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# Impact of Water Cooking on Losses of Polyphenols and Minerals from Parts of Different Yams During Post-Harvest Storage

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**ABSTRACT**

The objective of this study is to evaluate the influence of cooking with water on the variation of the mineral and total polyphenol contents of the flours of the different parts (distal, median, and proximal) of the yam tuber during the post-harvest conservation. Thus, four varieties of yams, *Dioscorea cayenensis-rotundata*, cv "Kangba" and "Krenglè" and *Dioscorea alata*, cv "Florido" and "Bètè-bètè" were harvested at physiological maturity and stored. Every two months, six tubers of each yam cultivar were selected. Each of them has been cut into three equal parts (proximal part, middle part, and distal part). The losses of minerals and polyphenols were evaluated by determining the contents of these elements in the flours of the parts of the various fresh yam tubers and those boiled in water. The results revealed that the flours from different parts of the yam tuber of *Dioscorea alata*, cv "Florido" have the highest polyphenol loss rates. They are between 70 and 80%. As for the ash, the different parts of the tuber of the freshly harvested yam *Dioscorea alata*, cv "Bètè-bètè" have the highest ash loss rates (respectively 32.40%, 28.56%, and 27.69% for the proximal, middle and distal parts). In terms of mineral elements, the rate of loss varies from one mineral to another mineral and from one cultivar to another cultivar. The study shows that cooking alters the micronutrient content of different parts of yam tubers.

## INTRODUCTION

Yam (*Dioscorea spp*.) has a very important role in food security and livelihood systems for at least 60 million people in West Africa. It is mainly cultivated in the secondary savannah and the savannah of southern Guinea. About 57 million tons of yams, or about 93% of world production, are produced annually on 4.7 million hectares in this sub-region, mainly in five countries. These are Benin, Côte d'Ivoire, Ghana, Nigeria and Togo (Dumont and Vernier, 2000; Mignouna and Dansi, 2003; Tostain et al., 2003; Scarcelli *et al.*, 2006). Yam tubers help to improve the living conditions of rural populations (Malaurie *et al.*, 1998; FAO, 2011; Demasse-Mawamba et al., 2007). Yams (Dioscorea spp) are tuberous herbaceous plants belonging to the genus Dioscorea and which includes more than 600 species (Sahoré and Amani, 2005). Unlike cassava, yams cannot be stored for long in the ground beyond their maturity stage. During storage, the tuber is subjected to several deterioration factors (Medoua et al., 2005 a). Yams undergo a high degree of postharvest loss due to their high moisture content (Falade et al., 2007). The transformation of yams into flour is therefore a way of limiting post-harvest losses. This product helps extend product supply through the off-season, reducing storage losses as well as marketing and transportation costs. This yam tuber flour is commonly used in various culinary preparations. Rehydrated, it helps to reconstitute the elastic dough distinct from foufou and foutou (Dumont, 1995). Yam tubers consist of three parts which are the distal part, the middle part, and the proximal part. These tubers are always eaten after having undergone a series of transformations including a cooking step (Medoua et al., 2005b; Digbeu et al., 2009; Dje et al, 2018). However, cooking is a source of physicochemical and nutritional variability of foods. Cooking changes the nutritional values of different parts of yam tubers. According to the study of Dje et al, (2018), cooking with water leads to a considerable decrease in the levels of total and reducing sugars. It also causes a small decrease in lipid and protein nutrients. Many studies have indicated nutrient losses after cooking yam tubers. However, in these works, the impact of water cooking on the variation of total polyphenols and minerals of different tuber parts during postharvest storage was not evaluated. Indeed, phenolic compounds and minerals have an important role in the body. Phenolic compounds can help alleviate infections of viral or bacterial origin (Ghedira 2005). As for minerals, they allow humans to maintain their health and ensure their biological and mechanical functions (Rayssiguier et al. 2001). In this study, therefore, the aim is to assess the loss rates of total polyphenols and minerals from each part of the yam tuber after cooking in water during post-harvest storage.

## MATERIAL AND METHODS

### 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*. 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.

### Technical conservation

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 a ceiling. The shelves were made of wood. The temperature and relative humidity of the store during the storage time were 26.56 ± 3 °C and 82 ± 5 % respectively.

### Collection of samples

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 each representing the proximal part (tuber head), the middle part (middle of the tuber), and the distal part (tail of the tuber). The losses of micronutrients were evaluated by determining the total phenolic compound, ash, and minerals of flour of different parts of fresh yam tubers and those cooked in water.

**Preparation of yam tuber flour**

The flour was obtained using methods adapted from Bell and Favier (1982) and Elanga (2016). For a given cultivar, one kilogram of each part of yam tubers was used. The process for obtaining the flours is shown in figure 1. The peeling was done with a stainless knife. The cooking was carried out with one liter of distilled water.

