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Original Research Article

BIOCHEMICAL AND FUNCTIONAL PROPERTIES EVOLUTION OF YAM FLOUR IN THE POST-HARVEST CONSERVATION OF YAM TUBERS (*Dioscorea alata*) CULTIVAR « Azaguié »

ABSTRACT

Aims: To follow the evolution of biochemical and functional properties of yam flour during the post-harvest conservation of yam « Azaguié » (*Dioscorea alata*) tubers.

Study design: Analysis of variance (ANOVA) was employed in this work.

Place and duration of the study: Unité de Formation et de Recherche des Sciences et Technologies des aliments (UFR-STA), Université Nangui Abrogoua, Abidjan, Côte d'Ivoire, from December 2014 to February 2016.

Methodology: The yam tubers stored after harvest in a warehouse are kept for 6 months. Tubers are randomly taken in the preparation of flour every two months. Flours are obtained after grinding and sieving the pulp pieces dried at 45 °C for 48 h. Thereafter, the biochemical and functional analyses were performed on these different flours.

Result: except for the lipid contents, all biochemical properties that were measured vary significantly ($P \leq 0.05$) with post- harvest conservation time of the yam tubers. Dry matter, total sugars and reducing sugars increase. By cons, protein, phenolic compound, ash and minerals (calcium, copper, potassium, Magnesium and zinc) decreased with post- harvest conservation time of the yam species tubers. With regard to functional properties studied, water absorption capacity (WAC), oil absorption capacity (OAC) and wettability increase significantly ($P \leq 0.05$) with post-harvest conservation time of the yam tubers. However, the water absorption index (WSI), hydrophilic lipophilic index (HLI), bulk density, foaming capacity and foam stability decrease significantly ($P \leq 0.05$) during post-harvest conservation of yam tubers.

Conclusion: This study shows the importance of post-harvest conservation time of the yam tubers in the use of these categories of flour in food technology

Keywords : Dioscorea alata ; biochemical properties ; functional properties ; post- harvest conservation.

UNDER PEER REVIEW

INTRODUCTION

Yams (*Dioscorea spp.*, Dioscoreaceae) are the third most important tropical root crop after cassava and sweet potato [1]. The tubers of various species of *Dioscorea* constitute one of the stable carbohydrate foods for the people in many tropical countries [2]. Many different forms and cultivar of the edible yam species are available in different areas and it is likely that these differ in composition and nutritional values [3]. Water yam (*Dioscorea alata*) is the most economically important yam species which serve as a staple food for millions of people in tropical and subtropical countries [4, 5]. *D. alata* is a crop with potential for an increased consumer demand due to its low sugar content necessary for diabetic patients [6]. Yam is an excellent source of starch, which provides calorific energy [7], but suffers a high degree of a post-harvest loss due to its high moisture content [8]. The processed form, in which yam tubers are consumed or preserved, is flour [9]. This product makes it possible to extend the supply of the commodities through the off-season, thereby reducing storage losses as well as marketing and transportation costs [10]. This flour of yam tubers is commonly used in various culinary preparations. Rehydrated, it helps replenish elastic pasta distinct fufu and foutou**.** [10, 11].Yam flour has found increasing use in bakery [10]. Thus, in view of these various uses of yam flour. It is therefore necessary to determine biochemical and functional properties. Thereby, several authors have worked in the use of yam flour by studying their biochemical and functional properties but very few have reported the influence of post-harvest conservation of yams tuber on these properties in yam flour. This study aims at providing information on the choice of yam tubers for the use of flour in food technology.

MATERIAL AND METHODS

Material

Cultivars « Azaguié » of *D. alata* species were harvested (matured) in December 2014 from a farm at Sandégué in the eastern region of Côte d'Ivoire. They were transported to the laboratory of biocatalysis and bioprocesses of the Nangui Abrogoua University in Abidjan (Côte d'Ivoire) where a study was conducted. Yam tubers were stored for six months in a heap aired store in which the temperature and the relative humidity rate are respectively 26.56 ± 3 °C and 82 ± 5%.

