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INFLUENCE OF WATER COOKING ON THE MACRONUTRIENTS LOSS RATE OF YAM TUBER PARTS DURING POST-HARVEST STORAGE

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ABSTRACT: The purpose of this study was to assess the influence of water cooking on the macronutrient contents change of different parts (distal, median and proximal) flours of yam tubers during post-harvest storage. Thus, four yam varieties, *D. cayenensis-rotundata*, cv "Kangba" and "Krenglè" and *D. alata*, cv "Florido" and "Bètè-bètè" were harvested at physiological maturity and stored. Every two months, six (6) tubers of each yam cultivar were selected. Each of them has been cut into three equal parts (proximal, median and distal parts). Macronutrient losses were assessed by determining total sugars, reducing sugars, crude protein and lipid contents of flours from different parts of fresh yam tubers and those cooked with water. The results revealed that the total sugars loss rates in the different parts increased with the storage time. As for reducing sugars, significant differences ($p \leq 0.05$) were observed between the losses of different tubers parts before two months of storage. However, after the second month of storage, there are no significant differences ($p > 0.05$). Concerning crude proteins, the loss rate of proximal and distal parts of *D. cayenensis-rotundata*, cv "Krenglè" and *D. alata*, cv "Florido" were constant during the first and second months of storage. Regarding lipids, the loss rates of different parts of freshly harvested yams differed significantly ($p \leq 0.05$) except those of proximal and distal portions of the tuber of yam *D. alata*, cv "bètè-bètè". The study shows that cooking changes the macronutrient content of the different parts of yam tubers.

KEYWORDS: Yam, Loss rate, Tuber part, Post-harvest storage.

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1. INTRODUCTION

The edible roots and tubers, namely cassava, taro, sweet potato and yam, occupy a prominent place in the agriculture of tropical Africa. Among them, the yam tubers are the food of choice for millions of people living in sub-Saharan area, where they constitute 12% of their basic diet [1, 2, 3, 4]. The yam tubers have an important role in improving food security and living conditions for rural people because they provide calories and protein. Yam (*Dioscorea spp*) is among the oldest recorded food crops and ranked second after cassava in the study of carbohydrates in West Africa [5]. West Africa remains the most important yamproducing region of the world [6]. Besides, yams also have a considerable economic interest [7, 8, 9]. They are tuberous herbaceous plants belonging to the genus Dioscorea. This genus includes over 600 species [10]. In West and Central Africa, five species are encountered. These are *Dioscorea cayenensis-rotundata, Dioscorea dumetorum*, *Dioscorea alata, Dioscorea esculenta* and *Dioscorea bulbifera*. In Ivory Coast, those are the cultivars of *Dioscoreacayenensis-rotundata* complex and *D. alata* dominating yam cultivation [11]. They are the most economically important of all cultivated species since they give the highest yields [12]. The tubers of various species of *Dioscorea spp* constitute one of the stable carbohydrate foods for the people in many tropical countries [13]. After harvest, yam tubers enter into dormancy. Once the dormancy is broken, sprouting occurs and prolonged storage is no longer possible. Indeed, fresh yams are difficult to store and are subject to deterioration during storage [14]. Moreover, yam like other root and tuber crops such as cassava and taro, suffers from post-harvest losses estimated at 30% caused partly by external agents, such as insects, rodents and moulds [15]. The mode of most widespread storage in Côte d'Ivoire is the preservation in hurdles. The others traditional storage modes of are made in heap, in mounds and in straw hut. The storage time of yam tuber under fresh shape is five (5) months and even on a longer time according to [16]. Yams tubers consist of three portions (the distal portion, the medial portion and the proximal portion) [17]. They are always consumed after series of changes with a cooking step [18]. Otherwise, many consumers show less attachment to the distal portion of the yam tuber in favor of the proximal and medial parts. Besides, the distal portion of the tuber deteriorates faster than the proximal and median parts. This distal part is soft after cooking while the proximal and median parts are firm [17]. Many studies have indicated various levels of macronutrients in the proximal, median and distal. However, in this work, the impact of water cooking on the variation of macronutrients in these parts of tuber during post-harvest storage is not evaluated. On the one hand, it is therefore necessary to follow the evolution of the macronutrients of these different parts of yam tubers during post-harvest storage and also to evaluate the macronutrient loss rates for each part of yam tuber after cooking with water.