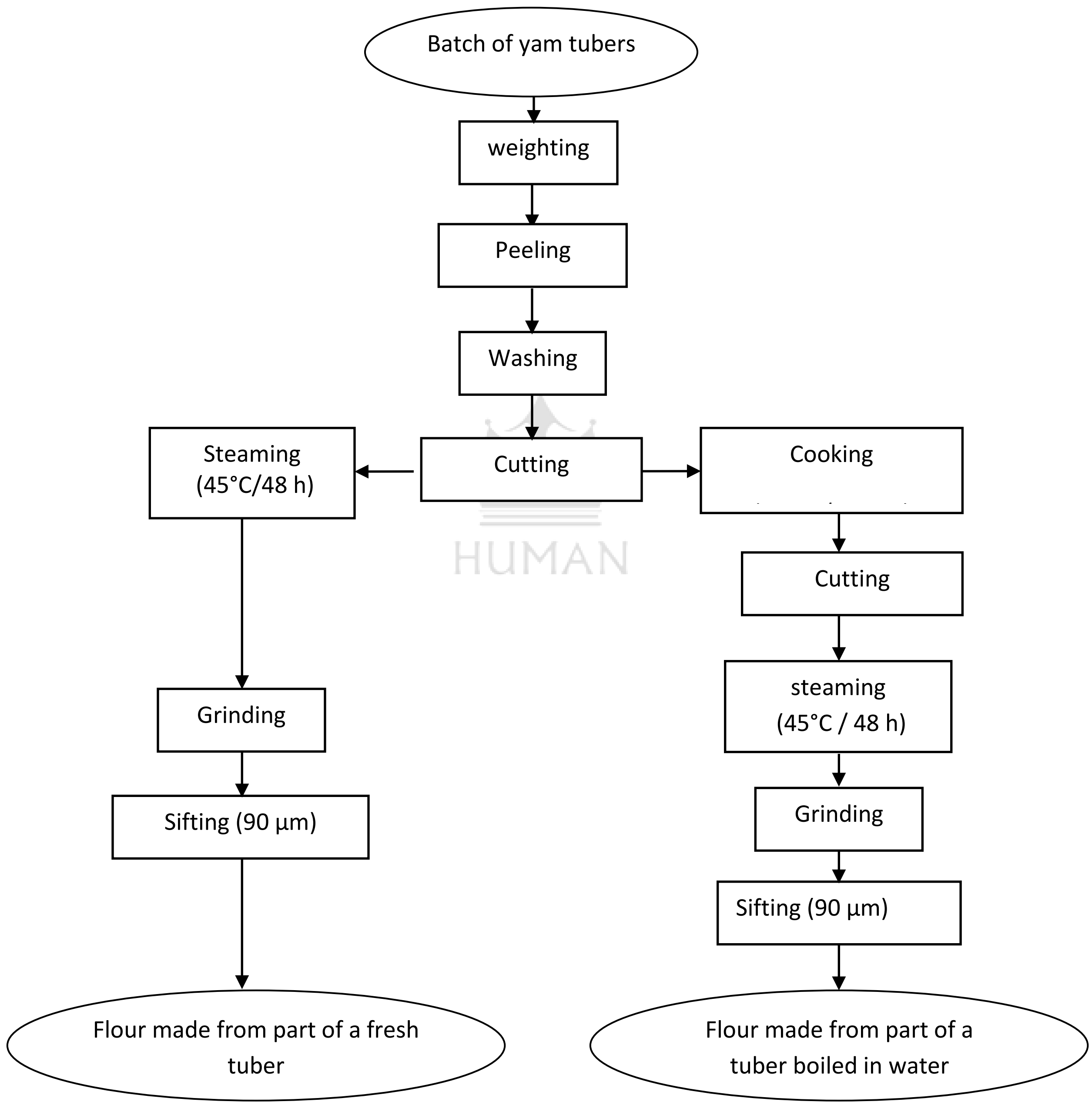


**Figure 1: Production process of yam tuber flour**

**Extraction of total phenolic compounds**

The total phenolic compounds of the flour of each batch of yam tubers were extracted according to the technique described by Boizot and Charpentier (2009). One gram of flour from each batch of yam tubers was weighed in a centrifuge tube. Ten milliliters of acetone (80%, v / v) was added to it. The mixture was homogenized and incubated at 37°C in a water bath for 30 min then centrifuged at 6000 rpm for 10 min. The supernatant was collected and stored in a 50 ml of Erlenmeyer flask. The pellet was taken up in 10 ml of acetone (80%, v / v). The mixture was homogenized and centrifuged under the same conditions as before. The new supernatant was added to the first contents in the 50 ml Erlenmeyer flask. The total supernatant collected was used for the determination of total phenolic compounds.

**Determination of total phenolic compound**

The phenolic compounds of the flour of each batch of yam tubers were determined according to the method of Swain and Hillis (1959) and Fahima et al. (2018). The aceto-soluble extract (0.1 ml) was taken and placed in a test tube containing 0.5 ml of Folin Ciocalteu reagent and 0.4 ml of sodium carbonate (20%, w / v). Another tube prepared under the same conditions additionally contained polyvinylpolypyrrolidone (0.1 g). Mixtures adjusted to 2 ml with distilled water were well homogenized. The optical density was read using a JASCO V530 spectrophotometer (UV / VIS, MODEL TUDC 12 B4, JAPAN SERVO CO. LTD INDONESIA) at 735 nm against a control which not containing the aceto-soluble extract. The optical densities obtained were converted to total phenolic compounds using a calibration curve obtained with different concentrations of gallic acid (1 mg/ml).

