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Possibilities of sweet potato [*Ipomoea batatas* (L.) Lam] value chain upgrading as revealed by physico-chemical composition of ten elites landraces of Benin

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Sweet potato is one of the most important food security promoted root crops in the world, especially in sub-Saharan Africa. Unfortunately, the crop is still neglected and underutilized in Benin Republic. To establish baseline data for its better utilization for upgrading its value chain, 10 selected local varieties (01 cream, 02 white, 03 yellow, and 04 orange flesh-colored) were compared for their macro-nutritional composition assessed using standard Association of Official Analytical Chemists (AOAC) procedures and spectrophotometry methods. The results indicate that sweet potato dry matter, protein, fiber, and ash content ranged from 46.11 to 25.9%, 4.09 to 1.97%, 1.81 to 3.00%, and 4.70 to 2.56%, respectively and orange flesh cultivars were found very rich. Pearson correlation analysis of variables revealed that dry mater content is positively correlated with carbohydrate and energy values, but negatively correlated with ash and fiber content, while starch content is strongly correlated with fiber content. Principal component analysis allowed us to classify the sweet potato varieties into 03 varietal groups among which Group 2 (05 varieties) exhibited rich fiber, ash, and protein contents and may be recommended for infant foods formulations. These results constitute important orientation for sweet potato processing chain organization in Benin and for the establishment of future nutrition and breeding programme.

Key words: Benin, sweet potato, *Ipomoea batatas*, nutritional composition, orange flesh cultivar, value chain.

INTRODUCTION

Sweet potato [*Ipomoea batatas* (L.) Lam.] is one of the major staple crops and the most important food security promoting root crops in the world, especially in sub-Saharan Africa (Low et al., 2009). Well adapted to the tropical and subtropical regions, sweet potato has nutritional advantage for the rural and urban dwellers (Ingabire and Hilda, 2011). Sweet potato is an excellent source of energy (438 kJ/100 g edible portion) and can produce more edible energy per hectare per day than cereals, such as wheat and rice (Abu et al*.,* 2000) and has other advantages, such as versatility, high yield, hardiness, and wide ecological adaptability (Laurie et al., 2012).

Sweet potato roots are rich in starch, sugar, vitamin C, β-carotene, iron, and several other minerals (Laurie et al., 2012; Oloo et al., 2014). Despite its high carbohydrate content, sweet potato has a low glycemic index due to low digestibility of the starch making it suitable for diabetic or overweighed people (Ellong et al., 2014; Fetuga et al., 2014; ILSI, 2008; Ooi and Loke, 2013). The root is reported to usually have higher protein content than other roots and tubers, such as cassava and yams (Oloo et al., 2014). In addition, some varieties of sweet potatoes contain colored pigments, such as β-carotene, anthocyanin, and phenolic compounds. These pigments form the basis for classifying the foods as nutraceuticals (Oloo et al., 2014). Sweet potato's leaves are recognized to be rich in essential amino acids, such as lysine and tryptophan which are always limited in cereals. Hence, sweet potato can easily complement cereal based diets in the region (Mwanri et al., 2011; Oloo et al., 2014). Moreover, sweet potatoes have high technological potential and it is reported that it can be used for various products, such as drinks (wine, liquor, vinegar), sugar production, biscuits, flour, pasta, alcohol, etc. (Ellong et al., 2014).

Nowadays, several research programmes are focusing on orange-fleshed or vitamin A sweet potato with great potential to prevent and combat vitamin A deficiency for the crops value chain upgrading within the West African sub-region (Inaghe and Hilda, 2011). However, in Benin, cassava and yam appear as major roots and tubers crops and they are valorized through various food products across the country. According to Gnonlonfin (2008), cassava and yam processing into chips is common traditional activity in Benin. In addition, cassava is also largely consumed after processing into garri, traditional flour, lafun, and improved flour. However, the potential benefits of crop such as sweet potato are marginalized and are underutilized despite their technological potential which is well recognized and exploited elsewhere. In Benin, Sanoussi et al. (2015) reported the existence of high diversity of sweet potato that are poorly managed for proper value chain development as they are only eaten boiled, fried or as puree. Unfortunately, no reports on the nutritional (macronutrient) composition of Benin sweet potato cultivars is available to help in identifying landraces that have interesting nutritional and technological aptitude for more efficient utilization in diverse agro-food chain sector. In order to encourage diversification of utilization of the crop and upgrade sweet potato value chain in Benin Republic to fully exploit it potential, preliminary study focused on the study of existing diversity (Sanoussi et al., 2015). The objectives of the present study are to: evaluate the proximate composition of the selected varieties (including their total and reducing sugars contents) for better utilization through agro-food processing chain; examine the correlation between the chemical parameters to predict the probable link between the variable for future use or breeding purpose; clarify the relationship among the cultivars to predict the possibility of the crop efficient utilization and its value chain upgrading via sustainable food industry.

