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RESEARCH ARTICLE

PHYSICOCHEMICAL CHARACTERISTICS AND ANTI-NUTRITIONAL FACTORS OF SOME UNDERUTILIZED TUBERS (DIOSCOREA SPP AND COLEUS ESCULENTUS) GROWN IN CAMEROON.

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Abstract

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Food insecurity is a threat to most countries in Africa despite the presence of many food commodities. The objective of this work was to determine the nutritional composition and anti-nutritional factors of four underutilized tuber species (*Dioscorea spp* and *Coleus esculentus*) in Cameroon. The nutritional composition and contents in anti-nutritional factors were analysed using standard analytical methods. Analysis of Variance (p <0.05) revealed a significant difference in the levels of the parameters analysed in the different varieties of tubers. All the tubers were low in lipids (0.5 - 2.36 %) with traces of soluble sugars (0.24 - 0.40%), some amount of proteins (2.43 - 8.95%), crude fibres (2.32 - 8.34%), high levels of available carbohydrates (76.40 - 90.19%), starch (76.11 -89.91% dry weight) and energy (363.91 - 385.11 Kcal/100g dry weight). The most abundant minerals were potassium (217 - 557 mg), phosphorus (83 - 215 mg), magnesium (29-264 mg/100g) and Copper (23 - 617 µg/100g dry weight). They had low levels of sodium (<18mg/100g) and iron (18 - 46 µg/100g dry weight). All the tubers contained the antinutrients: tannins, oxalates, phytates and saponins, below toxic levels. These tubers could therefore contribute nutrients for human nutrition and for the management of some nutritional illnesses.

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Introduction:-

Millions of African families still suffer from poverty, malnutrition and food insecurity (FAO, 2015). Malnutrition is a public health problem in Cameroon. As is the case in developing countries, it mainly affects vulnerable groups such as children under 5 years of age (0-59 months). One third of children under 5 years of age (33 %) suffer from chronic malnutrition (moderate to severe). Chronic malnutrition, often of protein-energy origin, results in a smaller size for age and corresponds to growth retardation (EDSC-MICS, 2011). In Africa, more than a third of the

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population do not have access to sufficient food in quality and/or quantity to live an active life and maintain adequate health (Kennedy *et al*., 2003).

Africa produces a large variety of agricultural crops that can feed its population and meet its demands (Blein *et al*., 2008). Cereals (maize, wheat, millet), cassava (*Manihot esculenta*), sweet potato (*Ipomea batatas*), cocoyam (*Xanthosoma sagittifolium*), and yam (*Dioscorea*) play a major role in feeding people in tropical areas (Gouado *et al*., 2003). Tubers, like yams, are part of this wealth and could contribute to the fight against noncommunicable diseases (stroke, diabetes, etc.) and to solve the problem of food insecurity (FAO, 2015; Fashina *et al*., 2017). Yams contribute greatly to the food security of West African populations: Côte d'Ivoire, Ghana, Togo, Burkina Faso and Nigeria (Zannou, 2006). Nigeria is the World's leader with about 23 million tons for a total of 32 million tons worldwide, or 72% of the World's production (FAO, 1994). In Cameroon, yam production is still growing. Its production increased from 399,615 tons in 2008 to 517,069 tons in 2011, with a 4% increase compared to 2010 (MINADER, 2013). 9 species of yams are cultivated in Cameroon (Dumont *et al*., 1994).

Tubers are consumed in Cameroon in several forms (porridge, stew, roasted, crushed and fried) and are used in ceremonies like widowhood, skull worship (Bamiléké ritual), in connection with ancestral beliefs officiated by one or more "Megni sii" (Tchiègang and Ngueto, 2009). Previous studies have shown that yams are high in energy (373.16 kcal) but low in fat (1 - 1.49 g/100g DM). They are the tubers with highest protein levels (6.24 - 8.98 g/100g DM) (Herzog *et al*., 1993; Tchiègang and Ngueto, 2009; Jacques *et al*., 2016). Medoua (2005) showed that the yam, *Dioscorea dumetorum*, which is widely consumed in Cameroon, contained 10 g/100g DM of proteins. Tchiègang and Ngueto (2009) also showed a poor balance between the essential amino acids and the total amino acids of *Dioscorea schimperiana*, the limiting factor being the combination, methionine + cysteine (0.98 g / 100 g of protein). It is necessary to associate its consumption with foods rich in sulphur amino acids, in order to reach the value of 2.2 g of méthionine + cystéine / 100 g of reference protein (FAO / WHO, 1985).