Sample preparation

UNDER PEER REVIEW

Every two (2) months during the storage period (six months), tubers were randomly picked. The chosen tubers were peeled, cut in small slices (3x3x3 cm thickness) and washed with pure water. Slices were dried at 45 °C for 48 h. The dried slices were ground and pass through sieve (250 µm size). The obtained flour was kept for analysis.

Proximate analysis

The dry matters contents, crude protein, crude fat and ash were determined in accordance with the standard methods of the AOAC [12]. Dry matters were determined by drying in an oven at 105 °C for 24 h to constant weight. Crude protein determination involved the use of routine Kjeldahl nitrogen assay (N × 6.25). Crude fat was determined by exhaustively extracting samples in a soxhlet apparatus using hexane as solvent. Ash was determined by incinerating in a fumace at 550 °C for 6 h, then weighing the residue after cooling to room temperature in a dessiccator. The method described by Dubois *and al*. [13] was used for the total sugar contents analysis. Reducing sugar contents were determined according to the method of Bernfeld [14] using 3.5 dinitrosalycilic acid. The total phenolic compound was determined according to the spectrophotometric method described by Swain and Hillis [15] using the Folin-Ciocalteu reagent.

Mineral analysis

Magnesium, calcium, copper, potassium and zinc were quantitatively determined from the digest using strong acids and the atomic absorption spectrophotometer with appropriate hollow cathode lamps [12].

Functional properties

Water absorption capacity (WAC) and solubility index (WSI)

The water absorption capacity (WAC) and solubility index (WSI) of flours from yam (*D. alata,* cv Azaguié) tubers were evaluated according to Philips and al. [16] and Anderson and al. [17] methods, respectively. The flour from yam tubers (1 g) were each weighed into a centrifuge tube and 10 mL distilled water added. The content of the centrifuge tube was shaken for 30 mn in a KS 10 agitator. The mixture was kept in a water-bath (37ºC) for 30 mn and centrifuged (Ditton LAB centrifuge, UK) at 5000 rpm for 15 mn. The resulting sediment (*M2*) was weighed and then dried at 105ºC to constant weight (*M1*). The WAC was then calculated as follows:

UNDER PEER REVIEW

$$WAC\ (\%) = \frac{M_2 - M_1}{M_1} \times 100 \quad (1)$$

While the WSI was calculated using the following equation:

$$WSI\ (\%) = \frac{M_0 - M_1}{M_0} \times 100 \quad (2)$$

Oil absorption capacity and hydrophilic-lipophilic index

The oil absorption capacity (OAC) or flours was assayed according to the method of Sosulski [18]. One (1) g of flour (*M0*) was mixed with a 10 ml of oil. The mixture was shaken for 30 mn in a KS10 agitator and centrifuged (Ditton LAB centrifuge, UK) at 4500 rpm for 10 mn. The resulting sediment (*M1*) was weighed and the OAC was then calculated as follows:

$$OAC\ (\%) = \frac{M_1 - M_0}{M_0} \times 100 \quad (3)$$

While hydrophilic-lipophilic index (HLI) was determined as the ratio of WAC to that of OAC [19].

Bulk density

The method of Narayana and Narasinga [20] was used to determine the bulk density of yam flour samples. A 50 g flour sample was put into a 100 ml measuring cylinder. The cylinder was tapped continuously on a laboratory bench until a constant volume was obtained. The bulk density (g/cm3) was calculated as weight of flour (g) divided by flour volume (cm3).

Wettability

The wettability was determined by Onwuka method [21]. 1 g of flour sample was added into a 25 ml graduated cylinder with a diameter of 1 cm. A finger was placed over the open end of a cylinder, it was inverted and clamped at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was then removed to allow the test material to be dumped. The wettability is the time required for the sample to become completely wet (Onwuka, 2005).