MATERIALS AND METHODS

Ten sweet potato landraces were selected for the chemical analysis. These were selected from the 108 accessions collected from the southern and central part of Benin Republic and maintained at the experimental farm of the Faculty of Sciences and Technology of Dassa. Selection of cultivars was based on their productivity and/or their predominant and secondary flesh color and peel color. Flesh color was considered as it is known to be related to vitamin A content which needs to be promoted for combating vitamin A deficiency and associated illness among the local population. Table 1 presents the ten selected cultivars description including their vernacular name, the name of the sites (village) of provenance, their flesh and peel colors as well as their estimated yield after plantation in the experimental farm.

Treatments

For the analysis, five medium size sweet potato roots, freshly harvested from the farm were thoroughly washed with potable tap water and cleaned using toweling paper. Cleaned roots were peeled manually with a stainless steel knife and cut into small pieces, wrapped into aluminum paper and kept into refrigerator for future analysis. Before the analysis, the samples of sweet potato flesh were dried in oven at 72°C for 72 h and ground using GRIND-MILL laboratory grinding machine for obtain flour (dried) samples for the analysis.

Proximate composition

The proximate composition analysis was focused on the evaluation of moisture, protein, fat, carbohydrate, ash, as well as fiber content of each of the ten varieties of the sweet potato and carried out

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Table 1. List and characteristics of the selected cultivars.

Accession number	Vernacular name	Collecting sites	Peel color	Predominant flesh color	Secondary flesh color	Estimated mean yield (t/ha) on Wet weight basis
E5	Wêli F	Sissèkpa	White	Cream	None	76.38
E1	Avoungokan vôvô	Sagon	Pink	White	None	40.80
E6	Gbagolo	Dasso	Purple	White	None	33.90
E10	Bombo wéwé	Sokan	Cream	Yellow	Pink	12.65
E4	Atanboué	Dasso	White	Yellow	None	18.53
E9	Carrotti	Bozoun	Orange	Dark orange	None	21.32
E3	Loki kpikpa	Pira	Pale orange	Pale orange	None	36.96
E8	Dokouin C	Kétou	Pink	Pale orange	Orange	36.35
E7	Mansawin	Sokan	Yellow	Pale orange	Yellow	18.51
E2	Bombo vôvô	Sokan	Dark purple	Yellow	Purple	38.88

according to the standard procedures of Official Method of Analysis of the Association of Official Analytical Chemists (AOAC, 2000). The determination of moisture was carried out by oven method, while ash content was determined by the sample ashing method in a muffle furnace. The protein (total nitrogen) content was determined by Kjeldahl method while the fat content was evaluated by extraction of 10 g of dried sample through Soxhlet apparatus using petrol ether as solvent. Crude fiber was determined from the residue of defatted sample by keeping 5 g of sample in a muffle furnace at temperature of 900°C for 6 h after extraction of insoluble matter following AOAC methods. The carbohydrate content was determined by simple differences (dry extract - ash+ lipids + proteins) following Ellong et al. (2014).

Total and reducing sugars as well as starch content were determined by Spectrophotometric method. Reducing sugars content was evaluated using dinitrosalycilic acid DNS as reagent (Eleazu and Eleazu, 2012) while for total sugars determination, phenol and sulfuric acid were used and the absorbance were read at 546 nanometers for these two parameters. Starch content of the sample was determined by reading solution floated after preparing the (hydrolysis of starch) medium using the different sweet potato flour sample, sodium hydroxide (1 M) and chlorhydric acid (1 M) at 580 nanometers using BioMate™ 3 spectrophotometer.

Calorie value was estimated following Etong et al. (2014) using Atwater factors by multiplying the proportion of protein, fat, and carbohydrate by their respective physiological fuel values of 4, 9, and 4 kcal/g, respectively and taking the sum of the products.

Proximate analysis were carried out at Laboratory of Food Sciences and Technology of the Faculty of Agronomics Sciences (University of Abomey-Calavi), while starch, total, and reducing sugars analysis was proceeded at the Laboratory of Protein Biochemistry and Enzymology of the Faculty of Sciences and Technology (University of Abomey-Calavi).