In addition to yams, other tubers of the Lamiaceae family, especially the genus *Coleus*, are much more consumed by the elderly. According to a survey conducted between February and April 2016, some people consume these tubers as food while others consume them to better manage their disease, especially hypertension and type 2 diabetes. This genus has been shown to have significant fibre contents (7.1- 8.9 g/100 g DM) and minerals such as calcium, magnesium and iron (Gouado *et al*., 2003). Given their protein content and energy value, tubers of the genera *Coleus* and *Dioscoreae* could effectively contribute to the fight against protein-energy malnutrition. In addition, the high fibre and low fat levels would be an asset for people with chronic diseases, especially type 2 diabetes. Despite the nutritional and socio-cultural interest of these tubers, some species are neglected and therefore under-utilized, namely *Dioscorea schimperiana* and *Dioscorea bulbifera* (Dumont *et al*., 1994; Tchiègang and Ngueto, 2009). However, the reasons are not well known. Very little work has been done on *Dioscorea burkilliana* and *Coleus esculentus* (Sahoré and Amani, 2012; Agyeno *et al*., 2014). Several neglected and/or underutilized food commodities in Africa have been used to improve food and nutritional security and build resilience to famine, such as *Gnetum africanum*, *Telfairia occidentalis*, *Gongronema latifolium*, *Solanum scabrum*, *Piper guineense* and *Talinum fruticosum* (Baldermann *et al*., 2016).

In order to enhance the value of these tubers, this study focused on the characterization of their nutritional and anti-nutritional factors in order to encourage their production and consumption for better health. This will also promote biodiversity in order to contribute to maintaining a balanced ecosystem.

Materials and methods:-

Study materials and identification:-

The Samples were four varieties of yam tubers: *Dioscorea schimperiana*, *Dioscorea bulbifera*, *Dioscorea burkilliana* and *Coleus esculentus*. *D. schimperiana*, *D. bulbifera* and *D. burkilliana* were identified by comparing with samples of the National Herbarium, under the numbers 42 549, 42 539, and 30 882/HNC respectively. *Coleus esculentus* was identified at the National Herbarium under number 66 891/HNC.

Sample collection and processing:-

Twelve tuber samples were collected between December 2017 and February 2018 from three regions of Cameroon (Adamawa, West and North-West) and stored separately in the Laboratory for Food Science and Metabolism. The tubers were washed, peeled and cut into 3 mm thick slices. These tubers had the following flesh colour: white, yellow, dull yellow, orange, and red-orange. They were dried in an oven at 60°C for 48 hours. After drying, the dry slices were bagged in sealed plastic bags with food preservatives and stored in a dry place. Before performing each analysis, these slices were ground using an electric grinder. The resulting powders were sieved with a sieve of mesh size of 200 µm in diameter and dried again in an oven at 105°C until constant weight.

Proximate analysis:-

The moisture content was determined on fresh sliced samples after oven-drying at 105ºC for 24 hours according to the procedure of AOAC (1990). The total ash, fat and crude fibre levels of the tubers were determined by the AOAC (1980) method on dried and ground samples. Soluble sugars were extracted using the method described by Cerning and Guilbot (1973) and quantified by the method involving the anthrone reagent (Hedge and Hofreiter, 1962). Starch contents were determined by difference as described by AOAC (1990). For crude protein contents, the dry powders were digested using the Kjeldahl technique described by AFNOR (1984) and the nitrogen was then determined by the Devani *et al*. (1989) method. The crude protein content was calculated by multiplying the nitrogen content by the conversion factor 6.25. Energy values were computed by adding the calorific values of proteins, fats and carbohydrates based on the Atwater factors of 4, 9 and 4 respectively (Eneche, 1999). Available carbohydrates were calculated as difference of 100 minus the sum of moisture, ash, crude fat, crude protein and crude fibre contents (AOAC, 1980).

Mineral analysis:-

The minerals were extracted with 0.2 N nitric acid using the method of Pauwels *et al*. (1992). Phosphorus and iron levels were determined by spectrophotometry (Jasco V-630 molecular absorption spectrophotometer) at wavelengths of 430 and 510 nm respectively. The levels of potassium, sodium, copper, magnesium and zinc were determined by atomic absorption spectrophotometry (Agilent Technologies 55 AA Atomic Absoption Spectrometer) at wavelengths of 766.5; 589.0; 327.4; 285.2 and 213.9 nm, respectively. Calcium contents were determined by complexometry using the procedure of Pauwels *et al*. (1992): titration was performed with the Na_2-EDTA 0.002 M complex and the equivalence point was reached when the solution turned from purple to blue.

Analysis of antinutritional factors:-

The total tannin content of the tubers was determined by the spectrophotometric procedure described by Brainbridge *et al*. (1996). The phytic acid content was analyzed by the spectrophotometric method (Gao *et al*., 2007). The oxalate content was quantified by titration with $KMnO_4$, 0.05mol/L according to the method of Aina *et al*. (2012) and the saponin content was determined with the Kozol method (1990).

Statistical analysis:-

The data obtained (in triplicates) was calculated as mean ± standard deviation (mean ± SD) and significant differences were calculated using ANOVA coupled with Tukey. For statistical comparison, p-values of 0.05 were taken as significant. The statistical package used was IBM SPSS for Windows (Version 20.0 Armonk, New York: IBM Corp).

Results and Discussion:-

Macronutrient composition:-

The macronutrient composition of the tubers is found on Table 1.

The water content of the tubers ranged from 52.08 % for white *Dioscorea schimperiana* from Adamawa to 74.85 % for *Coleus esculentus* from the North West. These values obtained were similar to those of *Dioscorea rotundata* (58.18) and *Dioscorea dumetorum* (79.26) by Polycarp *et al*. (2012). Water content is an index of perishability and storability of food materials, so the amount of moisture detected in these yam species indicates that these tubers may not last long in the house after harvest and can easily germinate, leading to unpleasant taste. Varieties with low moisture content would be suitable for prolonged tuber storage and more efficient for industrial processing.