UNDER PEER REVIEW

Foam capacity and foam stability

The foam capacity (FC) and stability (FS) of flours were studied by the method of Coffman and Garcia [22]. Three (3) g of flour was transferred into clean, dry and graduated (50 ml) cylinders. The flour samples were gently leveled and the volumes noted. Distilled water (30 ml) was added to each sample; the cylinder was swirled and allowed to stand for 120 mn while the change in volume was recorded every one 10 mn.

$$FC\ (\%) = \frac{Vol.after\ homogenization - Vol.beforehomogenization}{Vol.\ before\ homogenization} \times 100 \quad (4)$$

$$FS\ (\%) = \frac{Foam\ volume\ after\ time\ (t)}{Initial\ foam\ volume} \times 100 \quad (5)$$

Statistical analysis

All analyses in this study were threefold. In each case a mean value and standard deviation were calculated. Statistical analyses of the data were performed using software Statistica 7.1. Comparisons between the dependent variables were determined using variance analysis (ANOVA) and the Duncan test. Statistical significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Proximate composition

The proximate composition of yam flour « Azaguié » during the post-harvest conservation is presented in Table 1. Statistical analysis showed significant differences ($P \leq 0.05$) between the means of variables estimated except for lipid content. Dry matter of yam flour « Azaguié » increased from 88.73 ± 0.15 to 92.67 ± 0.12% during the 6 month of storage. This observation is similar to what was reported by Otegbayo *et al.* [23] who noted variation from 25.32% to 26.72% of yam (*D. alata*) and 34.83% to 41.77% of yam (*D. rotundata cayenensis*). Dry matter increasing was due to the loss of water by tubers during storage. This phenomenon was caused by the setting up of the germination process that requires a strong increase of the respiratory intensity and perspiration acceleration [24].

Total and reducing sugars contents were ranged from 2.90 ± 0.15 to 5.60 ± 0.14 g / 100g dm and from 0.71 ± 0.03 to 2.01 ± 0.02 g / 100 dm, respectively. Total and reducing sugars

UNDER PEER REVIEW

increasing could be attributed to hydrolysis of starch by the amylolytic enzymes present in the tuber starch degradation by amylolytic enzymes[25]. The presence of reducing sugars in flour may cause caking and damping during their storage because of sugar's hygroscopic property. However, yam be desirable in bakery products like bread and cake where the tenderising effects positively affect texture and where sugars serve as substrate for fermentation of the dough [26].

Protein content of yam « Azaguié » (*D. alata*) decreased from 8.59 ± 0.39 to 6.90 ± 0.30 g / 100g dm. The decrease of protein content during conservation could be explained by reduction of the protein synthesis capacity as well as proteolysis initiated by the proteases [27].

Ash content of yam flour was decreased from 3.20 ± 0.10 to 2.60 ± 0.10 g / 100g dm. Ash content gives an indication of minerals present in a particular food sample and it is very important in many biochemical reactions which aid physiological functioning of major metabolic processes in the human body [28]. Decrease in ash content may be due to the involvement of minerals in the tuber phenomenon of respiration and metabolic processes in the bud [27, 29]. Values were in agreement with those reported by Amani and Kamenan [30]. They recorded in whole tubers of yams (*D. alata*) cv « Florido », « Bètè-bètè » (*D. cayenensis-rotundata*) cv « Kponan » and « Krenglè » respective rates of 3.3%; 3.4%; 2% to 2.9%.

Phenolic compound content was ranged from 437.09 ± 15.25 to 99.55 ± 13.36 mg / 100 dm. Changes in phenolic compounds exhibited during post-harvest storage were attributed to the role of phenolic compounds in the morphogenesis of the stems formed on the tuber [31]. This author observed reduction of total phenols in *D. dumetorum* from 318 to 248.4 mg / 100 g dw after 56 days of storage.