Statistical analysis

The results obtained were analyzed using descriptive statistics (means and standard deviation) and Pearson correlation coefficient. The analysis of variance (ANOVA) and test of Newman-Keul were performed to assess the significance of differences between means of proximate analysis variable of the ten sweet potato cultivars at probability p=5%. Pearson correlation coefficient was calculated and correlation matrices were generated to assess the correlation between variables. Principal component analysis (PCA) was also performed to examine the relationship between the 10 cultivars by considering them as individuals and proximate composition parameters (dry matter, fat, protein, carbohydrate, ash, fiber, total sugars, reducing sugars, and starch contents as well as energy value) as variables. Apart from the PCA which was performed using XLSTAT software, MINITAB® software version 14 was used for all the statistics analysis.

RESULTS AND DISCUSSION

Proximate composition

The proximate composition including dry matter, protein, fat, carbohydrates, ash, and fibers of the selected ten cultivars as well as their energy value, their total and reducing sugars and starch content were evaluated.

The dry matter content of the ten selected cultivars ranged from 46.12 to 25.09%. These values are similar to the one reported by Ellong et al. (2014) in Martinique (29.56 to 39.32%), but higher than those reported by Laurie et al. (2012) in South Africa (18.5 to 30.5%). This result is an indication of the existence in Benin of high dry matter content sweet potato cultivars. The higher dry matter content was recorded with E4 (Table 2), a yellow flesh sweet potato cultivar while the lowest rate was obtained with E3, an orange flesh sweet potato (OFSP) variety. Tomlins et al. (2012) reported that OFSP varieties with high carotenoid content tend to have lower dry matter contents. Therefore, OFSP cultivars E3, E7 and E9 that exhibited lower dry matter content (Table 2) might present higher carotenoids content than E8(38.56%) and others colored (white, cream, yellow) flesh sweet potato cultivars. Dry matter content relates to good cooking qualities and extended storage lives (Eleazu and Eleazu, 2012; Eleazu and Ironua, 2015) and could contribute to increase the yield and the

Table 2. Proximate composition of roots of selected ten sweet potato cultivars from Southern and Central Benin.

Sample	Flesh color	Name and proximate composition parameters (g/100 g on dry weight basis) of sweet potato cultivars							
		Vernacular name	Dry matter (%)	Protein (%)	Fat (%)	Carbohydrates (%)	Ash (%)	Fiber (%)	Energy value (kcal)
E1	White	Avoungokan vôvô	27.79±1.01^{b}	3.40±0.00^{cd}	0.67±0.07^{a}	20.19±0.93^{b}	3.53±0.00^{d}	2.51±0.05^{e}	100.39±4.39^{a}
E6	White	Gbagolo	31.64±0.05^{C}	3.35±0.04^{cd}	8.88±0.30^{c}	15.71±0.23^{a}	3.70±0.00^{d}	2.35±0.01^{d}	156.18±1.71^{d}
E5	Cream	Wêli F	35.46±0.13^{d}	3.61±0.05^{cd}	1.45±0.21^{b}	27.39±0.48^{c}	3.00±0.10^{bc}	2.11±0.04b^{c}	137.06±0.15c
E2	Yellow	Bombo vôvô	30.33±1.08^{bc}	3.20±0.03^{c}	1.49±0.22^{b}	22.36±1.19^{b}	3.28±0.31^{cd}	2.56±0.05^{e}	115.68±6.68^{b}
E4	Yellow	Atanboué	46.12±0.17^{f}	4.09±0.01^{e}	0.54±0.13^{a}	38.92±0.04^{f}	2.56±0.01^{a}	1.81±0.05^{a}	176.96±1.33^{e}
E10	Yellow	Bombo wéwé	31.26±1.13^{C}	3.22±0.09^{c}	1.81±0.23^{b}	35.49±0.70^{e}	3.61±0.01^{d}	1.99±0.02^{b}	171.15±1.06^{e}
E3	Pale orange	Loki kpikpa	25.09±0.08^{a}	4.19±0.25^{e}	1.74±0.09^{b}	14.46±0.07^{a}	4.70±0.01^{e}	2.98±0.00^{f}	90.24±0.10^{a}
E7	Pale orange	Mansawin	30.15±0.45^{bc}	2.03±0.06^{a}	2.22±0.51^{b}	22.86±0.43^{b}	3.03±1.00^{bc}	3.00±0.04^{f}	119.54±1.92^{b}
E8	Pale orange	Dokoui C	38.56±0.41^{e}	2.82±0.05^{b}	2.05±0.23^{b}	30.97±0.73^{d}	2.71±0.04^{ab}	2.19±0.01^{c}	153.63±0.64^{d}
E9	Dark orange	Carroti	30.73±0.88^{bc}	3.71±0.04^{d}	2.04±0.24^{b}	21.50±1.10^{b}	3.07±0.02^{bc}	2.33±0.05^{d}	122.86±2.06^{b}

texture of derivative products (Mégnanou et al., 2009). Following Odebode et al. (2008), these high dry matter cultivars could be recommended to flour production industries for various products such as baking flour, composite flour, weaning formula, stabilizer in ice cream industry, etc. According to Eleazu and Ironua (2015), processing sweet potato roots into flour, is one way of minimizing post-harvest losses and increasing its utilization. However, future study can be suggested to understand the relationship between the flesh color of the varieties and their real storage life, since good storage shelf life is requested quality in sweet potatoes.