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2. MATERIALS AND METHODS

2.1. Materials

Plant material

Tubers of four yam cultivars were used in this study. Those are "Kangba" and "Krenglè" cultivars belonging *D. cayenensis-rotundata* and "Florido" and "Bètè-bètè" cultivars belonging *D. alata* (Photograph 1). These yam tubers were harvested at physiological maturity (after drying of leaves and stems) in village fields (Douibo, Bomizambo and Koubi) in the department of Tiébissou(located in the center of Côte d'Ivoire, 284 kilometers from Abidjan, Latitude: 7.16306; Longitude: -5.22056). The tubers were without injury and 44.07 ± 4.46 cm long. After the harvest, they were transported to Abidjan in jute bags and placed individually on the shelves of a conservation store.

Photograph 1: Tubers of *D.cayenensis-rotundata*(cv "Kangba" (a), "Krenglè"(b)) and *D. alata* (cv "Florido" (c), "Bètè-bètè" (d))

2.2. Methods

Conservation technique

The yam tubers were individually placed on shelves in the preservation store. The store was 10 meters long, 3.70 meters wide and 2.70 meters high. It was covered with metal sheets and ventilated by the wall shutters. There isn't ceiling. The shelves were made of wood. The temperature and relative humidity of store during the storage time were 26.56 ± 3 °C and 82 ± 5 % respectively.

Sampling

Six (6) tubers of each yam cultivar were selected every two months from the date of harvest. Each of them has been cut into three equal parts (Photograph 2) each representing the proximal part (tuber head), the middle part (middle of the tuber) and the distal part (tail of the tuber). Losses macronutrient were evaluated by determining total sugar content, reducing sugars, protein and fat flour of different parts of fresh yam tubers and those cooked in water.

Photograph 2: Different parts of yam tubers ((a) proximal part; (b): median part; (c): Distal Part)

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Preparation of yam tuber flour

Preparation of fresh yam tubers flour

The obtaining of the flour was made according to the method of [19]. For a given cultivar,one (1) kg of each yam tuber portion was washed with tap water and peeled with a stainless knife. The obtained pulps were washed twice with distilled water and cut into small pieces. These small slices were spread on aluminum foil at room temperature (28 ± 2 °C) and then dried in an oven ventilated at 45°C for 2 days. After drying, the slices were crushed using a grinder and then sieved with a mesh of mesh 90 microns to obtain the flour.

Preparation of yam tubers flour boiled in water

The obtaining of flour was made according to the method of [20, 21]. For a given cultivar, one (1) kg of each yam tub portion was washed with tap water and peeled with a stainless knife. The obtained pulps were washed twice with distilled water and cut into small cylindrical pieces of about 50 g. The resulting pulps were washed twice with distilled water and cut into small cylindrical pieces of about 50 g. The cooking lasted for 15 minutes. After cooking, the pieces of yam tubers were placed on aluminum foil at room temperature (28 ± 2 °C). Then, they were cut into small slices and allowed to cool for 25 minutes at room temperature and then allowed to dry in a ventilated oven at 45°C for 2 days. After drying, they were ground using a grinder. The ground material obtained was sieved through a sieve of mesh 90 microns. The flour was stored in a glass bottle previously oven-dried at 45 °C for one day.

Dry matter content

The solids content of each batch of yam tubers was determined according to [22].

