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Physicochemical characterization of cassava (*Manihot esculenta*) elite cultivars of Southern Benin

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Abstract

Cassava (*Manihot esculenta*) is one of the main food crops that significantly contributes to food security and poverty alleviation in Benin. A great diversity of cassava based foods and beverages exist but the mostly known are gari, starch (tapioca), cassava flour, attièkè and alcohol. In terms of food processing, existing cultivars are known to exhibit different technological performances. It is therefore important to identify the best one to be used by the processors. In this study, 28 previously identified elite cassava cultivars were assessed for dry mater, starch content, cyanide contents and alcohol production capacity. From the cultivars analyzed, Ouéminnou has the most important (55.52%) dry mater content. The starch content varies from 0.08 ± 0.01mg/g (cultivar Faingnintin vêvê) to 12.98 ± 1.92 mg/g (cultivar Okin blanc). The alcohol production capacity after fermentation varies from 0.015 ml/g of starch for cultivar Agrik Blanc to 0.162 ml /g of starch with cultivar Agbakomessi. The screening for cyanide content revealed that four cultivars contain a higher dose of cyanide whereas only one cultivar is without cyanide. Base on the data obtained 14 cultivars (Agbakomessi, Agrik blanc, Atinwé, Batchégô, Dawé, Gbakaya, Glégbodji, Hêwadô, Hombêté, Koutéwé, Kpokpoiroko, Okin, Ouéminnou and Sodaf) were identified as super elites that can be recommended for good and profitable production of gari, tapioca, cassava flour, attièkè and alcohol.

Keywords: Benin, *cassava*, elite cultivars, food processing, physicochemical characterization.

Introduction

Roots and tubers crops constitute an important source of energy in the tropical countries especially in Africa (FAO, 2014). Among them, cassava (*Manihot esculenta* Crantz) is a key food crop and contributes significantly to the nutrition and livelihood of more than 800 million people (Kumba et al., 2012) and thousands of processors and traders around the world, and forms a base for a wide variety of fermented foods in Africa, Asia and Latin America (Elohor et al. 2008). In terms of production, cassava (*Manihot esculenta*) ranks the fifth most important crop worldwide after maize, rice, wheat and potato (FAO, 2014). It constitutes food and cash crops for the producers and its world annual production was estimated at 263.58 million tons in 2012 (FAO, 2014). Cassava belongs to the group of Euphorbiaceae and Africa is considered as its second center of diversity (Kawuki et al., 2013). The crop is adapted to various ecological conditions, often unfavorable for cereals or other crop species (Kombo et al., 2012; Kumba et al., 2012; Agre et al., 2015).

In West Africa, cassava roots are consumed fresh in a raw way (sweet cassava) or as gari (bitter and sweet cultivars) and as tapioca (Diallo et al., 2013). In Benin, cassava is grown as a major root crop for cash, food, feed and raw material for the production of starch, alcohol and confectioneries (Agre et al. 2015a). Due to its easy propagation, its availability all over the year, its adaptation to poor soil and drought resistance and its tolerance to biotic stress, a large diversity of cassava cultivars exists in all the agro-ecological zones (Lebot et al., 2008; Agre et al., 2015b). However, cassava roots are very perishable due to its high water content and require rapid utilization after harvest (Megnanou et al., 2012). In addition, the presence of cyanhydric compound in some cultivars limits their utilization in the fresh unprocessed form (Elohor et al. 2008). According to Niba et al. (2002) and to Sanoussi et al. (2015), the processing techniques are employed to detoxify cassava root and reduce cyanogenic glycosides to safe levels.