The protein content of cultivars studied ranged from 2.03 to 4.19% on dry weight basis (Table 2). These values are in the same range of 3.28 to 4.16% obtained by Ukom et al. (2009) in Nigeria, but higher than the values of 0.71 to 0.91% reported by Ingabire and Hilda (2011) in Rwanda. Among the cultivars studied, higher protein contents were recorded with some of the yellow (E4=4.09%) and the dark orange (E3=4.19%; E9=3.71%) flesh cultivars. This suggested that colored flesh (yellow and orange) sweet potato cultivars, in addition to their probable highest β-caroten content, could be good sources of protein than white flesh varieties. Therefore, they could be recommended as good food for alleviating protein-energetic malnutrition and vitamin A deficiency. In comparison with the leaves protein content (15.10 to 27.10%) as reported by Nkongo et al. (2014), the storage roots exhibited lower protein content, hence indicating the necessity of encouraging the promotion and the consumption of composite foods mixing sweet potato storage root and leaves for balanced diet. With regards to the recommended daily allowance of proteins for infants (9.1 to 13.5 g/day), children (13 to 19 g/day), adult women (34 to 46 g/day), and adult men (45 to 50 g/day) (Eleazu and Ironua, 2015), the consumption of only 100 g of the storage roots (dried) of the studied sweet potato cultivars is enough to help meet one third (1/3) to one fourth (1/4) protein requirements of infant and children and about one tenth (1/10) protein requirements of adults. Protein plays an important role in human body and have numerous benefits, such as provision of vital body constituents, maintenance of fluid balance, contribution to the immune function and formation of hormones and enzymes which control a variety of body functions, such as growth, repair and maintenance (Iheanacho and Udebuani, 2009; Eleazu and Ironua, 2013).

Lipids are very important in food substances since they are vital to the structure and biological function of cells and contribute significantly to the energy value of foods (Eleazu and Ironua, 2013). Cultivars E6 (Table 2) showed a very high fat content (8.88%) which did not fall in any range of sweet potato fat content reported in the literature, while the other cultivars have fat content of 0.54 to 2.22%. In previous morphological characterization (Sanoussi et al., 2015), E6 has been distinguished itself from others cultivars of the collection with its general leaves shape which is also different from leaves shape proposed in sweet potato descriptors. Therefore, future studies could be undertaken on this sweet potato landrace through use of molecular tools to better understand the genes responsible for its characteristics. Knowing that vegetable oils provide essential fatty acids, it will be interesting to know the fatty acid profile of this sweet potato variety and especially its essential fatty acids content. Fats function in the increase of palatability of food by absorbing and retaining flavours (Antia et al., 2006) are well recognized. Thus, sweet potato cultivar E6, due to its exceptional fat content could be promoted as food flavoring. In addition, the utilization of this cultivar could be recommended in food diet for prevention of obesity and cardiovascular diseases as excess fat consumption is implicated in certain cardiovascular disorders such as atherosclerosis, cancer and aging. Diet providing 1 to 2% of its caloric of energy as fat is said to be sufficient to human beings (Antia et al., 2006).

Ash content varied from 2.56 to 4.70% and are higher than those (0.40 to 2.35%) generally presented in fresh weight basis in literature (Eleazu and Eleazu, 2012; Eleazu and Ironua, 2013; Ellong et al., 2014). Following Ukom et al. (2009), this high ash content indicates that cultivars studied are rich in some mineral salt. E3, pale orange flesh cultivar, exhibited the higher ash content (4.70% on dry weight basis) and could be promoted for preventing and curing hidden hunger especially among children, pregnant, and lactating women.

Dietary fiber content (Table 2) varied from 1.81 to 3.00% in dry weight basis. Orange flesh cultivars recorded higher fibers content indicating that they could be more digestible than the others. The values obtained are similar to the ones reported by Inghabire and Hilda (2011), higher than those of Ukom et al. (2009) in Nigeria but lower to the values (3.30 to 5.40%) reported by Ellong et al. (2014) in Martinique. According to Trinidad et al. (2013), dietary fibers are important in preventing cardiovascular diseases and diabetes mellitus and they are also efficient in reducing the incidences of colon cancer and certain digestive diseases (Ingabire and Hilda, 2011).