Table 1: Evolution of biochemical parameters of the yam flour « Azaguié » during the post-harvest conservation of yam tubers

Parameters	Conservation time (months)			
	0	2	4	6
Dry matter (%)	88.73 ± 0.15[a]	90.10 ± 0.23[b]	91.60 ± 0.26[c]	92.67 ± 0.12[d]
Proteins (g/100g dm)	8.59 ± 0.39[a]	7.91 ± 0.32[b]	7.41 ± 0.25[bc]	6.90 ± 0.30[c]

UNDER PEER REVIEW

Lipids (g/100g dm)	0.30 ± 0.01[a]	0.30 ± 0.01[a]	0.30 ± 0.01[a]	0.30 ± 0.01[a]
Total sugar (g/100g dm)	2.90 ± 0.15[a]	3.42 ± 0.13[b]	4.39 ± 0.17[c]	5.60 ± 0.14[d]
Reducing sugars (g/100g dm)	0.71 ± 0.03[a]	1.21 ± 0.05[b]	1.60 ± 0.06[c]	2.01 ± 0.02[d]
Ash (g/100g dm)	3.20 ± 0.10[a]	3.01 ± 0.06[b]	2.81 ± 0.06[c]	2.60 ± 0.10[d]
Phenolic compounds (mg/100g dm)	437.09 ± 15.25[a]	306.33 ± 14.85[b]	197.36 ± 14.65[c]	99.55 ± 13.36[d]

dm :dry matter
The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter are significantly ($P \leq 0.05$) different between them according to the Duncan test.

Minerals

Minerals are important to diet because of their physiological and metabolic function in the body. The result presented in Table 2 showed the mineral evolution of the yam flours during the post-harvest conservation from yam tubers. Generally, the mineral contents were decreased significantly ($P \leq 0.05$) with the conservation time. Within this flour, calcium content varied from 56.82 ± 1.05 to 50.13 ± 0.64 mg / 100 g dm. Copper content ranged from 1.77 ± 0.04 to 0.97 ± 0.04 mg / 100 g dm. Potassium content decreased from 698.02 ± 3.67 to 567.99 ± 2.77 mg / 100g dm. Magnesium content varied from 86.53 ± 2.16 to 80.88 ± 2.53 mg / 100 g dm. Zinc content ranged from 3.15 ± 0.05 to 1.11 ± 0.03 mg / 100g dm. Decrease of all minerals content during the post-harvest conservation would be caused by their transfer towards the bud for the metabolic process entailed by germination [29]. This observation is similar to what was reported by Djè *and al.* [25] who noted a decrease of minerals (magnesium, calcium and zinc) during the post-harvest conservation of yam flour from different part (distal, median, proximal) of tubers.

Table 2: Evolution of some minerals yam flour « Azaguié » during the post-harvest conservation of yam tubers

Minerals (mg / 100g dm)	Conservation time (months)			
	0	2	4	6
Calcium	56.82 ± 1.05[a]	53.66 ± 0.92[b]	53.19 ± 0.70[b]	50.13 ± 0.64[c]
Copper	1.77 ± 0.04[a]	1.18 ± 0.03[b]	1.00 ± 0.03[c]	0.97 ± 0.04[c]
Potassium	698.02 ± 3.67[a]	618.42 ± 2.52[b]	606.19 ± 2.16[c]	567.99 ± 2.77[d]
Magnesium	86.53 ± 2.16[a]	82.70 ± 2.27[b]	81.99 ± 2.23[b]	80.88 ± 2.53[c]
Zinc	3.15 ± 0.05[a]	1.40 ± 0.05[b]	1.19 ± 0.10[c]	1.11 ± 0.03[c]

dm :dry matter

UNDER PEER REVIEW

The obtained values are averages ± standard deviati on of triplicate determinations. On the lines of each parameter, the averages affected of no common letter are significantly (P ≤ 0.05) different between them according to the Duncan test.

Functional properties

In this study, the change in conservation time led to a significant ($P \leq 0.05$) variation in the functional properties of yam flour « Azaguié » as shown in Table 3. The Water absorption characteristic represents the ability of a product to associate with water under conditions where water is limiting e.g. dough and pastes [32]. Water absorption capacity (WAC) is important to certain product characteristics, such as the moistness of the product, starch retrogradation, and subsequent product scaling [33]. The WAC of the flour ranged from 265.74 ± 1.91 to 302.61 ± 2.16%, indicating that flour from tubers during the post-harvest conservation has higher WAC. According to Diallo *et al.* [34], flour with high WAC can add more water to the dough and improve maneuverability. Therefore, it is useful in baking property. The range of WAC observed for flour sample analyzed is higher compared to those of flours from yam (*Dioscorea dumetorum*) (182.3 ± 4.1 to 390.7 ± 4.4%) during 56 days post-harvest conservation [35].