The ash content of the tubers ranged from 1.84 (*Dioscorea burkilliana,* North West) to 3.65 g DM (*Dioscorea schimperiana,* red-orange, West). These values obtained were greater than 2.03 % for *Colocacia esculenta* from Chad (Djibrine, 2011). Red-orange *Dioscorea schimperiana* from the West can be considered as a significant source of minerals.

The crude fibre content of the tubers was between 2.32 and 8.34 g/100g DM for white *Dioscorea schimperiana* from Adamawa and red-orange *Dioscorea schimperiana* from the West respectively. These values were much higher than the findings (1.34 to 1.56 g/100g of dry matter (DM) obtained by Tchiègang and Ngueto (2009) with *Dioscorea schimperiana* from the West collected in three villages. The presence of fibres in these tubers is an important factor in consumption. Indeed, due to their moisturizing properties, fibres facilitate gastric emptying and intestinal transit, thus reducing the risk of constipation. They are also beneficial for diabetics and people with arteriosclerosis (Liu *et al*., 2000). Red (6.65) and red-orange (8.34 g/100g DM) *Dioscorea schimperiana* from the West had the highest levels of crude fibres. This could be good for inclusion in the diet of diabetics and people suffering from constipation.

The protein content of the tubers varied from 2.43 to 8.95 g/100 g DM for *Dioscorea bulbifera* from Adamawa and *Coleus esculentus* from the West respectively. The protein contents of *Dioscorea schimperiana (*2.85-8.87%) is similar to the values (6.24 to 8.98 g/100g DM) obtained by Tchiègang and Ngueto (2009) for *Dioscorea schimperiana* from the West collected in three villages. The protein content of *Coleus esculentus* from the West (8.95 g/100g DM) was also closed to the results obtained by Tchiègang and Ngueto (2009), but lower than that of Medoua (2005) on *Dioscorea dumetorum* (10 g/100g DM) from Cameroon. Red (6.34) and red-orange (8.87) *Dioscorea schimperiana* from the West, *Coleus esculentus* from the West (8.95) and North-West (7.07 g/100g DM) can thus be considered as alternative protein sources for the management of protein-energy malnutrition in children.

The lipid content of the tubers ranged from 0.5 g (*Dioscorea burkilliana* from Adamawa) to 2.36 g/100g DM (red *Dioscorea schimperiana* from the West). These values were similar to those reported by Tchiègang and Ngueto (2009) where the lipid contents ranged from 1.00 g (Bamena) to 1.41 g/100g DM (Bangou). These findings were also similar to those of Polycarp *et al*. (2012) for 13 yam varieties (*D. rotundata* Poma, *D. rotundata* Labrekor, light grey *D. bulbifera*, grey *D. bulbifera*, light yellow *D. cayenensis*, yellow *D. cayenensis*, *D. praehensalis*, white *D. dumetorum*, yellow *D. dumetorum*, *D. alata* Matches, *D. alata* Akaba, large and small *D. esculenta*) with lipid contents of less than 1%. Tchiègang and Ngueto (2009) showed that the fatty acids of the lipid fraction of yams contained: palmitic (31%), linoleic (27%) and oleic acids (20%), followed by linolenic (13%), palmitoleic (4%), myristic (3%) and stearic (2%) acids. The low-fat levels in these yam samples could be beneficial for people with non-communicable diseases, such as heart disease, stroke and diabetes (Fashina *et al*., 2017).

The soluble sugar contents varied from 0.24 to 0.40 g/100 g DM for *Dioscorea burkilliana* from the West and *Coleus esculentus* from the North West respectively. These values were significantly lower than those of *Dioscorea burkilliana* (2.34 g/100g DM) and *Dioscorea bulbifera* (3.59 g/100g DM) from Côte d'Ivoire reported by Sahoré and Amani (2012). In general, these tubers had very low levels of soluble sugars.

The carbohydrates content was high and varied from 76.40 to 90.19 g/100 g DM for red-orange *Dioscorea schimperiana* from the West and *Dioscorea burkilliana* from Adamawa respectively. Carbohydrates were the major component of all these tubers. Their levels were higher than of *Solenostemon* sp (73.2 g/100g DM), but similar to that of *Coleus rotundifolius* (83.5 g/100g DM) from West Cameroon, (Gouado *et al*., 2003). The carbohydrate level of red-orange *Dioscorea schimperiana* (76.40 g/100g DM) was lower than that of *Dioscorea schimperiana* (88.7g/100g DM) (Malaise, 1997). That of *Dioscorea burkilliana* (90.19 g/100g DM) from Adamawa was similar to the values for *Ipomea batatas* (94) and *Manihot esculenta* (91g/100g DM) from Cameroon (Agbor and Trèche, 1984). These findings suggest that these tubers can therefore be considered as the main source of carbohydrates just as *Ipomea batatas* and *Manihot esculenta*.