Extraction and determination of ethanosoluble sugars

Extraction of ethanosoluble sugars

The sugars of flour of each batch of yam tubers were extracted according to the technique described by [23]. One (1) gram of flour from each batch of yam tubers was weighed in a centrifuge tube. Ten (10) ml of ethanol (80 %, v/v) was added thereto. The mixture was homogenized and centrifuged at 6000 rpm for 10 min. The collected supernatant was stored in a 50 ml Erlenmeyer flask. The pellet was taken up in 10 ml of ethanol (80 %, v/v). The obtained mixture was homogenized and centrifuged under the same conditions as before. The new supernatant was added to the first content in the 50 ml Erlenmeyer flask. The ethanol contained in this mixture was evaporated in a sand bath for 10 minutes. The collected supernatant was used for assays of the ethanosoluble sugars.

Determination of ethanosoluble sugars

Determination of total sugars content

The total sugars content was determined according to the method described by [24] using phenol and concentrated sulfuric acid.

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Determination of reducing sugars content

The reducing sugars content was carried out according to the method [25] using 3,5-dinitrosalicylic acid (DNS).

Determination of crude Protein content

The dosage of proteins of the flour of each part of yam tubers was performed using the Kjeldahl method [22]. The protein content was obtained by multiplying the nitrogen content by 6.25.

Determination of lipid content

The lipid content of each batch of yam tubers was extracted using the method [22] using SOXHLET.

Determination of nutrient loss rates

The rate of nutrient loss was calculated as follows:

$$T_{PN} = \frac{T_{FNC} - T_{FC}}{T_{FNC}} \text{ x } 100 \qquad (1)$$

T_{PN} : Nutrient Loss Rates

T_{FNC} : Nutrient content of flour from not boiled yam tuber part with water

T_{FC} : Nutrient content of flour from boiled yam tubers in water.

Statistical analyzes

All measurements were done in triplicate. The statistical analyzes of the data were carried out using the software STATISTICA 7 (Stat soft Inc., Tulsa-USA Headquarters) and XLSTAT-Pro 7.5.2 (AddinsoftSarl, Paris-France). Comparisons between the dependent variables were determined using the three-way analysis of variance (ANOVA) and the Duncan test. Statistical significance was defined at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1. RESULTS

Total Sugars

The loss rate of total sugars of flour from different tuber parts of *Dioscorea alata*, cv "Florido" and "Bètè-Bètè" and *Dioscorea cayenensis-rotundata*, cv "Kangba" and "Krenglè" (cooking with water) based on the post-harvest storage time are shown in Figure 1. In freshly harvested tubers, the rates of loss in the different tuber parts of *Dioscorea cayenensis-rotundata*, cv "Krenglè" were higher than those of same parts of other yam tubers. The lowest rates were obtained with the different parts of the tuber of *Dioscorea cayenensis-rotundata*, cv "Kangba". These rates ranged from 6.21% to 11.92%. The distal portions of freshly harvested yam tubers and subjected to cooking lose much more total sugars than other yam tuber parts subjected to the same heat treatment. The loss rate of total sugars of various tuber parts of *Dioscorea alata* cv "Florido" and "Bètè-Bètè" and *Dioscorea cayenensis-rotundata*, cv "Kangba" and "Krenglè" increased with storage time. As for the cultivar "Krenglè", the evolution of total sugars loss rate was low in the fourth and sixth months of storage.

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The statistical analyze, according to Duncan's test, revealed no meaningful differences (p>0.05) between the total sugar loss rates of different tuber parts of *Dioscorea alata,* cv "Bètè-bètè" stored after harvest. It is the same for the different tuber parts of *Dioscorea cayenensis-rotundata*, cv "Kangba", except the loss rate of total sugars of median tuber part that differed significantly (p≤0.5) from the fourth month of storage. Concerning the tuber of *Dioscorea alata,* cv "Florido", the rate of loss of total sugars varied significantly (p≤0.05) of one tuber part to another and during storage except the median and distal tuber parts that didn't follow this characteristic from the fourth to the sixth month of storage.