About 80% of the cassava production are processed into gari (50%), lafou (dried cassava; 15%), tapioca (5%) and starch (5%) (Kobawila et al., 2005), while other products such as: flour, alcohol, attièkè, foufou, are well recognized and consumed throughout the African regions (Nago et al., 1998; Diallo et al., 2013). As the quality of the end products depends essentially on the cassava cultivar used (Kobawila et al., 2005), a better knowledge of the cultivars would help in the choice of the right cultivars to be used for good quality end-products with a better profit margin. Most of cassava end-products are obtained by traditional processing assured by local processors, mostly illiterate and less informed. The basic knowledge on the physicochemical properties of cultivars in relation to their aptitude to be processed into specific end-products is not documented (Rakipov, 1985; Sanoussi et al., 2015). Though, several research works have been focused on the post-harvest processing of cassava roots (Padonou et al., 2009), there are however limited reports devoted to the technological aptitude of Benin cassava cultivars for good quality gari, tapioca , chips (dried cassava), attièkè and alcohol production with a very high profitability.

With their traditional knowledge, farmers have defined, among themselves, several criteria of performance and preference to select best cassava cultivars for different uses. However, no link has been set between these criteria and scientific data, especially the physicochemical characteristics of cassava cultivars in relation to their end-uses. To better understand the physicochemical characteristics of the local elite cassava cultivars as they influence over the quality and the profitability of local end-products (gari, tapioca, dried cassava, attièkè, flour, alcohol), the present work aims at contributing to the improvement of cassava value chain through the identification of the cassava elite cultivars of southern Benin better adapted for good quality of gari, tapioca, cassava chips, alcohol and high quality cassava flour production. Its specific objectives are two-folds:

- assess the physicochemical composition of the elite cassava cultivars of southern Benin;
- Predict technological aptitude of the elite cultivars for gari, tapioca, cassava chips, alcohol and high quality cassava flour (HQCF) production, through their physicochemical characteristics.

Materials and Methods

Plant Material and preparation of samples for analysis

Twenty eight (28) cassava elite cultivars (**Table 1**) originated from southern Benin and maintained as field collection at the experimental farm of the Faculty of Sciences and Technology of Dassa (FAST/Dassa) were considered for the physicochemical analysis. The elite cultivars are those produced by many households on large area (Agre et al., 2015). Among the 28 cultivars selected, 14 (**table 2)** were of bitter taste with a probably high hydrocyanic acid content (Agre et al., 2015). These cultivars were analyzed for their level of toxicity via their real Cyanide content. For this last analysis, the cultivar Ouémènou known as a sweet cassava was used as control. For each cultivars to be analyzed, fresh root flesh were collected, groundby Moulinex DPA1 41 and the obtained paste homogenized and stored in a refrigerator (10° C) for future analysis of dry matter and starches content as well as cyanide content.

Physicochemical analysis

Dry matter was determined following standard method of AOAC (AOAC, 2000) by drying 5 g of cassava mash in the oven at the temperature of 105∘C until stable products weight was obtained following Sanoussi et al. (2015)

Starch content was evaluated using spectrophotometry method which involves peeling, cutting, grating and cold drying at 10 °C of cassava sample. The sample were then finely ground and sieved in 0.5 nm diameter siever. 5 g of the sieved mash are introduced into a test tube to which was added 5 ml of potassium hydroxide KOH 1 M followed by 5 ml of chlorhydric acid (HCl) 1M. The mixture obtained was homogenized using vortex and the pH of the resulting mixture neutralized. The neutral mixture obtained was boiled at 100 °C for 5min, and the volume adjusted to 10 mL by addition of distilled water. An aliquot of this solution was centrifuged at 3000 rpm for 10min to obtain a filtrate. The supernatant volume (Vs) was then measured and 1 ml is removed and diluted to 10 ml with distilled water. The absorbance of subsequent dilution of each sample is read on spectrophotometer set at 580nm. The starch content was calculated as followed (Sanoussi et al., 2015):

$$C = Vs \times ((\Delta DO\ Sample - 0.016)) \times 2 / 1.808$$

with:
C: weight of starch per gram of sample in mg;
Vs: volume of supernatant
White ΔDO: 0.016
Dilution factor: 2
ΔDO sample: Optical density of the sample