The starch content of the tubers ranged from 76.11g for red-orange *Dioscorea schimperiana* from the West to 89.91g/100g DM for *Dioscorea burkilliana* from Adamawa. These levels are higher than those noted by Jacques *et al*. (2016) with *Dioscorea bulbilis* (70.49 g/100g DM). These results showed that starch makes up about 99.5% of the carbohydrate levels of these yams. Starch is the most important chemical component in flours. In addition to its energy contribution, starch in most processed foods contributes to the texture, organoleptic qualities and nutritional properties (Tharanathan and Mahadevamma, 2003). These tubers can be used for the production of flours for the preparation of infant foods.

Table 1: Some nutritional properties of *D. schimperiana, D. bulbifera, D. burkilliana* and *C. esculentus* in g/100 g of dry matter (DM)

Sample	Water content (in % fresh matter)	Ash	Crude Fibres	Proteins	Lipids	Soluble Sugars	Carbohydrates	Starch	Energy (in Kcal/100g DM)
C. esculentus **NW**	74.85 ± 0.58^{a}	3.61 ± 0.24^{d}	4.30 ± 0.15^{bcd}	7.07 ± 0.14^{de}	1.03 ± 0.01^{bc}	0.40 ± 0.01^{e}	82.40 ± 0.08^{de}	82.00 ± 0.09^{cd}	367.75 ± 0.82^{ab}
D. burkilliana **NW**	61.05 ± 0.60^{d}	1.84 ± 0.33^{a}	2.71 ± 0.09^{ab}	4.33 ± 0.20^{ab}	0.84 ± 0.05^{b}	0.28 ± 0.01^{abcd}	89.25 ± 0.56^{h}	88.97 ± 0.55^{gh}	383.00 ± 1.59^{ef}
D. bulbifera **NW**	62.50 ± 0.17^{d}	3.40 ± 0.17^{d}	4.55 ± 0.53^{cd}	6.62 ± 0.29^{d}	1.26 ± 0.07^{cd}	0.30 ± 0.01^{cd}	82.11 ± 0.78^{cd}	81.81 ± 0.80^{c}	368.06 ± 0.82^{ab}
C. esculentus **W**	66.33 ± 0.60^{e}	3.13 ± 0.08^{bcd}	4.07 ± 0.16^{abc}	8.95 ± 0.04^{e}	1.57 ± 0.11^{e}	0.32 ± 0.00^{d}	80.79 ± 0.08^{bc}	80.48 ± 0.08^{bc}	372.00 ± 0.71^{bc}
D. shimperiana **Yellow W**	67.66 ± 0.43^{ef}	3.42 ± 0.05^{d}	5.96 ± 0.10^{de}	3.23 ± 0.25^{ab}	1.40 ± 0.05^{de}	0.27 ± 0.01^{abcd}	84.28 ± 0.12^{f}	84.00 ± 0.14^{e}	363.91 ± 0.80^{a}
D. burkilliana **W**	61.40 ± 0.75^{d}	2.59 ± 0.07^{abc}	3.20 ± 0.29^{abc}	4.56 ± 0.39^{bc}	2.08 ± 0.04^{gh}	0.24 ± 0.00^{a}	86.75 ±0.23^{g}	86.51 ± 0.23^{f}	385.11 ± 1.92^{f}
D. bulbifera **W**	58.17 ± 0.48^{c}	3.28 ± 0.02^{cd}	3.20 ± 0.21^{abc}	6.92 ± 0.19^{d}	1.90 ± 0.06^{fg}	0.28 ± 0.02^{bcd}	83.79 ±0.18^{ef}	83.50 ± 0.20^{de}	378.70 ± 0,32^{de}
D. shimperiana **White AD**	52.08 ± 0.77^{a}	3.18 ± 0.06^{bcd}	2.32 ± 0.00^{a}	2.85 ± 0.49^{ab}	0.89 ± 0.02^{b}	0.25 ± 0.01^{ab}	89.65 ± 0.84^{h}	89.39 ± 0.83^{h}	379.77 ± 2.41^{de}
D. burkilliana **AD**	67.76 ± 0.92^{ef}	2.46 ± 0.05^{ab}	2.53 ± 0.77^{ab}	2.75 ± 0.71^{ab}	0.50 ± 0.04^{a}	0.28 ± 0.01^{abcd}	90.19 ±0.14^{h}	89.91 ± 0.15^{h}	379.34 ± 0.30^{de}
D. bulbifera **AD**	55.41 ± 0.36^{b}	2.53 ± 0.11^{abc}	4.04 ± 0.30^{abc}	2.43 ± 0.20^{a}	1.66 ± 0.05^{ef}	0.26 ± 0.00^{abc}	87.67 ± 0.17^{g}	87.41 ± 0.16^{fg}	375.56 ± 0.80^{cd}
D. shimperiana **Red W**	68.11 ± 0.08^{f}	3.32 ± 0.20^{cd}	6.65 ± 0.08^{ef}	6.34 ± 0.31^{cd}	2.36 ± 0.03^{i}	0.27 ± 0.01^{abc}	79.54 ± 0.09^{b}	79.27 ± 0.08^{b}	366.11 ± 0.99^{a}
D. shimperiana **Red-Orange W**	68.02 ± 0.05^{f}	3.65 ± 0.13^{d}	8.34 ± 0.60^{f}	8.87± 0.68^{e}	2.30 ± 0.04^{hi}	0.29± 0.00^{bcd}	76.40 ± 0.24^{a}	76.11 ± 0.24^{a}	364.67 ± 0.75^{a}