Carbohydrate is represented in higher quantities (14.86 to 38.92%) for all the ten selected sweet potato cultivars indicating that they are good source of energy. Apart from the light orange flesh cultivar E3 (14.86%), the cream, the yellow, and the light and dark orange fleshes seem to have higher carbohydrate content than white flesh cultivars. It is well recognized that foods with carbohydrates that break down quickly during digestion and release glucose rapidly into the bloodstream tend to have a high glycemic index and foods with carbohydrates that break down more slowly, releasing glucose more gradually into the bloodstream, tend to have a low glycemic index (Jenkins et al., 1981). The type of carbohydrate available in these local varieties and their effects on blood glycaemia needs to be more investigated for better understanding of the reported potential of sweet potato in diabetes management. According to Eleazu and Ironua (2015) significant amounts of carbohydrates in foods give them a role in human health and they can serve as substrates for the production of aromatic amino acids and phenolic compounds through the shikimic acid pathway. The shikimate pathway leads to essentials amino acids, such as tryptophan and phenylalanine synthesization.

On the basis of the total sugars content, the sweet potato cultivars studied can be classified into four groups of low (1.63 to 7.00 mg/g; E1, E3, E5, E7 and E8), intermediate (24.23 to 27.42; E2 and E6), high (42.64 mg/g; E4), and very high (242.68 and 684.63 mg/g; E9 and E10) total sugars content. Once again E6 distinguished itself from the others white flesh cultivars after been demarked for it specific fat content. E10 (yellow flesh) and E9 (dark orange flesh) could be recommended to intervene as natural sweeteners for food industry or for diabetics consumption since sweet potato has been reported as low index glycemic food (Ellong et al., 2014) that have natural nutraceutical capacity of controlling glycaemia (Ooi and Loke, 2013). In addition, the individuals of intermediate and high total sugar content groups could also be recommended as raw material in food industries aimed at limited sugar addition from others sources.

The reducing sugars content (Table 3) ranged from 0.38 to 12.11 mg/g and is lower than the range of the value 1.74 to 2.50% reported by Ingabire and Hilda (2011). Cultivars E2 (yellow flesh cultivar; 12.11 mg/g) and E9 (orange flesh cultivar; 10.86 mg/g) that exhibited relatively higher values of reducing sugars show promising potential for ethanol production. Apart from E4, all the yellow flesh cultivars exhibit higher reducing sugars than white and cream flesh cultivar. Similar results were obtained by Eleazu and Eleazu (2012), who stipulated that yellow cassava cultivars have higher quantities of reducing sugars than the white cassava cultivars. According to these authors, the difference in reducing sugars content among the cultivars may be due to the difference in genotype being analyzed and possibly to phenolic compound present in the yellow and orange flesh cultivar.

The starch content of sweet potato cultivars studied ranged from 70.56 to 326.73 mg/g. Apart from cultivar E4 which recorded the highest starch content (326.73 mg/g equal to 32.67%), all the sweet potato analyzed, present the starch content values lower than the values ranging from 20.30 to 31.05% as reported by Ellong et al. (2014) in Martinique. The differences may be due to genotypes variations or to a probable conversion of the starch of the sweet potato studied and only the resistant starch has been quantified. Iheagwara (2013) have mentioned the relatively low stability of sweet potato starch. In addition, Eleazu and Ironua (2015) reported high amylasic activities of the sweet potato protein. Starch has a wide application in both food and sugar industry since it is

Table 3. Sugars and starch content of the ten sweet potato cultivars.

Sample	Flesh color	Vernacular name	Parameter (mg/g)		
			Reducing sugars	Total sugars	Starch
E1	White	Avoungokan vôvô	2.70±0.18[b]	7.00±0.35[a]	70.56±1.96[a]
E6	White	Gbagolo	1.22±0.06[a]	27.42±0.90[ab]	83.10±12.74[ab]
E5	Cream	Wêlli F	1.14±0.19[a]	1.63±0.07[a]	144.65±3.53[c]
E2	Yellow	Bombo vôvô	12.11±0.13[f]	24.23±0.70[ab]	172.87±3.14[d]
E4	Yellow	Atanboué	0.38±0.00[a]	42.64±1.50[b]	326.73±3.00[e]
E10	Yellow	Bombo wéwé	6.34±0.36[d]	684.43±16.0[d]	-
E3	Pale Orange	Loki kpikpa	3.98±0.09[c]	4.40±0.20[a]	169.34±4.30[d]
E7	Pale Orange	Mansawin	5.73±0.30[d]	6.00±0.01[a]	143.08±4.31[c]
E8	Pale Orange	Dokoui C	3.35±0.05[bc]	6.10±0.03[a]	78.40±1.96ab[ab]
E9	Dark Orange	Carroti	10.86±0.75[e]	242.68±14.0[c]	141.12±7.25[c]

Table 4. Pearson correlation matrice of the physico-chemical data.