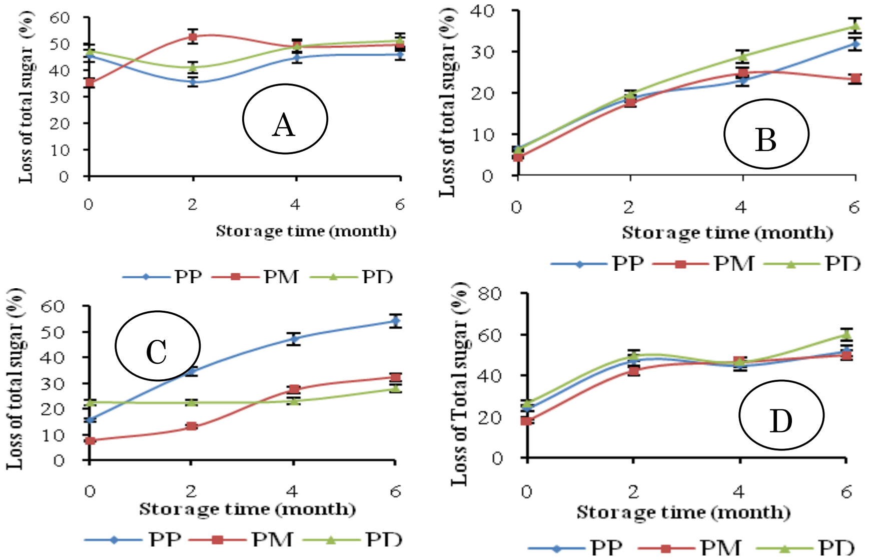

Figure 1: Total sugars loss rate of different tuber parts of *Dioscorea alata*, cv "Florido" (C) and "Bètè-bètè" (D) and *Dioscorea cayenensis-rotundata*, cv "Kangba" (B) and "Krenglè" (A) after cooking with water; **PP**: Proximal Portion; **PM**: Median le Part; **PD**: Distal Part

Reducing Sugars

The loss rates of reducing sugars of various tuber parts (proximal, median and distal) flours from *Dioscorea cayenensis-rotundata*, cv "Krenglè", which are cooking with water, according to post-harvest storage are shown by Figure 2. Statistical studies according to the Duncan test indicated significant differences (p≤0.05) between the loss rates of the different parts of freshly harvested tubers. However, they revealed no significant differences (p>0.05) between the loss rate of these parts after the second month of storage. This no significant variation during storage thus showed that the shelf life hadn't major influence on the loss of the reducing sugar content when the tuber of the cultivar "Krenglè" is subjected to cooking with water. The loss rate of reducing sugars varied from 22.40 to 31.25%. As for the tuber of cultivar "Kangba", the loss rates of reducing sugars decreased in the median and proximal parts of preserved tuber for two months and four months. At the sixth month of storage, the losses of reducing sugars in these same parts increased to reach the loss rates obtained from the freshly harvested tubers. The distal part knows another evolution. Indeed, the loss rates of reducing sugars in this part of the tuber were constant during the first two

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months of storage and increased from the second month to 19.01% in the sixth month. Also, the different tuber parts *Dioscorea alata*, cv "Florido" showed the same paces. It is the same for the different tuber parts of *Dioscorea alata*, cv "Bètè-bètè". The loss rate of reducing sugars of the different tuber parts of *Dioscorea alata,* "Florido" tuber fall considerably, reaching a maximum of 15% at two (2) months of storage. Beyond this storage time, they slowly increased to reach a maximum of 20%. As for the tuber of *Dioscorea alata*, cv "Bètè-bètè", the loss rate of the reducing sugars of the different yam tuber parts increased with the storage time to reach a maximum of 30% in the sixth month. At this storage time, the distal portion of yam tubers showed the highest loss rate of reducing sugars.