Table 1: List of cassava elite cultivars of southern Benin

N°	Vernacular names	Type of cultivar	Sites of collect	District
1	Aboïdassa	Bitter	Omou	Kétou
2	Agbakomessi	Sweet	Oko-Akaré	Kpobè
3	Agbeyido	Sweet	Gbakpodji	Bopa
4	Agoula	Sweet	Atchonssa	Bonou
5	Agrik Blanc	Sweet	Gbéhoué	Grand-Popo
6	Atinwé	Sweet	Akpadanou	Bonou
7	Azanminwé	Bitter	Aïdjèdo	Kpomassè
8	Bassia	Sweet	Akpadanou	Adjohoun
9	Batchégô	Sweet	Goutin	Adjohoun
10	Bawé	Sweet	Akpadanou	Bonou
11	Dawé	Bitter	Goutin	Adjohoun
12	FaingnintiVêvê	Bitter	Gbékandji	Adjohoun
13	Gbakaya	Bitter	Danhoué	Houéyogbé
14	Gbazé	Sweet	Dédékpoué	Athiémé
15	Glégbodji	Bitter	Glégbodji	Abomey-Calavi
16	Hêwado	Bitter	Akpadanou	Adjohoun
17	Hombètè	Sweet	Agbodji	Bopa
18	Ibécher	Sweet	Omou	Kétou
19	Kintôgbadji	Bitter	Lokogba	Lalo
20	Koutéwé	Sweet	Hékanmè centre	Zê
21	Kpèkè	Bitter	Yôkpôdjevié	Zê
22	Kpokpoiriko	Sweet	Omou	Kétou
23	Obassandjo	Bitter	Ikpedjilé	Sakété
24	Okin Pétiole blanc	Sweet	Ikédjilé	Sakété
25	Otègbèyè	Bitter	Ikpedjilé	Sakété
26	Ouéminnou	Bitter	Agbodji	Bopa
27	Sammi	Bitter	Igbo Edè	Kétou
28	Sodaf	Bitter	Glébodji	Abomey-Calavi

Table 2: Chemical composition of the cassava cultivars analysed

N°	Cultivars	Dry matter (%)	Starch (mg/g)	Alcohol content (ml /g of starch)	Cyanide presence
1	Aboidassa	17 .50	3.78 ± 0.38	0.096	+++
2	Agbakomessi	43.46	0.66 ± 0.07	0.162	n.a
3	Agbeyido	35.72	0.80 ± 0.06	0.068	n.a
4	Agoula	38.00	2.65 ± 0.03	0.090	n.a
5	Agrik Blanc	38.00	3.61 ± 0.51	0.015	n.a
6	Atinwé	44.45	3.06 ± 0.03	0.105	n.a
7	Azanminwé	33.59	1.54 ±0.16	0.110	+++
8	Bassia	37.92	3.22 ± 0.55	0.120	n.a
9	Batchégô	40.20	6.68 ± 0.70	0.081	n.a
10	Bawé	30.77	0.89 ± 0.09	0.150	n.a
11	Dawé	33.80	6.35 ± 0.64	0.090	++
12	Faingnintin Vêvê	33.80	0.080 ± 0.06	0.110	++
13	Gbakaya	33.29	7.25 ± 0.72	0.135	+++
14	Gbazé	25.90	4.62 ± 0.51	0.104	n.a
15	Glegbodji	31.66	7.50 ± 0.80	0.085	+++
16	Hêwadô	41.71	6.74 ± 0.27	0.070	+
17	Hombêtê	43.51	0.24 ± 0.02	0.083	n.a
18	Ibecher	28.40	4.68 ± 0.47	0.100	n.a
19	Kintogbadji	35.76	3.02 ± 0.3	0.105	++
20	Koutéwé	48.65	6.38 ± 0.64	0.06	n.a
21	Kpêkê	38.54	2.36 ± 0.02	0.090	++
22	Kpokpoiriko	40.03	1.50 ± 0.11	0.06	n.a
23	Obassandjo	35.38	3.14 ± 0.55	0.108	-
24	Okin blanc	50.44	12.98 ± 1.92	0.150	n.a
25	Otêgbêyê	32.45	0.38 ± 0.03	0.108	++
26	Oueminnou	55.52	2.71 ± 0.28	0.084	++
27	Sammi	25.79	5.53 ± 0.56	0.094	+
28	Sodaf	42.15	2.90 ± 0.04	0.077	++
Minimum		17.50	0.08	0.015	n.a
Maximum		55.52	12.98	0.162	n.a
Mean		37.01	3.75	0.096	n.a
Standard deviation		7.97	2.90	0.03	n.a
Coefficient of variation		21.53	77.25	31.40	n.a