**Determination of ash content**

The ash content of the flour of each batch of yam tubers was determined using the method of AOAC (1995). Five grams of flour from each batch of yam tubers weighed in a porcelain crucible of known mass (M1) was placed in a muffle oven at 550 ° C for 6 h. After this calcination, the crucible, left to cool in a desiccator for 30 min, was weighed (M2). The following mathematical expression was used to calculate the Ash content (Ac):

$$A_C = \frac{M_1 - M_2}{} \text{ X } 100$$

**Determination of mineral elements**

The mineral elements of the flour of each batch of yam tubers were determined by atomic absorption spectrophotometry according to the AOAC (1995) digestion method using strong acids. One flour from each batch of yam tubers (0.5 g) was dissolved in 31 ml of an acid mixture consisting of perchloric acid (11.80 mol / l), nitric acid (14, 44 mol / l), and sulfuric acid (18.01 mol / l). The mixture, stirred well in the hood, was heated on a brand P SELECTA AGIMATIC-N hotplate (Barcelona, Spain) until thick white fumes appeared. After this heat treatment, the reaction mixture was cooled on the bench for 10 min then diluted in 50 ml of distilled water. It was boiled again for 30 min using the same hotplate and then cooled again under the same conditions. The mixture was then filtered through Whatman N°42 filter paper. The filtrate thus obtained was made up to the mark with distilled water. The level of the mineral matter was determined using a VARIAN AA.20 brand flame atomic spectrophotometer (New Jersey, USA) at a specific wavelength by comparison with standard solutions.



**Determination of element losses**

The following mathematical expression was used to calculate the loss of the elements:

$$L_R = \frac{C_{FF} - C_{CF}}{} \text{ X } 100$$

$L_R$ = Element Loss Rate

$C_{FF}$ = Content of the element in Fresh Flour

$C_{CF}$ = Content of the element in the cooked flour

## RESULTS

### Losses of total phenolic compounds

The loss rates of phenolic compounds of yam tuber flour give generally similar curves from one part of the tuber to another regardless of the cultivar (**Figure 2**). The loss rates of phenolic compounds of the flours of the different parts of the yam tubers studied increase significantly at the level 5% of the post-harvest storage time. In freshly harvested yam tubers, the flours from different parts of the yam tuber of *Dioscorea alata*, cv "Florido" have the highest loss rates. They are between 70 and 80%. Flour loss rates from different parts of freshly harvested yam tubers are identical. They are around 60% in the first month of storage. Statistical analyzes revealed that there are no significant differences at the 5% threshold between the loss rates of phenolic compounds from the flours of the different parts of each of the tubers of these yams. However, they differ significantly at the 5% threshold from cultivar to cultivar.

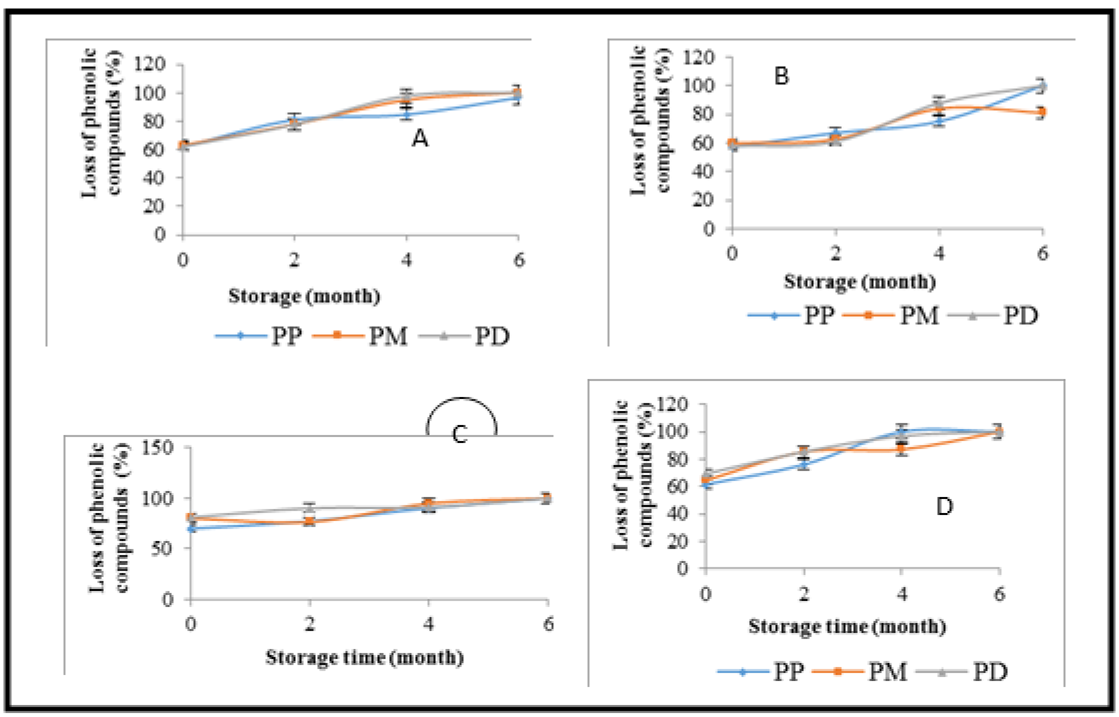


**Figure 2: rate of loss of phenolic compounds from parts of yams Dioscorea alata, cv "Florido" (C) and "Bètè-bète" (D) and Dioscorea cayenensis-rotundata, cv "Kangba" (B) and "Krenglè" (A) after water cooking**