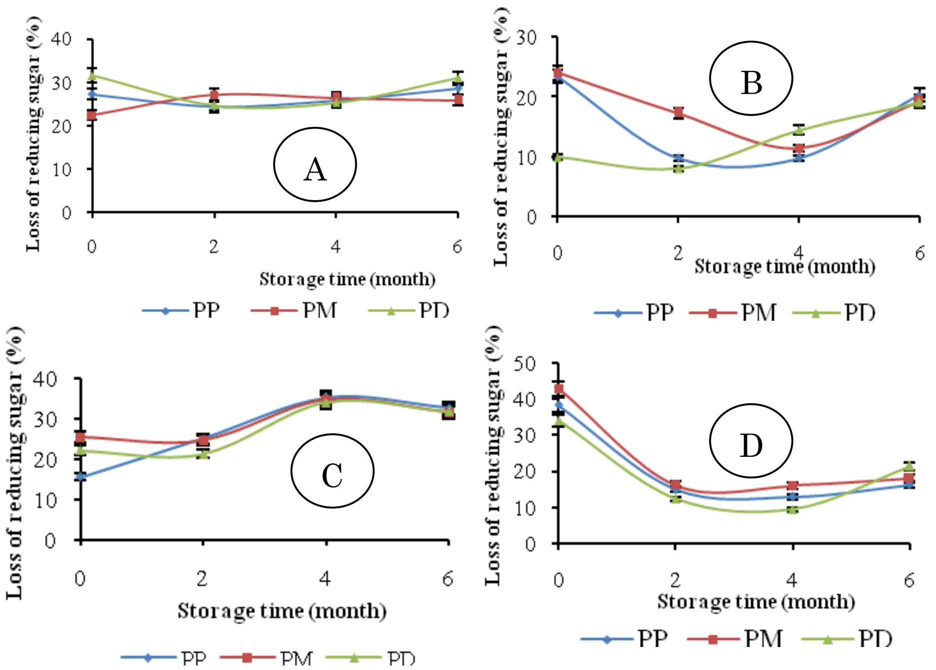

Figure 2: crude protein loss rate of different tuber parts of *Dioscorea alata*, cv "Florido" (C) and "Bètè-bètè" (D) and *Dioscorea cayenensis-rotundata*, cv "Kangba" (B) and "Krenglè" (A) after cooking with water; **PP**: Proximal Portion; **PM**: Median le Part; **PD**: Distal Part

Crude Protein

The protein loss rates of flours from different yam tubers parts are shown in Figure 3. The proximal and median tubers parts of *Dioscorea alata*, cv "Florido" and "Bètè-bètè" and *Dioscorea cayenensis-rotundata*, cv "Kangba" and "Krenglè" showed the same loss rates evolution. The protein loss rates of proximal and distal tubers parts of *Dioscorea cayenensis-rotundata* cv "Krenglè" and *D. alata* cv "Florido" were relatively constant during the first two months of storage. They increased from the second to the sixth month with the value of reach 13.75%. As for the same tuber parts of *Dioscorea cayenensis-rotundata*, cv "Krenglè", the protein loss rates increased until the fourth month to 12 % and then stabilize between the fourth and sixth month of storage. The crude protein loss rate of distal tuber part presented a different evolution comparing to other tuber parts. Concerning the tubers of *Dioscorea alata*, cv "Florido" and *Disocorea cayenensis-rotundata*, cv "Krenglè", they increased

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gradually until the fourth month to remain constant between the fourth month and the sixth month. Statistical analyzes revealed no significant differences (p>0.05) between the crude protein loss rate of flours from different parts of freshly harvested tuber, except the distal, proximal and median tuber portions of *Dioscorea cayenensis-rotundata*, cv "Krenglè". After the first month of storage, the statistical tests indicated meaningful differences (p≤0.05) between protein loss rate from one tuber part to another whatever the cultivar is, except between those of the proximal and median tuber parts of *Dioscorea alata*, cv "Bètè-bètè.