Variable/Correlation	Dry matter	Protein	Fat	Carbohydrate	Ash	Fiber	Energy	Reducing sugars	Total sugars
Protein	0.122								
Fat	-0.146	-0.130							
Carbohydrate	0.792*	-0.016	-0.445						
Ash	-0.777*	0.322	0.238	-0.660*					
Fiber	-0.758*	-0.315	0.065	-0.774*	0.551				
Energy	0.769*	-0.020	0.226	0.767*	-0.530	-0.832*			
Reducing sugars	-0.420	-0.202	-0.194	-0.181	0.038	0.289	-0.337		
Total sugars	-0.089	0.006	-0.069	0.417	0.098	-0.390	0.417	0.307	
Starch	0.549	0.429	-0.404	0.580	-0.227	-0.361	0.378	-0.042	0.158

Values with * indicate a significant correlation.

used to influence or control foodstuffs characteristics, such as aesthetics, moisture, consistency and shelf stability. In addition, starch is widely used as a thickener, water binder, emulsion stabilizer, and gelling agent (Iheagwara, 2013; Eleazu and Ironua, 2015). From the results of this study, there is a need to improve the starch content of the cultivars through molecular biology tools, in a bid to upgrade sweet potato value chain through a supply of various nutrient (starch, sugars, dry maters, protein, ash) rich sweet potato cultivars for different industrial application in Benin as suggested by Bovell-Benjamin (2007).

The energy value of the cultivars ranged from 90.24 to 176.96 kcal/100 g (Table 2) with an average of 134.37 kcal/100 g equal to 561.67 kJ/100 g. Cultivars E4 and E10 with both yellow flesh sweet potato, provided about 2 times more energy than E3 cultivars (OFSP). Consumption of 1 kg of E4 and E10 dry matter will provide about 1769.60 and 1711.60 kcal of energy which is not too far from the minimum (2500 kcal) daily calorie requirement for adults (Onyeike and Oguike, 2003). Based on the average caloric value of the other roots and tubers reported by Lebot (2009), it can be deduced that sweet potato cultivars analyzed can provide lower energy than cassava (600 kJ/100 g) roots and higher energy than yam (440 kJ/100 g) and aroids (400 kJ/100 g) tubers.

Correlation of the variables and PCA of the physico-chemical data

Pearson correlations analysis of the variables (Table 4) showed that the dry mater content is positively correlated with carbohydrate content and energy value, while negatively correlated with ash and fiber contents. This suggested that the more a cultivar is rich in dry matter, the higher its carbohydrate content and energy value and the lower its ash and fiber content. Therefore, improvement of dry matter content of the orange flesh cultivars as suggested earlier, may lead to the loss of their high mineral content via ash content losses. Total

Table 5. Contribution of each parameter to the variability on the first four principal components of PCA.

Variable	PC1	PC2	PC3	PC4
Dry matter	-0.439	0.179	0.084	-0.213
Protein	-0.068	-0.245	0.703	0.166
Fat	0.113	0.561	0.002	0.464
Carbohydrate	-0.447	-0.150	-0.142	-0.034
Ash	0.339	-0.150	0.337	0.387
Fiber	0.424	-0.041	-0.055	-0.234
Energy	-0.413	0.214	-0.101	0.318
Reducing sugars	0.148	-0.475	-0.438	0.025
Total sugars	-0.135	-0.372	-0.278	0.627
Starch	-0.291	-0.369	0.289	-0.105
Eigen-value	4.39	1.62	1.49	1.36
Proportion	43.96	16.22	14.99	13.61
Cumulative	43.96	60.18	75.17	88.79

sugars content (Table 4) is positively correlated with reduced sugars, carbohydrate content, and energy value, while negatively correlated with fiber content. Starch and fiber content are negatively correlated. Improvement of total sugars content may lead to the increase of reducing sugar which is a required parameter for directing a cultivar for bio-ethanol production. Among the cultivars studied, the same sweet potato cultivar could not be simultaneously breed for starch and ethanol (reducing sugars) industries as it was found out that a breeding programme focusing on improved reducing sugar content in a variety will lead to an increase of it fiber content and therefore a lowering of its starch content.