Values with the same letter superscript within the same column are not significantly different ($p \geq 0.05$)
Legend: NW = NorthWest; W = West; AD = Adamawa

The tubers showed a significant **energy value** ranging from 363.91 to 385.11 Kcal for yellow *Dioscorea schimperiana* and *Dioscorea burkilliana* from the West respectively. This high energy content was due to their carbohydrate level. These energy values are higher than those of the tubers of *Coleus esculentus* (352), *Dioscorea dumetorum* (327) and *Dioscorea schimperiana* (323 kcal) (Malaise, 1997). However, the value of *Dioscorea burkilliana* (385.11 Kcal) from the West was similar to the values observed in *Dioscorea esculenta* (388), *Ipomea batatas* (390), *Manihot esculenta* (392), *Coleus rotundifolius* (392) and *Solenostemon* sp (399 Kcal) (Agbor and Trèche, 1984). All these tubers, especially *Dioscorea burkilliana* from the West, can therfore be considered as energy sources.

Mineral composition:-

Table 2 summarizes the mineral composition of the yam tubers.

The Calcium content of the tubers ranged from 14 to 63 mg/100g DM for *Dioscorea burkilliana* from the North-West and *Coleus esculentus* from the West respectively. All these tubers had lower levels than that obtained for *Dioscorea bulbifera* (77.1 mg/100g DM) (Jacques *et al.*, 2016). Calcium is necessary for blood coagulation. It regulates the acid-base balance of the blood, thus preventing its acidity (Garcia-Chuit and Boella, 1993). The Dietary Reference Intake (DRI) values for calcium are 210 mg / day for infants aged 0 to 6 months, 270 mg / day of 7 to 12 months, 500 mg for children 1 to 3 years, 800 mg for 4 to 8 years (IOM, 1997). This shows that these yam tubers have low calcium levels (5 – 21 mg /100g edible portion (EP) far less than 210 mg/100g EP) and therefore need to be consumed with calcium-rich complements or soups.

The phosphorus values varied from 83 to 215 mg/100g DM for *Dioscorea bulbifera* from the Adamawa and North West regions respectively. These phosphorus levels were much higher than that of *Dioscorea bulbilis* (37.8 mg/100g DM) (Jacques *et al*., 2016). The high phosphorus content of tubers suggests that their consumption could help in the process of tooth and bone formation in children and their healthy development (Olaofe *et al*., 2009). The calcium / phosphorus ratio (Ca / P) ranged from 0.12 for *Dioscorea burkilliana* in the North West to 0.51 for *Coleus esculentus* from the West. This ratio is much lower than 2.03 obtained by Jacques *et al*. (2016) for *Dioscorea bulbilis*. All the samples presented a ratio ≤ 1/2, hence Ca will be rapidly absorbed in the gastrointestinal tract of children. The Ca/P ratio influences the absorption peak of these minerals in the gastrointestinal tract. A ratio of 1/2 for children and 1/1 for adults presents a maximum absorption for this mineral in the respective individuals (O'dell, 1989; FAO/WHO, 2001). The consumption of these tubers in the diet should therefore be encouraged to help prevent imbalance in these minerals.

The potassium content ranged from 217 to 557 mg/100g DM for *Dioscorea burkilliana* from the North-West and white *Dioscorea shimperiana* from Adamawa respectively. These levels were lower than that of the *Dioscorea bulbifera* level (847 mg/100g MD) reported by Jacques *et al*. (2016). Potassium regulates heart rate, blood pressure, body water content and excitability in neuromuscular disorders (Jacques *et al*., 2016). Recommended daily dietary intake values for potassium is 800 mg for children 2 to 3 years, 1600 mg for 7 to 9 years (SCF, 1993). Although these tubers have low potassium levels, some of them, especially the white *Dioscorea shimperiana* from Adamawa had good potassium levels and could therefore be used as a source of potassium.

The sodium content of the tubers were from 3 (*Dioscorea bulbifera* and white *D shimperiana* from Adamawa) to 17 mg/100g DM (*Dioscorea bulbifera* from the North West). *Dioscorea bulbilis* reported by Jacques *et al*. (2016) had a higher amount (48.10 mg/100 g DM). The daily consumption of sodium by an adult is 500 mg (NRC,1989). The sodium levels were low, hence these tubers could be used as safe food to promote the health of people at risk or people with chronic diseases (Jacques *et al*., 2016). The potassium / sodium (K / Na) ratio was between 21 and 186 for *Dioscorea bulbifera* from the North West and white *Dioscorea schimperiana* from Adamawa respectively. These values were much higher than those obtained with *Dioscorea bulbifera* (17.60) by Jacques *et al*. (2016). Diets with a higher K / Na ratio are recommended and these are generally found in whole foods (Arbeit *et al*., 1992). The K / Na ratio of these tubers is greater than 5.0. In addition, FAO/WHO (2001) recommends a reduction in sodium intake to < 2g of salt/day in order to regulate blood pressure and reduce the risk of stroke and coronary heart disease in adults. All these tubers contained very low levels of sodium (1- 6 mg /100g edible portion (EP), far less than 2g/100g EP), hence could be good for individuals with high blood pressure and coronary heart disease.