NB: (-) absent, (+) present, (++) good presence, (+++) very good presence, (n.a) non applicable

To determine the alcohol production capacity, a sample of 5 g of cassava flour was collected and 25mL of mixture of KCl (1g / L) and MgSO 4 (0.5g / L) diluted distilled water was added as well as 5mL of concentrate sulfuric acid (H2SO4). The resulting mixture was heated to boiling and then cooled down after been neutralized with NaOH to pH 3.7. Then 4. 5g of yeast (*Saccharomyces*) was added to the mixture obtained for each sample for fermentation at room temperature for 72 hours. The tubes containing the sample mixture are closed with cotton. After the fermentation, the mixture was centrifuged for 10 minutes and the alcohol content determined using alcoholmeter.

The cyanide presence in the cultivars was revealed using picric acid text method described as follow. This method involves the use of Wattman paper soaked in picric acid (as developer) then oven dried and later soaked in Calcium Carbonate (CaCO3) (as fixer) and again oven dried. Then 3g of cassava flour sample and 10mL of distilled water for each sample was taken and inserted into jars obtained for this purpose. The wattman paper previously prepared were attached to the lid of the jars and everything was sealed to observe evaporation of cyanhydric acid.

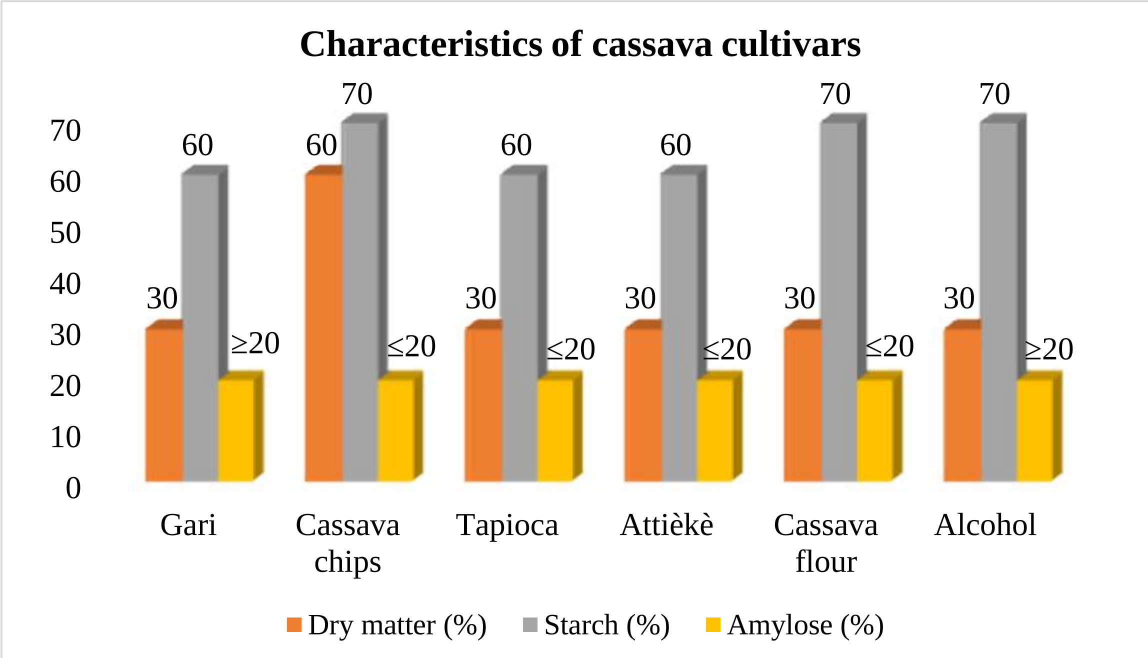

Figure 1: Chemical characteristics (% on dry weight basis) of cassava cultivars adapted for processing selected local foods

Statistical analysis

The data collected have been analyzed using descriptive statistics (minimum, percentages, means, maximum, standard deviation etc.) and the results presented in the form of tables and figures. To identify among the different elite cassava cultivars those that are better adapted for good quality gari, tapioca, cassava chips, and HQCF and alcohol production a multivariate analysis was performed. For this, the cassava cultivars were considered as individuals and the different physicochemical parameters assessed as variables and coded 1 when applicable and 0 when not. By using this methodology, a binary matrix of 28 individuals and 5 variables was constructed and used to generate a similarity matrix using SPAD 5.5 software. This matrix of similarity was now used to construct a dendrogramme and to carry out a Principal Component Analysis (PCA) with the same software following Chavent et al., (2007).

Results and Discussion