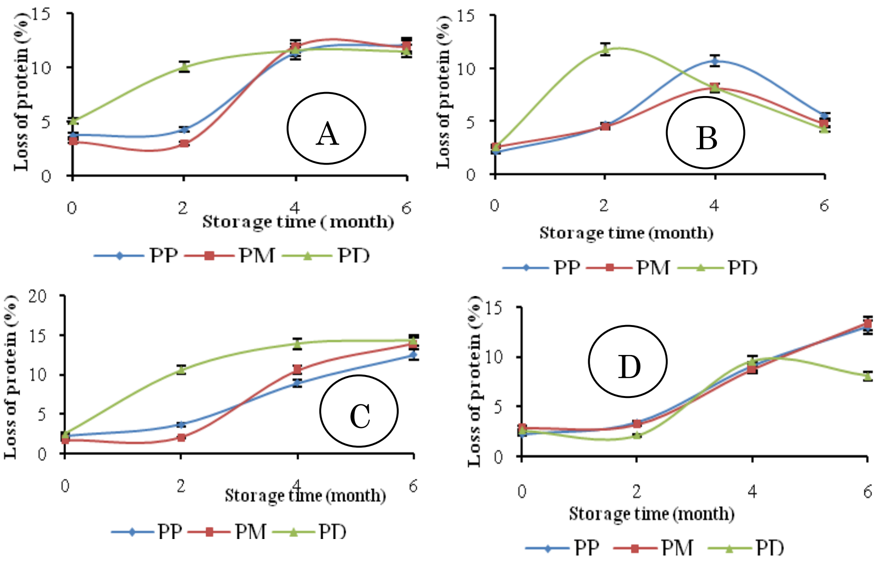

Figure 3: crude protein loss rate of different tuber parts of *Dioscorea alata*, cv "Florido" (C) and "Bètè-bètè" (D) and *Dioscorea cayenensis-rotundata*, cv "Kangba" (B) and "Krenglè" (A) after cooking with water; **PP**: Proximal Portion; **PM**: Median le Part; **PD**: Distal Part

Lipids

The lipids loss rate of different tuber parts of yams after cooking with water are different from one tuber part to another, whatever the cultivar is (Figure 4). The lipid loss rate of different tuber parts flours from *Dioscorea alata*, cv "Florido" and "Bètè-bètè" and the "*Dioscorea cayenensis-rotundata*", "Kangba" and "Krenglè" freshly harvested differed significantly (p≤0.05) except those of proximal and distal tuber parts of *Dioscorea alata*, cv "Bètè-bètè". Besides, the lipid loss rate of the proximal, median and distal portions fall considerably from the first to the second month of post-harvest storage to reach a value of 2.5%. They remained relatively constant between the second and sixth months of post-harvest storage. Otherwise, the lipid loss rates of proximal and median tuber parts of each cultivar generally changed in the same order during the first and the second month of post-harvest storage except those of proximal and median tuber portions of *Dioscorea cayenensis-rotundata*. , cv "Kangba" (Figure 4).

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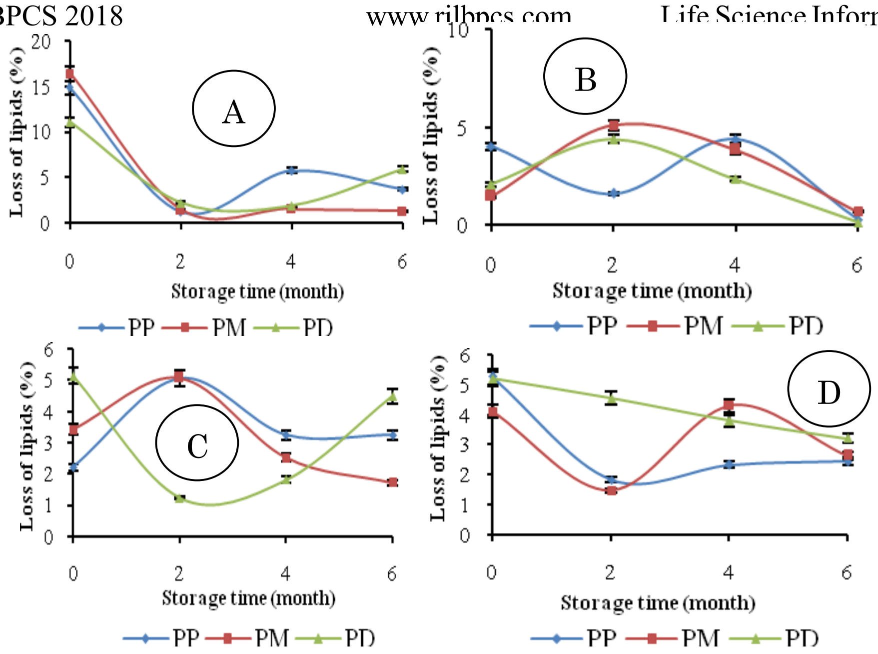