Table 2:-Composition in some macrominerals and trace elements of *D. schimperiana, D. bulbifera, D. burkilliana* and *C. esculentus* in mg and µg / 100 g of dry matter

Sample	Ca (mg)	P (mg)	K (mg)	Na (mg)	Mg (mg)	Fe (µg)	Zn (µg)	Cu (µg)
***C. esculentus* NW**	52 ± 0^{k}	153 ± 0^{f}	514 ± 0^{j}	7 ± 1^{e}	264 ± 0^{l}	39 ± 0^{g}	413 ± 0^{f}	353 ± 0^{c}
***D. burkilliana* NW**	14 ± 0^{a}	121 ± 0^{c}	217 ± 0^{a}	8 ± 0^{f}	41 ± 0^{b}	26 ± 1^{d}	482 ± 0^{g}	312 ± 0^{c}
***D. bulbifera* NW**	31 ± 0^{e}	215 ± 0^{j}	364 ± 0^{i}	17 ± 0^{h}	54 ± 0^{d}	33 ± 1^{f}	840 ± 1^{i}	472 ± 0^{d}
***C. esculentus* W**	63 ± 0^{l}	124 ± 1^{c}	246 ± 0^{d}	10 ± 0^{g}	150 ± 0^{k}	31 ± 1^{e}	306 ± 0^{e}	219 ± 0^{b}
***D. shimperiana* Yellow W**	51 ± 0^{j}	147 ± 2^{e}	287 ± 0^{f}	5 ± 0^{cd}	113 ± 0^{i}	35 ± 0^{f}	1181 ± 1^{l}	598 ± 0^{e}
***D. burkilliana* W**	24 ± 0^{b}	137 ± 1^{d}	253 ± 0^{e}	5 ± 0^{d}	63 ± 1^{e}	46 ± 1^{i}	928 ± 0^{k}	617 ± 0^{e}
***D. bulbifera* W**	46 ± 0^{i}	202 ± 1^{i}	243 ± 0^{c}	4 ± 0^{ab}	128 ± 0^{j}	41 ± 1^{h}	895 ± 0^{j}	472 ± 0^{d}

***D. shimperiana* White AD**	40 ± 0[f]	169 ± 1[h]	557 ± 0[k]	3 ± 0[ab]	92 ± 0[g]	26 ± 0[d]	9 ± 0[a]	23 ± 0[a]
***D. burkilliana* AD**	27 ± 0[d]	159 ± 2[g]	240 ± 0[b]	4 ± 0[ab]	48 ± 0[c]	20 ± 0[b]	679 ± 0[h]	379 ± 0[c]
***D. bulbifera* AD**	25 ± 0[c]	83 ± 1[a]	317 ± 0[g]	3 ± 0[a]	29 ± 0[a]	18 ± 0[a]	50 ± 0[c]	26 ± 0[a]
***D. shimperiana* Red W**	41 ± 0[h]	84 ± 1[a]	254 ± 0[e]	4 ± 0[ab]	91 ± 0[f]	22 ± 0[c]	46 ± 0[b]	ND
***D. shimperiana* Red-Orange W**	40 ± 0[g]	96 ± 0[b]	332 ± 0[h]	4 ± 0[bc]	108 ± 0[h]	26 ± 0[d]	63 ± 0[d]	32 ± 0[a]

Values with the same letter superscript within the same column are not significantly different ($p \geq 0.05$)
Legend: NW = North West; W = West; AD = Adamawa

The magnesium content of the tubers ranged from 29 to 264 mg/100g DM for *Dioscorea bulbifera* from Adamawa and *Coleus esculentus* from the North-West respectively. These magnesium levels were similar to those of *Dioscorea rotundata* (35.5mg), *Dioscorea bulbifera*, (83.5 mg) by Polycarp *et al*. (2012) and 86.5 mg/100g DM by Jacques *et al*. (2016). Magnesium is a cofactor for over 350 enzyme reactions, many of which involve energy metabolism. It is also involved in protein and nucleic acid synthesis and is needed for normal vascular tone and insulin sensitivity. The Dietary Reference Intake (DRI) values for magnesium are 30 mg / day for infants aged 0 to 6 months, 75 mg / day for 7 to 12 months, 80 mg for children 1 to 3 years, 130 mg for 4 to 8 years (IOM, 1997). These yams tubers have magnesium content ranging from 13 – 66 mg / 100g edible portion (EP). Some of the tubers studied, especially *Coleus esculentus* from the North-West (66 mg / 100 g EP) could provide some amount of Magnesium for infants aged 0 to 12 months, can be considered as a source of magnesium for infants.