Physicochemical characterization

The dry matter, starch content and the alcohol production capacity of the elite cassava cultivars are determined and reported in Table 3.

The dry matter content varies from 17.50 % to 55.52%. Cultivar Aboidassa recorded the lowest dry matter content (17.50 %) while cultivar Ouémènnou have the highest content (55.52%) (Table 3). The average dry matter content of the cultivars is significantly higher (37.74%) when compared to the standards according to which with 30% of dry matter, a cassava cultivar could be considered as of good profitability margin for processing into various products Sanoussi et al, 2015). 14 cultivars (50%) analyzed present a dry matter content below the average value hence indicating that only half of the elite cultivars analyzed have high dry mater content and could by promoted in different local food processing industries with high profitability. Four cassava cultivars (Aboidassa, Gbazé, Ibécher and Sammi) have a dry matter content inferior to 30% and ten cultivars have a dry matter content superior to 40%. It is known that with cassava high dry mater content is synonym of good quality and more profitable end-products (Mégnanou et al. 2009; Sanoussi et al. 2015). Therefore the analyzed cassava cultivars with dry matter content between 40.2% and 55.52% could be considered as super elite cultivars. These results are similar to those reported by Hongbété et al. (2011) on cultivars TMS 91/02319 (41.1%) and TMS 92B/0057 (40.8%).

With a value estimated to 12.98 ± 1.92 mg/g (**Table 3)** cultivar Okin blanc appeared as the richest in terms of starch content while Cultivar Faingnintin vêvê has the lowest content with 0.08 ± 0.06mg/g. The data revealed that the more the starch content of a cultivar is low, the more abundant is its dry content. In addition, significant differences in terms of starch content is noted among cultivars analyzed. The starch content in the cultivars studied is lower than the one reported by Sanoussi et al. (2015) for three elite cassava cultivars in Central Benin. This result can be explained by the difference in the genotypes analyzed, the harvest period and the method used for the assessment (Fiagan, 2007). Essuma et al. (2012) recommended that 6- 8 month are most appropriate to harvest roots intended for the evaluation of starch content as the more the root are kept in ground, the more the starch reservations are used by the plants to give place to fibers.

