing [52]. Such large variations were reported by others studies with different dietary plants and plant products [53]. The high correlation observed suggests that the total phenolic contents may be an important contributor to the scavenging activities of leaves. In agreement with Kirakosyan *et al*. [54], phenolic compounds in plants possess antioxidant activity and may help to protect cells against the damages caused by free radicals. A particular high correlation between DPPH scavenging activity and ascorbic acid was also noticed, suggesting a significant contribution of the ascorbate to antioxidant activities. It was clearly observed that the total phenolic content of the different cassava leaves may contribute to the antioxidant activity and confirms each leaves as an excellent source of dietary phytochemicals.

From the study it was observed that the fresh cassava genotypes leaves studied are good source of micronutrients and natural antioxidant in alleviating malnutrition problems of local societies especially the rural populace. Leaves from the improved genotypes were the best, amongst the improved genotypes. That is to say *IRAD4115* cassava genotypes presents leaves with good nutritional qualities.

## 5. Conclusion

This study compares physicochemical properties of leaves from two local and three improved cassava genotypes. The nutritional qualities of the studied leaves significantly vary among the cassava genotypes. Leaves from the improved genotypes exhibit the highest value of physicochemical properties. For example leaves from improved genotypes are rich in calcium (5.92 mg/g fresh weight), zinc (29.51 µg/g) and iron (76.19 µg/g) content. Amongst the improved genotypes, leaves from *IRAD4115* are the best in term of nutritional qualities. The local genotypes leaves from *EN* exhibit the best nutritional qualities. Leaves from *EN*, *AD*, *92/0326*; 96*/1414* and *IRAD4115* cassava genotypes can reduce some aspects of food insecurity especially micronutrient malnutrition in this Far North region of Cameroon. In other words, in the Far-North Region, if consumption of cassava leaves can be promoted as a vegetable, it can largely contribute to eradicate macro and micronutrients malnutrition. The highest total phenolic content and antioxidant activity is an indication that cassava leaf could be effective in improving oxidative problems in ill conditions. In fact, the natural dietary antioxidant content in food has been the focus of much investigation in last few years due to its contribution for protection against diseases.

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