**PP:** Proximal Part**; PM:** Middle Part**; PD:** Distal part

**Ash loss**

The curves of the ash loss rates from the flours of different parts of the yams vary from cultivar to cultivar. The ash loss rates of the proximal and middle parts generally evolve in the same order. The different parts of the tuber of the freshly harvested yam *Dioscorea alata*, cv "Bètè-bètè" have the highest ash loss rates (Figure 3). They are respectively 32.40%, 28.56%, and 27.69% for the proximal, middle, and distal parts. These loss rates drop drastically to reach a maximum of 12% for the proximal and distal parts and 8% for the middle part after two months of storage. These values increase until the sixth month of storage. It is the same for the ashes loss rate of the different parts of the tuber of yam *Dioscorea cayenensis-rotundata* cv "Kangba". As for the loss rates of ash of the flours of the different parts of the tuber of the yam *Dioscorea cayenensis-rotundata*, cv "Krenglè", they are relatively constant during storage. In general, statistical tests revealed significant differences at the 5% level between the rates of ash loss of flour of different parts of yam tubers of cultivar to another cultivar.

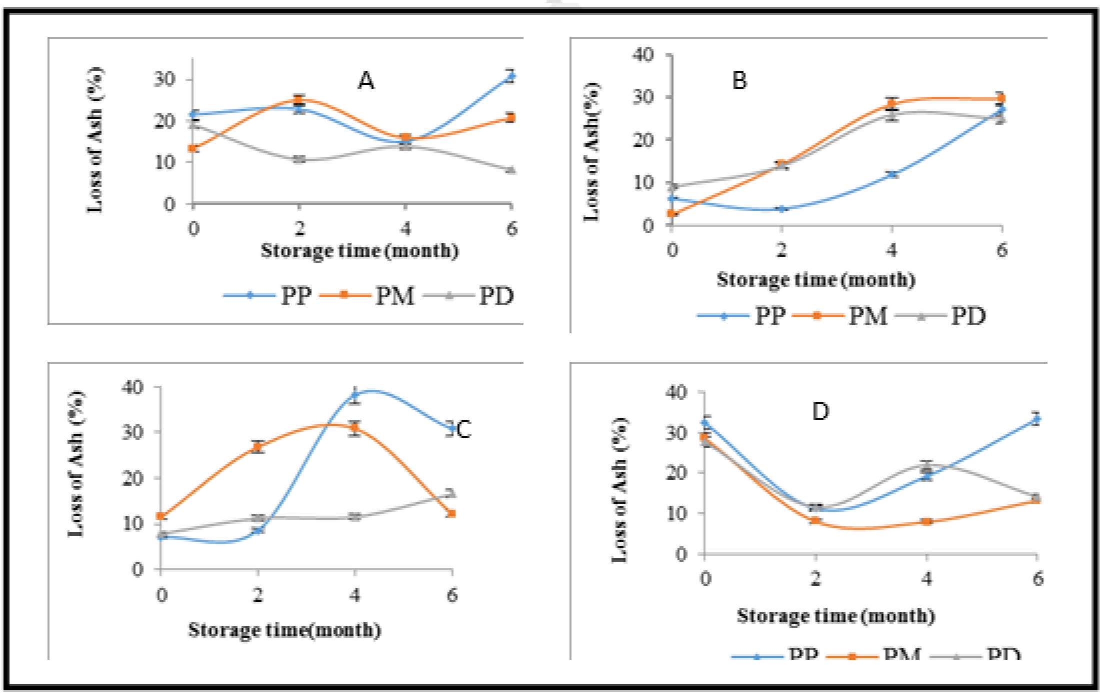


**Figure 3: Ash loss rate of parts of yams Dioscorea alata, cv "Florido" (C) and "Bètè-bètè" (D) and Disocorea cayenensis-rotundata, cv "Kangba" (B) and "Krenglè" (A) after water cooking**

**PP:** Proximal Part**; PM:** Middle Part**; PD:** Distal part

**Magnesium loss**

The curves of the rate of loss of magnesium from the flours of the proximal, middle, and distal parts of the yam tubers show relatively the same patterns (Figure 4). The rates of loss of magnesium from the flours of the different parts of these yam tubers drop in the second month and then increase in the fourth month of storage. Finally, they decrease in the sixth month to reach loss rates lower than those of the flours of the different parts of the tubers of freshly harvested yams. Statistical analyzes revealed significant differences at the 5% level according to Duncan's test between the rates of loss of magnesium from the flours of the different parts of the yam tuber (*Dioscorea alata*, cv "Florido"). In the tubers of the yams *Dioscorea alata*, cv "Florido" and *Dioscorea cayenensis-rotundata*, cv "Kangba", the distal parts have the highest rates of magnesium loss. As for the tubers of the yams *Dioscorea alata*, cv "Bètè-bète" and *Dioscorea cayenensis-rotundata*, cv "Krenglè", no part stands out from the others (Figure 4).