Table 3. Classification of the cassava cultivars according to their aptitude to be processed into selected local foods

Local food products	Favorable elite cassava cultivars
Gari	Agbakomessi, Agoula, Agick blanc, Atinwé, Bassia, Batchégô, Dawé, Ggakaya, Glégbodji, Hêwadô, Kintogbadji,Koutéwé, Obassandjo,Okin pétiole blanc, Oueminnou,
Tapioca	Azanminwé, Dawé, Gbakaya,Glégbodji, Hêwadô, Kintogbadji, Kpêkê, Obassandjo, Otêgbêyê, Oueminnou, Sodaf
Cassava chips	Atinwé, Batchégô, Koutéwé, Okin pétiole blanc, Kpokpoiriko, Faingnintin vêvê
Attiékè	Agbakomessi, Agoula, Agick blanc, Atinwé, Bassia, Batchégô, Dawé, Ggakaya, Glégbodji, Hêwadô, Kintogbadji,Koutéwé, Obassandjo,Okin pétiole blanc, Oueminnou,
Cassava flour (HQCF)	Atinwé, Batchégô, Koutéwé, Okin pétiole blanc
Alcohol	Agbakomessi, Agoula, Agrik blanc, Atinwé, Bassia, Batchégô, Koutéwé, Okin pétiole blanc, Bawé

The assessment of alcohol production capacity of the cassava cultivars analyzed showed that Agbakomessi was the most promising with 0.162ml of ethanol per g of starch while cultivar Agrik Blanc was the less productive with 0.015 ml of ethanol per g of starch (**Table 3**). Our results indicated that the more the cassava cultivars exhibit high starch content, the more its potential for alcohol production. Moreover, sweet cultivars were most profitable than the bitter ones for alcohol production. According to FAO (2013) one ton of cassava cultivar with 30% of starch content (on wet weight basis) can produce about 280 liters of pure ethanol.

Qualitative assessment of cyanide content

Out of the 28 cassava cultivars selected for the analysis in this study, 13 were identified as belonging to bitter cassava class and analyzed qualitatively for their cyanide content in comparison to cultivar Ouémainnou which is considered locally as sweet cassava that can even be consumed fresh. The qualitative cyanide assessment indicated that half (50%) of the bitter cassava cultivars analyzed exhibited an average cyanide content (++) while 28.57% revealed high presence of cyanide (+++) and 14.28% showed low presence of cyanide (+) (Table 4). Only the cultivar Obasandjo (7.14 %) has no trace of cyanide.

Cyanide content does not affect much the choice of cultivars but the knowledge of its presence helps to avoid the risks of food poisoning by using some processing technologies to limit harmfulness. The lethal dose for adult is about 60 mg HCN of daily consumption (Djoulde et al., 2007). The cyanogenic compounds level in the different parts of the plant depends on the genotypes but also on the environmental conditions. For instance,, the poisoning capacity of cassava cultivars considerably increases in non-irrigated and very poor fields with lack of potassium (Wilson 2003; Mkumbira et al., 2003). According to Diallo et al. (2013). The acceptable cyanhydric acid content fixed by FAO should not be more than 10 mg $HCN \cdot kg^{-1}$ of food product (Diallo et al., 2013). According to Sanoussi et al. (2015) and Hongbété et al (2011), low cyanide content cassava cultivars were scored as the most bitter. Hence the cassava cultivars analyzed in this study based on their perceived bitterness may contain after quantitative analysis less than 50mg HCN per kg of freshly grated cassava and then can be considered innocuous (Maziya-Dixon et al. 2007) for raw consumption of the roots. The quantitative analysis of cyanogenic content of both bitter and sweet cassava cultivars is highly recommended to clarify the toxicogenic status of each of the sample collected from southern Benin.

Aptitude of the cultivars analyzed for different cassava based foods

Following observations of preference criteria that have been used in choice of cassava cultivars for different types of processing and following the chemical characteristics associated to those preferred cultivars for production of different local foods for better profitability, the figure 1 have been proposed to specify desirable characteristics of cassava cultivars to be taken into account for production of gari, Tapioca, Chips, lafun, attièkè, HQCF and alcohol. Based on those characteristics and on the results of the physicochemical analysis, the cultivars suitable for Gari, Tapioca, chips (dry root), Attiékè, cassava flour (HQCF) and Alcohol were identified (table 3) in order to help processors to optimize their profitability.