PCA grouped the variables into nine components among which the first four are significant (Eigen value>1) and explained 88.79% of the total variability (Table 5). Principal Component 1 (PC1) is correlated with dry mater, carbohydrate, ash, fiber, and energy explains 43.96% of the total variability, while PC2 (16.22% of total variability) is associated with fat, starch, total, and reducing sugars (Table 5). Fat, reducing sugars, dry matter, and carbohydrate contents recorded the highest values for their coordinates on PC1 and PC2 and represent the most important factors of the variability between the sweet potatoes cultivars studied.

Projection of the cultivars on the factorial axis 1 and 2 allowed the classification of the sweet potato cultivars into three groups (Figure 1). Group 1 assembles cultivars (E4 -Atanboué, E5-Wêli F, E8-Dokoui C, and E10-Bombo wéwé) and is characterized by cultivars with high dry matter and high carbohydrate content with a subgroup of cultivars rich in starch and total sugars. These cultivars can be a good raw material for sweet potato flour and derivative (starch, noodle, confectionaries, baking, porridge, and sweeteners) production industry. Group 3 is represented by only one sweet potato cultivars (E6-Gbagolo) which is characterized by high fat content, while the group 2 combines five (05) sweet potato cultivars (E1-Avoungokan vôvô, E2-Bombo vôvô, E3-Loki kpikpa, E7-Mansawin, and E9-Carroti). Individual of group 2 recorded high protein content, high ash, and fiber content. The characteristics of this last group is quite interesting, because it can be used to combat malnutrition and this in two ways (helping in preventing or fighting against protein-energetic malnutrition and helping to alleviate hidden hunger through it mineral content via ash content). Individual of this last group is very important to be promoted as infant formula since FAO (2013) reported that apart from protein-energetic malnutrition, micronutrient deficiency is the most redoubtable form of malnutrition among children.

These last two analyses help to identify the most important variables that should be taken into account in breeding and selection program aimed at improving and creating varieties especially dedicated to serve as raw material in various food industries to upgrade the crop value chain. The results of the PCA seem particularly interesting, because the ten sweet potato local varieties can be directed to different applications at the processing chain and boosting the species' value chain.

As regards all the chemical parameters analyzed, cultivars “Bombo wéwé” and “Carroti” recorded the highest total sugars content, while “Atanboué” and “Bombo vôvô” on one hand and “Atanboué” and “Wêli C”, on the other hand, have the highest amount of starches and dry matter, respectively. These 05 varieties highly need to be promoted for the rapid implementation of sweet potato processing chain in Benin as it well recognized that dry matter, starch and total sugars contents are important parameters with large applications in agro-food processing and business. In terms of protein content cultivars, “Loki kpikpa” and “Atanboué” are the richest while “Loki kpikpa” and “Bombo wéwé” present the highest ash content. In addition, all of these local sweet potato varieties have yellow/orange flesh making them most useful for future orientation in vitamin A deficiencies alleviation programme.

However, in order to prevent the genetic erosion of the rest, an action should be undertaken over the ten cultivars for the *in situ* and *ex situ* conservation of their genetics materials on one hand. On the other hand, these sweet potato cultivars can be oriented as potentially good raw materials to implement food based approaches for combating malnutrition.

This study appears as very interesting for future applications in research and constitutes a significant contribution for better knowledge of Benin sweet potato genetic resources and for their future utilization in food and agribusiness development in Benin and around the world for more enhanced food nutrition and security level. However, due to the fact that chemical composition vary