The iron content of the tubers investigated ranged from 18 to 46 µg/100g DM for *Dioscorea bulbifera* from Adamawa and *Dioscorea burkilliana* from the West respectively. These levels were much lower than those of *Dioscorea bulbilis* (7140 µg/100g DM) (Jacques *et al*., 2016). Iron plays an important role in women of childbearing age, pregnant women and during child development (Kordas and Stoolzfus, 2004). The recent FAO/WHO Expert Committee on vitamins and minerals provided recommended intakes considering diets of 5, 10, 12 and 15% of iron bioavailability (FAO/WHO, 2002). The recommended amounts for children and male and female adolescents are 10, 12 and 15 mg per day, respectively (Herbert, 1987). Given the low iron content of these tubers (8 - 18 µg /100 g edible portion), they cannot be considered as good sources of iron and have to be consumed with iron-rich foods or soups, for a good nutritional balance.

The Zinc content ranged from 9 to 1181 µg/100g DM for white *Dioscorea schimperiana* from Adamawa and yellow *Dioscorea schimperiana* from the West respectively. These zinc contents were much lower than 5400 and 7800 µg/100g DM for *Dioscorea praehensalis* and *Dioscorea esculenta* respectively (Polycarp *et al*., 2012). Zinc is a component of more than 100 enzymes, among which are DNA polymerase, RNA polymerase and transfer RNA synthetase. Zinc deficiency has its most profound effect on rapidly proliferating tissues with growth retardation in children with mild deficiency. More severe deficiency results in growth arrest, teratogenicity, hypogonadism and infertility, poor wound healing, diarrhea, dermatitis on the extremities, loss of dark adaptation and impaired cellular immunity (Ringsted *et al*., 1990). The Recommended Dietary Allowances (RDA) for zinc are 3 mg for children of 1 to 3 years and 5 mg for children of 4 to 8 years old (IOM, 2001). All these tubers contained very low levels of zinc (4 - 382 µg /100g edible portion (EP), far less than 3 g/100g EP), hence cannot be considered as a sources of zinc and need to be consumed with zinc-rich foods or soups, for a good nutritional balance.

The Copper content of the tubers ranged from 23 to 617 µg/100g DM for white *Dioscorea schimperiana* from Adamawa and *Dioscorea burkilliana* from the West respectively, except red *Dioscorea schimperiana* from the West whose copper value was not determined. These copper contents were similar to those of Polycarp *et al*. (2012) who worked on 13 yam varieties and obtained contents that varied from 100 to 250 µg/100g DM. Copper is responsible for the structural and catalytic properties of multiple enzymes necessary for normal body functions. This metal is required for infant growth, host defence mechanisms, bone strength, red and white cell maturation, iron transport and brain development (Uauy *et al*., 1998; Olivares *et al*., 2000). The Recommended Dietary Allowances (RDA) for copper are 340 µg for children 1 to 3 years and 440 µg for children 4 to 8 years (IOM, 2001). The Copper content of the tubers ranged from 11 to 238 µg /100g edible portion (EP), these values were lower than RDA, hence these tubers also need to be consumed with copper-rich foods or soups for a good nutritional balance.

Antinutritional factors:-

Table 3 shows the levels of anti-nutrients in the tubers.

The phytate content of the tubers ranged from 1691 to 2705 mg/100g DM for *Dioscorea burkilliana* from the North West and white *Dioscorea schimperiana* from Adamawa respectively. These values were much higher than the values of 0.89 mg/100g DM for *Dioscorea alata* and 4.16 mg/100g DM for *Dioscorea cayenensis* reported by Polycarp *et al*. (2012). High levels of phytates in human nutrition are toxic and limit the bioavailability of calcium, magnesium, iron and phosphorus by the formation of insoluble compounds with these minerals (Aletor, 1994). The mean daily intake of phytate is estimated to be 2000-2600 mg for vegetarian diets as well as diets of inhabitants of rural areas in developing countries, and 150-1400 mg for mixed diets (Grases *et al*., 1999). The phytate level of these samples is higher than the acceptable content for mixed diets, but within the mean daily intake of phytate, hence will have a lesser binding effect on some minerals such as Ca, Mg, Fe and Zinc.

The oxalate content of the raw tubers ranged from 487 to 1084 mg/100g DM for red *Dioscorea schimperiana* and *Coleus esculentus* from the West respectively. These oxalate contents were much higher than those of *Dioscorea esculenta* (0.20) and *Dioscorea bulbifera* (0.63 mg/100g DM) (Polycarp *et al*., 2012). The presence of oxalate in food causes irritation in the mouth and interfers with the absorption of divalent minerals, particularly calcium, by combining to form insoluble salts with them. However, the level of oxalate in these tubers is not a major concern against health, as one needs to consume 2 to 5 g of oxalate per day, which is thought to be the toxic level for humans (Hassan and Umar, 2004).

The tannin content of the tubers ranged from 26 to 143 mg/100g DM for *Dioscorea bulbifera* and red *Dioscorea schimperiana* from the West respectively. The tannin content of *Dioscorea bulbilas* (66 mg/100g DM) reported by Jacques *et al*. (2016) was within this range of values. The consumption of tannin-rich foods (≥ 5000 mg/100g DM) can cause esophageal cancer (Shils *et al*., 2006). Tannin-protein complexes are insoluble and this decreases protein digestibility by inhibiting the activities of digestive enzymes (Carnovale *et al*., 1991). The tannin content of the tubers is far below the total acceptable tannin daily intake for man, 560mg (Ikpeme, 2012). The results showed that the concentrations of tannin in the tubers were below toxic levels.