Figure 4: Lipid loss rate of different tubers part of *Dioscorea alata*, cv "Florido" (C) and "Bètè-bètè" (D) and *Dioscorea cayenensis-rotundata*, cv "Kangba" (B) and "Krenglè" (A) after cooking with water; **PP**: Proximal Portion; **PM**: Median le Part; **PD**: Distal Part

3.2. DISCUSSION

The loss rates of total and reducing sugars related to the water cooking of different tubers parts of *Dioscorea alata*, cv "Florido" and "Bètè-bètè" and *Dioscorea cayenensis-rotundata*, cv "Kangba" increased with the storage time. This observation suggested that storage time and hydrothermal treatment could affect the carbohydrates of these yam tubers including starch. Indeed, during post-harvest storage, amylolytic and phosphatic enzymes degrade starch to release significant amounts of total and reducing sugars in tuber tissues [26, 27]. The hydrothermal treatment of these tubers acts on the starch. Furthermore, the starch grain in the presence of an excess of water and subjected to a temperature above 60°C, swells and then gelatinizes and finally its content is solubilized. Thus, the hydrothermal attack causes a disruption of the crystalline structure of the starch grain with release of amylose, amylopectin and soluble sugars [28, 29]. The post-harvest storage and hydrothermal treatment degrade starch and promotes the solubilization of total and reducing sugars. These sugars are dispersed in the cooking water thus causing significant losses of total sugars and reducing sugars. The results of this study were in agreement with those of [30] who reported losses of sugar after water cooking tubers. The distal parts of freshly harvested yam tubers lose much more total sugars than the other parts. This could be due to the fact that the distal part of the tuber is younger therefore less firm than other fabrics. This situation would easily facilitate the penetration of water into this tissue in order to degrade the starch and release the sugars. Otherwise, the no significant change in total and reducing sugars of *D. cayenensis-rotundata*, cv "Krenglè" during post-harvest storage showed that the shelf life hadn't major influence on the loss rate of these substances when the tuber is boiled. The high losses of these nutrients could be related to the fact

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that the cooking was carried out after peeling the tubers. Indeed, losses are limited by keeping the skin to minimize dissolution and protect nutrients during cooking [31]. The loss rate of protein after water cooking of different tuber parts of *Dioscorea alata*, cv "Florido" and "Bètè-bètè" and *Dioscorea cayenensis-rotundata*, cv "Kangba" and "Krenglè" increased in depending on the storage time. This result could be due to the heat destruction of the proteins of the different tuber parts of stored and cooked yams with water. Indeed, cooking with water leads to a loss of nitrogenous matter [32]. Our findings were agreement with those of [19] who reported that crude protein contents of cooked yam tubers were lower than those of raw tubers. The lipid loss rates of proximal, median and distal yam tuber parts were relatively constant between the second and the sixth month post-harvest storage. The variation in lipid contents of yam tubers after cooking is similar to that observed in the work of [18].

4. CONCLUSION

This study revealed that the nutrient loss rates of proximal, median and distal portions of boiled yam tubers at different storage time differed from one tuber part to another, whatever the cultivar is. Indeed, the cooking changed the nutritional values of different tubers parts of studied yams. It appeared a considerable decrease in rates of total and reducing sugars. Moreover, water cooking caused a slight decrease in lipid and protein nutrients. The distal tuber part of yam loses a lot more nutrients than the other parts.

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CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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