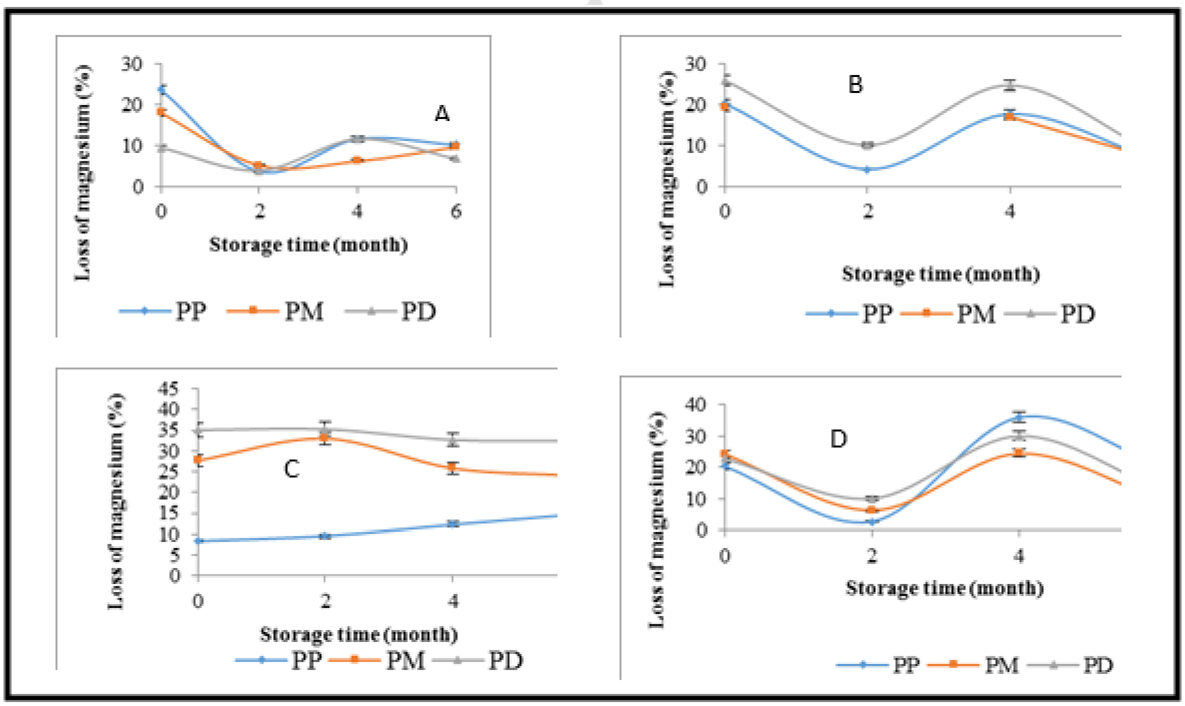


**Figure 4: Rate of magnesium loss of parts of yams Dioscorea alata, cv "Florido" (C) and "Bètè-bète" (D) and Disocorea cayenensis-rotundata, cv "Kangba" (B) and "Krenglè" (A) after cooking in water**

**PP:** Proximal Part**; PM:** Middle Part**; PD:** Distal part

**Zinc loss**

The curves of the zinc loss rates of the flours of the proximal and distal parts of the tubers of yams (subjected to water cooking) based on post-harvest storage time give the same trends. The zinc loss rates from the flours of the different parts of the tuber of the yam *Dioscorea cayenensis-rotundata*, cv "Kangba" decrease slightly with the storage time. However, they increase in the same parts of the tubers of the yams *Dioscorea alata*, cv "Florido" and "Bètè-bète" and *Dioscorea cayenensis-rotundata*, cv "Krenglè". Statistical analyzes indicated significant differences at the 5% threshold between the zinc loss rates of the flours of these different parts (Figure 5).