The saponin content of the tubers ranged from 90 to 474 mg/100g MS for red-orange *Dioscorea schimperiana* and *Dioscorea burkilliana* from the West, respectively. However, these levels were much lower than that of *Dioscorea alata* (2710 mg/100g DM) from Nigeria (Ezeocha and Ojimelukwe, 2012). Saponins form foams in aqueous solutions, have a haemolytic activity and cholesterol binding properties and bitterness. On the other hand, they have a natural tendency to ward off germs, assisting in treating infections caused by fungi and yeasts. These compounds serve as natural antibiotics, which help the body fight infections and microbial invasions (Sopido *et al*., 2000). Given that these tubers are consumed when cooked, the saponin levels in these tubers will be greatly reduced, providing some beneficial effects on health.

Despite the presence of antinutrients in these tubers, most antinutrients in food can be reduced by proper heat application, at a temperature of 100°C (Ezeocha and Ojimelukwe 2012).

On the whole, there was variability in the physico-chemical constituents from one variety of tubers to another and even within the same variety harvested from different locations. This variability could to be due to the variety of yams, geographical location, nature of the soil and agricultural practices (Chandrasekara and Kumar, 2016).

Table 3: Antinutrient contents of *D. schimperiana*, *D. bulbifera*, *D. burkilliana* and *C. esculentus* expressed in mg/100 g of dry matter

Sample	Phytates	Oxalates	Tannins	Saponins
C. esculentus NW	1918 ± 11^{b}	921 ± 10^{g}	55 ± 0^{e}	106 ± 1^{b}
D. burkilliana NW	1691 ± 11^{a}	638 ± 10^{e}	81 ± 1^{h}	313 ± 3^{g}
D. bulbifera NW	2076 ± 31^{c}	998 ± 8^{h}	64 ± 1^{f}	125 ± 2^{cd}
C. esculentus W	2167 ± 28^{c}	1084 ± 9^{i}	36 ± 1^{c}	123 ± 5^{cd}

D. shimperiana Yellow W	1726 ± 54[a]	569 ± 8[c]	44 ± 1[d]	133 ± 1[de]
D. burkilliana W	1911 ± 12[b]	526 ± 8[b]	34 ± 2[bc]	474 ± 5[i]
D. bulbifera W	1751 ± 43[a]	928 ± 9[g]	26 ± 2[a]	122 ± 5[c]
D. shimperiana White AD	2705 ± 79[f]	737 ± 8[f]	29 ± 2[ab]	217 ± 4[f]
D. burkilliana AD	1951 ± 33[b]	670 ± 5[e]	74 ± 2[g]	365 ± 4[h]
D. bulbifera AD	2151 ± 7[c]	604 ± 10[d]	78 ± 2[gh]	143 ± 3[e]
D. shimperiana Red W	2470 ± 29[e]	487 ± 3[a]	143 ± 2[j]	103 ± 4[b]
D. shimperiana Red-Orange W	2337 ± 15[d]	574 ± 8[cd]	117 ± 1[i]	90 ± 1[a]

Values with the same letter superscript within the same column are not significantly different ($p \geq 0.05$)
Legend: NW = NorthWest; W = West; AD = Adamawa

Conclusion:-

This study showed that the nutrient composition of the tubers varied significantly from one specie to another and within the same specie, from one variety to another. The dry matter contained mostly carbohydrates, especially starch, followed by proteins, crude fibres, ash and some minerals, particularly phosphorus**,** potassium, magnesium and copper**.** They had high energy levels especially from carbohydrates. The tubers had very low lipid levels. Red and red-orange *Dioscorea schimperiana* from the West presented the best profile in crude fibres hence could be good for inclusion in the diet of diabetics and people suffering from constipation. *Coleus esculentus* from the West and North West and red-orange *Dioscorea shimperiana* from the West, had the best profile in proteins, and so could have potential as protein sources for the management of protein-energy malnutrition in children.

Concerning the mineral content of these tubers, *Dioscorea bulbifera* from the North West had the highest content in phosphorus. White *Dioscorea shimperiana* from Adamawa and *Coleus esculentus* from the North West had the highest content in potassium. *Coleus esculentus* from the North West also had high Magnesium while *Dioscorea burkiliana* and yellow *Dioscorea shimperiana* from the West had high levels of Copper. The consumption of these tubers could help prevent imbalance in these minerals especially phosphorus and potassium. The K/Na ratios of all the samples were greater than 5/1, and could have potential for controlling high blood pressure and coronary heart disease.

These tubers contained tannins, phytates, oxalates and saponins. Their contents were lower than daily recommended allowances except phytates when used for mixed diets, but this can be reduced by heating. They therefore have potential beneficial effects on health.

In view of their nutritional profile, these tubers are good to be integrated into root and tuber development programmes, in order to contribute to the fight against malnutrition, food insecurity and also to preserve biodiversity, for maintaining the balance of the ecosystem.

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