The dendrogramme constructed using the cassava cultivars as individuals and the physicochemical parameters as variable allowed to group the 28 cassava cultivars into 5 groups (Figure 2).

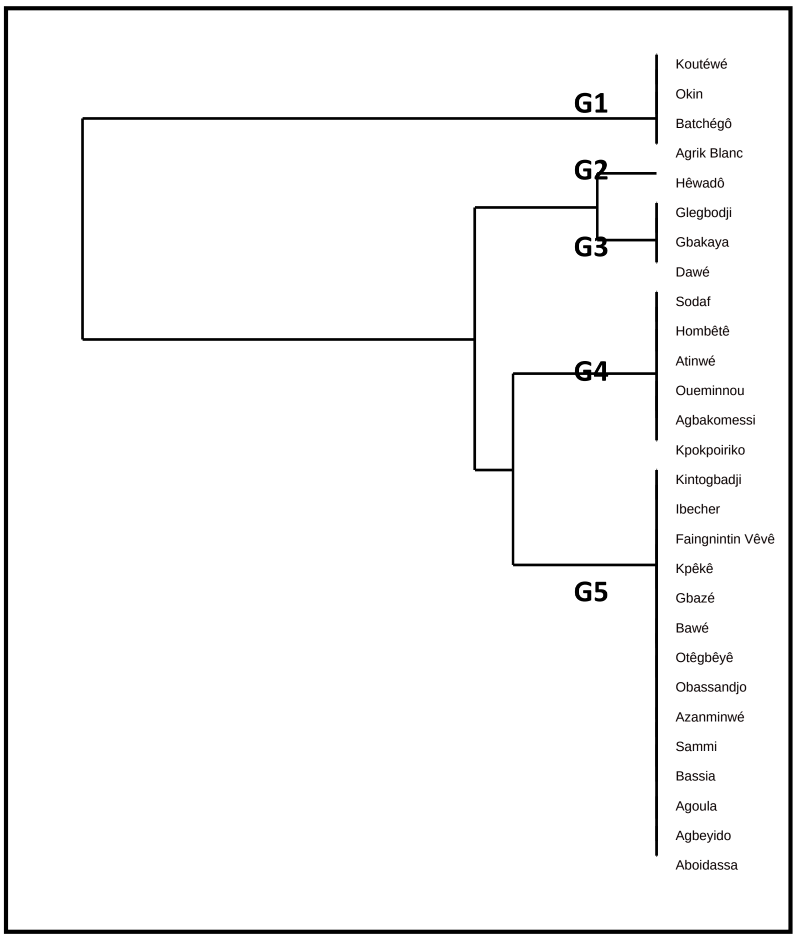

Figure 2: Dendrogram showing the grouping of the cultivars following chemical analysis

- Group 1 consisted of 4 sweet cassava cultivars (Agrik Blanc, Batchégô, Koutémé, Okin blanc) characterized by very high dry matter content and high starch content. These cultivars can be used at the same time for cassava chips, attièkè, HQCF as well as alcohol production.
- Group 2 is represented by only one cultivar (Hêwadô) that also has high dry matter content and high starch content. This cultivar is used for the production of tapioca and also for attièkè and HQCF. It is separated from group 1 because of its bitterness.

- Group 4 is consisted of six bitter and sweet cultivars that have high dry matter content and low starch content. This group made of cultivars Agbakomessi, Atinkwé, Hombêté, Kpokpoiroko, Ouémènnou, and Sodaf is good for production of good quality gari with high profitability.
- Group 5 assembled all the others cultivars that do not exhibited important technological values.