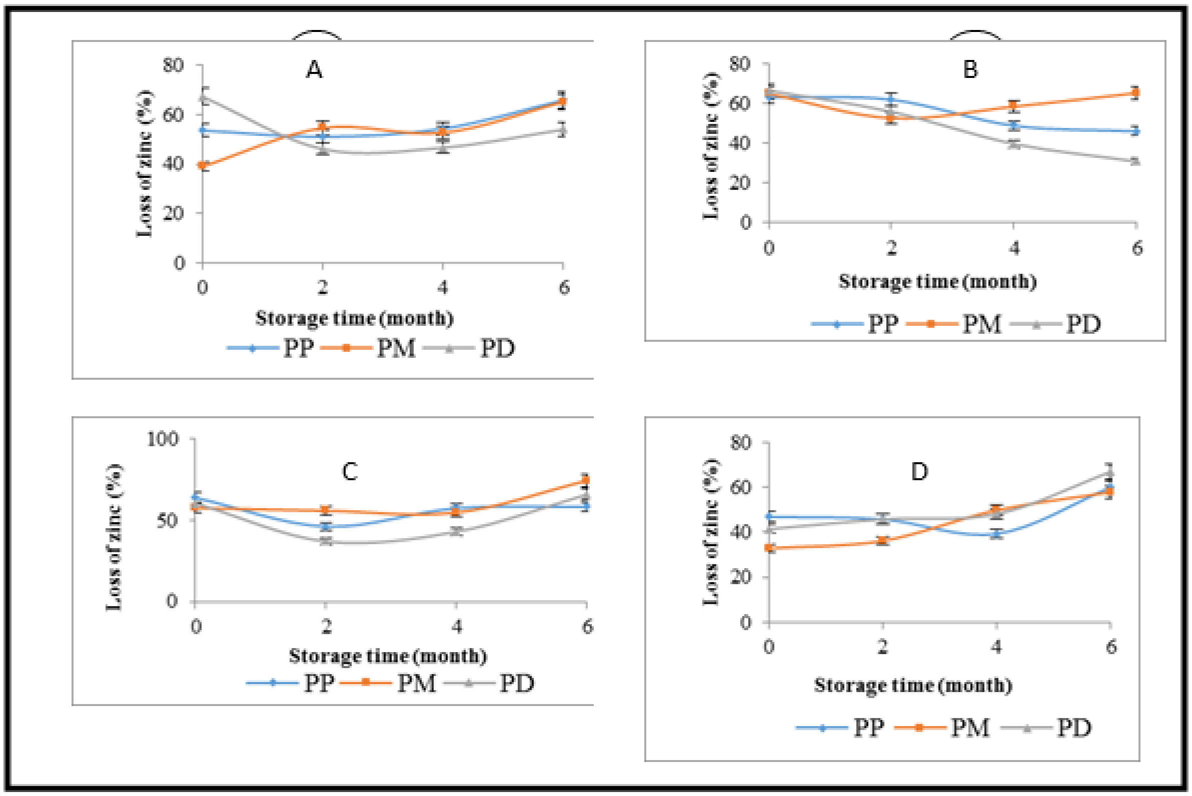


**Figure 5: Rate of zinc loss of parts of yams Dioscorea alata, cv "Florido" (C) and "Bètè-bète" (D) and Disocorea cayenensis-rotundata, cv "Kangba" (B) and "Krenglè" (A) after water cooking**

**PP:** Proximal Part**; PM:** Middle Part**; PD:** Distal part

**Calcium losses**

The curves of the calcium loss rates of the flours of the proximal and distal parts of the yam tuber (subjected to cooking in water) as a function of storage time show the same trends. The rates of calcium loss of the proximal and distal parts of tubers of *Dioscorea cayenensis-rotundata*, cv "Krenglè" and *Dioscorea alata*, cv "Florido increase with storage time. For the same parts of the tubers of the yam *Dioscorea alata*, cv "Bètè-bète", the loss rates gradually decrease during storage. As for the yam tuber *Disocorea cayenensis-rotundata*, cv "Kangba", the calcium loss rates of these parts increase during the first two months of storage, then decrease considerably in the fourth month of storage to increase to new until the sixth month to achieve lower values than the tubers of freshly harvested yams (Figure 6). Statistical analyzes generally revealed significant differences at the 5% threshold between the rates of calcium loss of flour from one part of the tuber to another and from one cultivar to another.