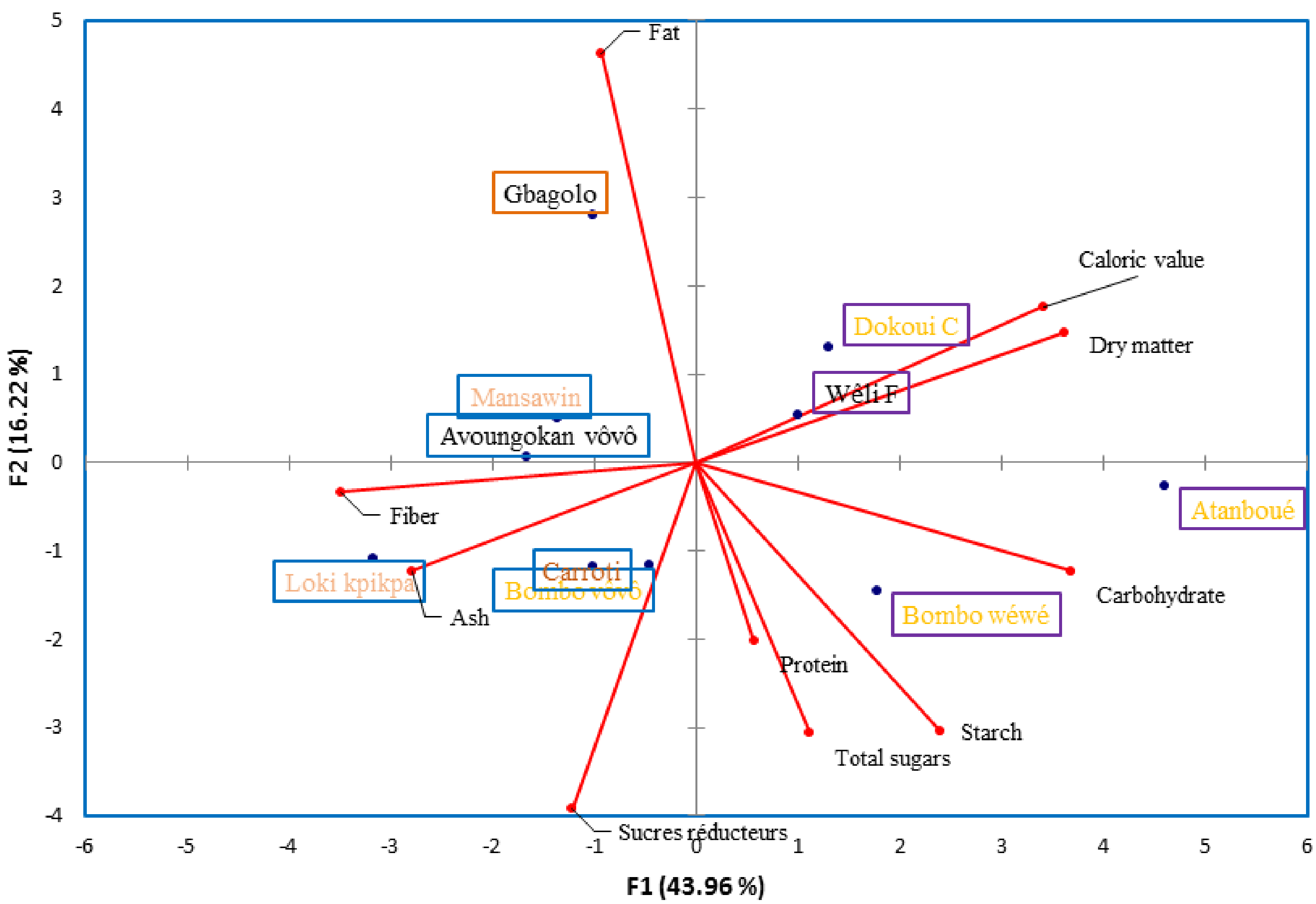

Figure 1. Projection of the sweet potato cultivars on the first and second component axes. Boxes represent the sweet potato cultivars name. Boxes with different colors indicate sweet potato cultivars that belong to different varietal groups. Group 1= Cultivars with indigo boxes; Group 2=Cultivars with blue boxes; Group 3: Cultivar with orange boxes.

greatly in crop depending on soil conditions, temperature and environment in which it grows; further analysis of samples planted at different regions of the country are recommended.

Conclusion

This study allows the establishment preliminary data on nutritional composition of sweet potatoes landraces of Benin Republic. The ten selected sweet potato cultivars of the study present interesting nutrient composition which varies significantly following the genotypes and dry matter, fat, reducing sugars, and carbohydrates contents represent the most important factors of variability among the cultivars studied.

The orange flesh sweet potatoes local varieties recorded the highest nutrient content for almost all the parameters analyzed. However, the study also shows the existence of important significant correlations between certain chemical analyses variables (dry matter content correlated with carbohydrate, ash and fiber contents) which can be useful in future breeding programme. In addition, the different varieties of sweet potatoes analyzed have been structured into groups with potential good technological aptitude to be promoted in different agro-food sectors for sweet potato value chain upgrading in Benin Republic and for orientation in future nutrition programme. The new trend for utilization of six promising local varieties (Atanboué, Carroti, Bombo wéwé, Dokoui C, Loki kpika and Bombo vôvô) which presented quite interesting values for the parameters analyzed out of the ten cultivars analyzed is highly whished. In addition, these six (06) cultivars can be promoted through different sector of the food chain in order to improve food security among both children and aged people.

Sweet potato local varieties mineral and vitamin content analysis could be the next step to validate the possibly potential of these varieties in sweet potato value chain upgrading in Benin as well food security insurance.

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Conflict of Interests

The authors have not declared any conflict of interests.

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