As the 28 cultivars analyzed already belong to Benin elite cassava cultivars based mainly on agronomic performances, individuals classified within G1, G2, G3 and G4 can be considered as super elite cultivars good for quality gari, cassava chips, attièkè, HQCF and alcohol production with better profit margin. The super elite cultivars (agbakomessi, Agrik blanc, Atinwé, Batchégô, Dawé, Gbakaya, Gblégbodji, Hêwadô, Hombètè, Koutéwé, Kpokpoiroko, Okin, Ouéminnou, Sodaf) represent 50% of the total cultivars studied. A similar approach of classification of cassava cultivars was reported by Diallo et al., (2013) in Senegal. The massive production of those super elite cultivars in different cassava production zones to supply processors will help to upgrade cassava value chain in Benin. However, the other cultivars that exhibit a low dry matter and starch content may also have their relative importance which are not clarified here and can be used in future cassava breeding programmes. The results of the dendrogramme was confirmed by a principal component analysis (Figure 3) which also showed the 5 groups initially obtained.

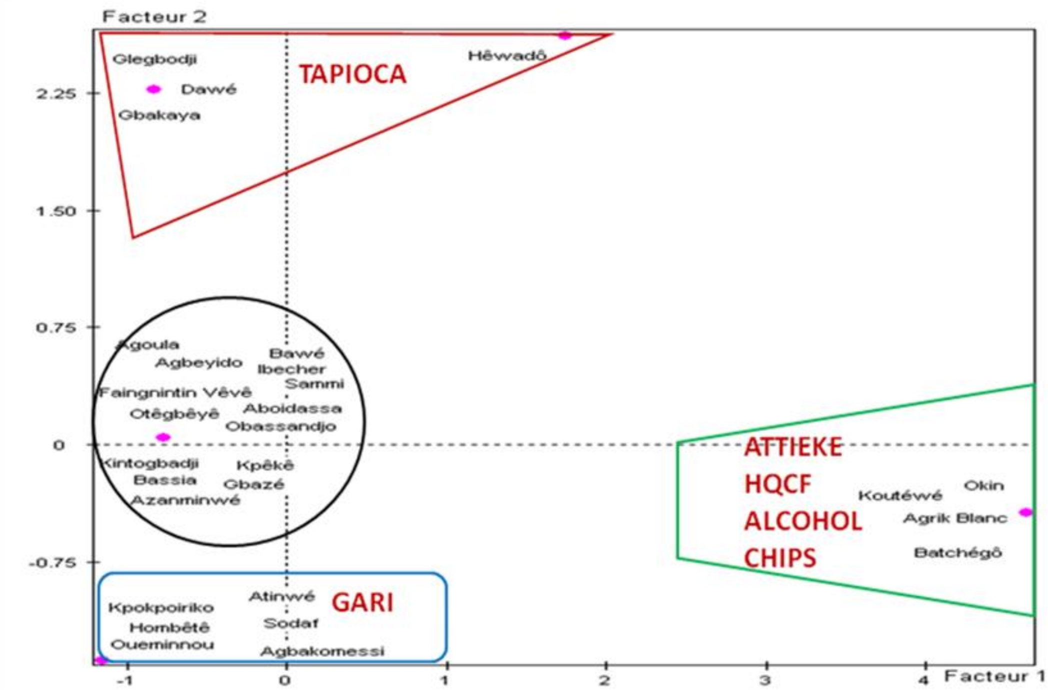

Figure 3: Grouping of the cultivars analysed on the factorial axis 1 and 2 of the PCA

Conclusion

The elite cassava cultivars of southern Benin showed high variability for the physicochemical parameters considered and this allowed the identification of 14 super elite cultivars for the production of good gari, tapioca, alcohol, attièkè, and HQCF with profit margins for the processors. As cassava is well known as food security crops, it will be interesting to assess minerals salts and the vitamins (mainly A) content of the local cultivars for their promotion through different food chain in Benin.

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