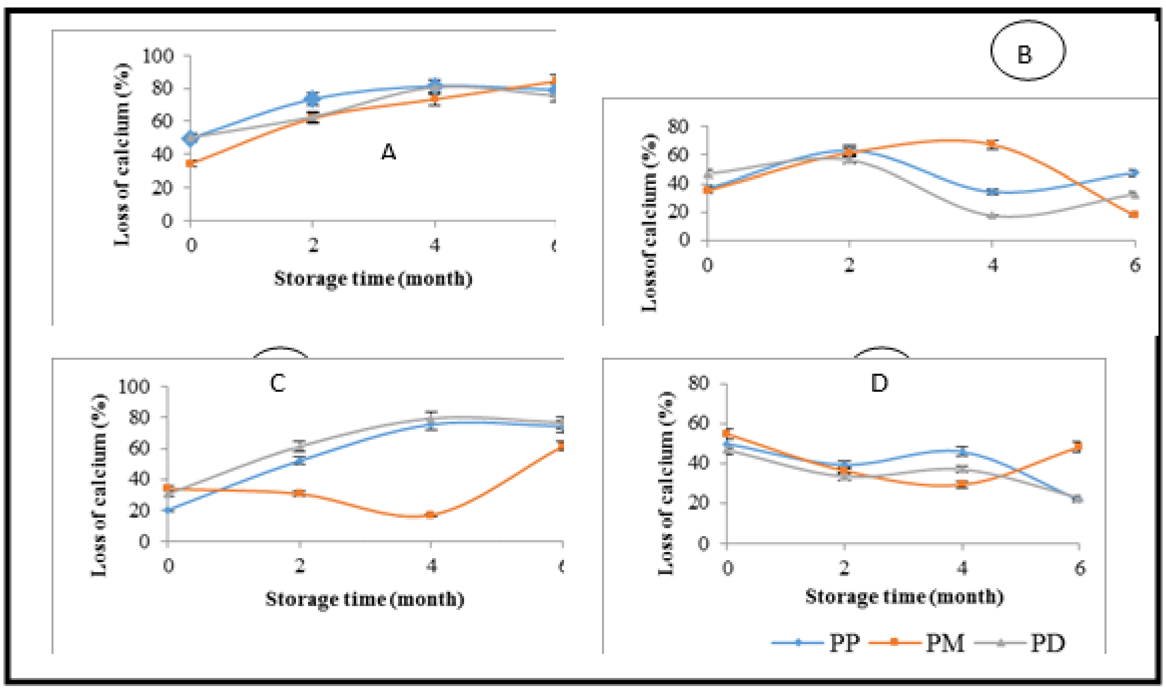


**Figure 6: Rate of calcium loss of parts of yams Dioscorea alata, cv "Florido" (C) and "Bètè-bète" (D) and Disocorea cayenensis-rotundata, cv "Kangba" (B) and "Krenglè" (A) after water cooking**

**PP:** Proximal Part**; PM:** Middle Part**; PD:** Distal part

The curves of the nickel loss rates of the proximal and middle parts of the tubers of the yams *Dioscorea alata*, cv "Florido" and "Bètè-bètè" and *Dioscorea cayenensis-rotundata*, cv "Kangba" and "Krenglè" (subjected to cooking at water) depending on the storage time have roughly the same appearance. The rates of nickel loss of the flours of the proximal and middle parts of the tubers of the yams of *Dioscorea alata*, cv "Florido" and *Dioscorea cayenensis-rotundata*, cv "Krenglè" are identical, while in the other cultivars the rates are different (Figure 7).

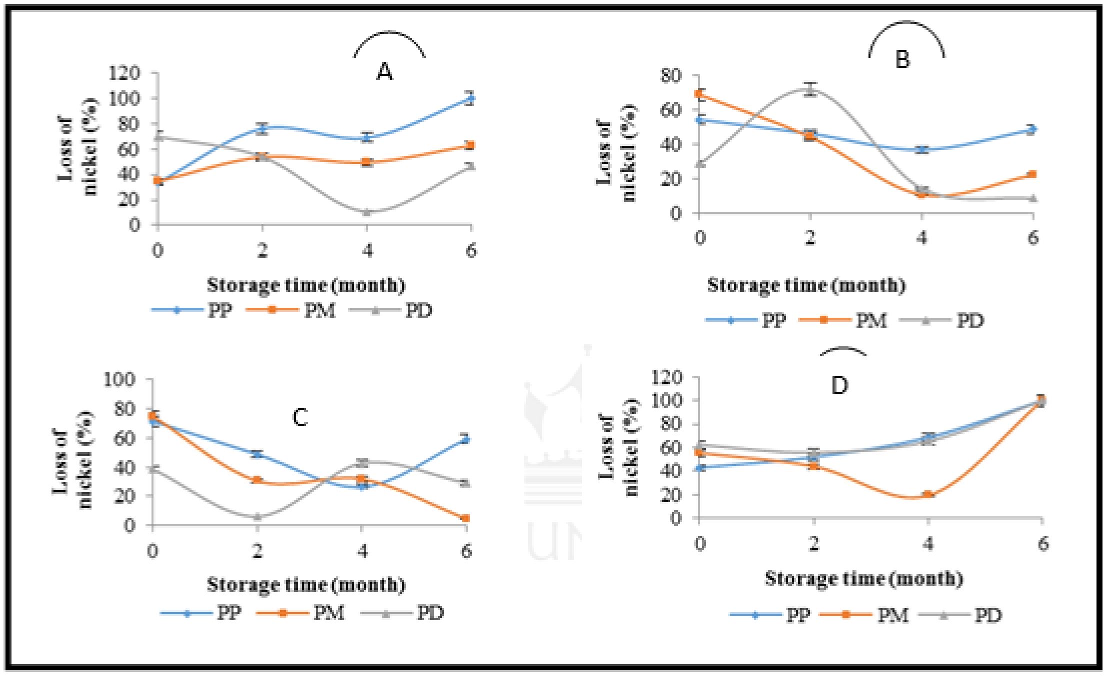


**Figure 7: Rate of nickel loss of parts of yams Dioscorea alata, cv "Florido" (C) and "Bètè-bète" (D) and Disocorea cayenensis-rotundata, cv "Kangba" (B) and "Krenglè" (A) after water cooking**

**PP:** Proximal Part**; PM:** Middle Part**; PD:** Distal part

## DISCUSSION

The loss rates of phenolic compounds from the flours of the different parts of the yam tubers studied increase significantly at the 5% level with the post-harvest storage time. At the level of freshly harvested yam tubers, flours of different parts of the tuber of yam *Dioscorea alata* cv "Florido" have the highest rate of loss. This situation suggests that storage time and hydrothermal treatment would not affect the polyphenols of all cultivars in the same way. The absence of significant differences at the 5% threshold between the loss rates of the phenolic compounds of the flours of the different parts of each of the tubers of these yams, demonstrates that the loss of these compounds is not related to the part of the yam but rather to the cultivar. The differences in the loss rates of total polyphenols from one cultivar to another can be explained by the nature and content of the different phenolic compounds specific to each cultivar (Barkat and Kadri, 2011). The increased loss rates of total phenolic compounds could be explained by the great ease with which the phenolic compounds are extracted from the different parts of the tubers of boiled yams following a strong weakening of the cell walls of the pulps by heat (Barkat et al. Kadri, 2011). In plants, cells are linked to each other at the middle lamella through pectic polymers, and it is this cell-cell bond that is responsible for their texture (Waldron et al., 1997). During cooking, the native protopectin inside the middle coverslips turns into soluble pectin which rapidly depolymerizes, allowing rapid entry of water and movement through the cells (Stanley & Aguilera, 1985). The loss by cell bursting facilitating the release of total phenolic compounds in the cooking water, as well as the destruction at high temperature would contribute to the decrease in the levels of total phenolic compounds of the boiled pulps of the different parts of the tubers of the yams studied. These rates of loss of total phenolic compounds observed during this study were indicated on hybrid cultivars ("CRBP 39", "CRBP 755" and "FHIA 21") of *Musa spp* and fresh broccoli (Zhang and Hamauzu, 2004). Also, the loss of total phenolic compounds would result either in their ability to form stable complexes with proteins and sugars or in enzymatic hydrolysis (Lugasi et al., 2003). These compounds inhibit or slow down the oxidation of a substrate (Wainsten, 2009). They have protective effects against multiple sclerosis, osteoporosis, and pathologies linked to brain aging (Alzheimer's disease, other types of dementia, Parkinson's disease, etc.). Phenolic compounds can also attenuate infections of viral or bacterial origin (Ghedira 2005; Scalbert et al. 2005; Gonzalez-Gallego et al. 2010; Spencer, 2010). Given the important role they have in the organization, their loss should be limited.

The increased rate of loss of mineral elements of different parts of yam tubers after boiling is related to postharvest storage time. This increase reflects the decrease in the levels of these nutrients in different parts of the tubers of preserved and boiled yams. The decrease in the levels of these substances is thought to be due to their diffusion into the cooking water during cooking with water (Trèche et al., 1984). This assertion is supported by Bell (1985) and Wang et al.

(2009). Bell (1985), recorded a similar decrease for most edible yam species. As for Wang et al. (2009), they showed that cooking reduced the level of minerals in the grains of *Phaseolus vulgaris L*. and *Cicer arietinum L*. As the ash is made up of all the minerals, leaching of the minerals in the cooking water leads to a decrease in the ash content (Sénan, 2012). The significant differences observed or not between the rates of loss of magnesium, zinc, and calcium of the flours of the different parts of the tuber of yams *Dioscorea alata*, cv "Florido", reflects the importance of each part of the tuber in the loss or not of the different minerals during the cooking of these tubers. Indeed, the leaching of minerals would be more marked in some parts of the tubers (distal parts) than in others (proximal).

Also, the variation in the rate of mineral loss, which depends on the mineral and especially the cultivar, reflects the particularity of each mineral and each cultivar of yam tuber during post-harvest storage and cooking. Indeed, some minerals diffuse faster compared to other minerals during cooking. The significant differences observed or not between the rates of loss of minerals of the flours of the different parts of the yam tuber cultivars also reflect the difference in reactivity of the different cultivars to post-harvest storage and cooking with water.

These mineral losses reduce the nutritional value of the yam after cooking. The minerals provided by food allow humans to maintain their health and ensure their biological and mechanical functions. They play for this purpose, an important role in intercellular exchanges and inter tissue. Iron, calcium, copper, and zinc are therefore essential minerals for the body (Rayssiguier et al. 2001). Iron is involved in the transport of oxygen in the body (Yip, 2000). Calcium is important in the prevention of chronic diseases, risks of osteoporosis, hypertension, colon cancer, and breast cancer (Miller & Anderson, 1999). Copper is a trace element involved in the maintenance of bone cartilage, in the fight against infections, and the proper functioning of the heart (Olivares and Uauy, 1996). Zinc is an antioxidant involved in vitamin metabolism, in reproductive and sensory functions (Arnaud, 1995; Shankar and Prasad, 1998).

**CONCLUSION**

This study found that the rates of loss of phenolic compounds and minerals of the proximal, middle, and distal parts of yam tubers subjected to boiling at different storage times differ from one part of the tuber to another. They also differ from one cultivar to another cultivar and from one mineral to another mineral. The cooking resulted in a considerable reduction of total phenolics rates. In addition, it caused a slight decrease in mineral elements (calcium, zinc, and magnesium). The distal part of the yam tuber loses many more micronutrients than the other parts.

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