Oil absorption is an important property in food formulations because fats improve the flavour and mouthfeel of foods [36]. In this study, the oil absorption capacity (OAC) ranged from 35.87 ± 0.45 to 40.13 ± 0.40%. These values were lower than those obtained for yam (*D. dumetorum*) flour (72.3 ± 1.9 t0 94.8 ± 2.4 %) [35].The variation in OAC depends on the presence of non-polar side chains, which bind the hydrocarbon side chain of oil. The mechanism of oil absorption may be explained as a physical entrapment of oil related to the non-polar side chains of proteins. Both the protein content and the type contribute to the oil-retaining properties of food materials [37]. The increase in protein also enhances the hydrophobicity and exposed more the polar amino acid to the fat [38]. Thus, the decrease in protein in yam « Azaguié » flours would tend to reduce the hydrophobicity, and thereby causing a low fat binding to protein. The oil absorption capacity of the protein is required in ground meat formulations, meat replacers and extenders, doughnuts, pancake, baked food and soups. [39].

Ease of dispersibility or wettability is important in food formulations. Wettability of protein is affected by surface polarity, topography, texture and area and by the size and microstructure of the protein particles, but not necessarily by the amount of native structure. Wettability among the samples ranged from 50 ± 2 to 87 ± 2 sec. These values are lower at

UNDER PEER REVIEW

120 dry which would mean that these flours are wettable [40]. Values obtained are higher than those recorded by Udensi *and al.* [41] for different flour varieties of *D. alata* (27-35 secs).

Water solubility index (WSI) reflects the extent of starch degradation [42]. The WSI of flour from yam tuber « Azaguié » decreases from 40.17 ± 0.25 to 30.83 ± 0.40% during the post-harvest conservation. WSI indicates that post-harvest conservation had more profound effects on starch degradation. Similar observations were recorded by Hsu *et al.* [43] and Medoua *et al.* [35] when using yam (*Dioscorea spp*) flour (9.26 ± 0.11 to 15.31 ± 0.85 %) and yam (*D. dumetorum*) flour (15.0 ± 0.1 to 14.8 ± 0.4%), respectively.

The hydrophilic-lipophilic index (HLI) varied from 8.44 ± 0.12 to 6.62 ± 0.11. HLI variation would be related to the different variations of the WAC and OAC during the post-harvest conservation of yam tubers. The values obtained in this study are higher than those reported by Medoua *et al.* [35] for (*D. dumetorum*) flour (2.5 ±0.1 to 4.1 ± 0.1), suggesting that yam « Azaguié » flour has more affinity for water than for oil.

The bulk density of flour from yam tuber « Azaguié » ranged from 1.14 ± 0.02 to 0.76 ± 0.01 g / cm3. The values obtained are higher than those found by Udensi *et al.* [41] (0.64 - 0.76 g / cm3). High bulk density increases the rate of dispersion [44], which is important in the reconstitution of yam flours in hot water to produce yam fufu dough. According to Bello and Okezie [45], bulk density of a good material is also important in relation to its packaging.

The foaming properties of proteins, the ability to form stable and consistent foams are important in preparing cakes and desserts [46]. Indeed, the foams are used to improve the texture, consistency and appearance of food [47]. In our study, the foaming capacity (24.41 ± 0.94 to 18.80 ± 0.63%) and foam stability (Figure 1) decrease during the post-harvest conservation of yam tubers. This variation may be due to protein denaturation during post-harvest conservation. Moreover, according Halling [48], the protein concentration would play on the formation and stability of foams. Similar variations were recorded by Koné et al. [47] when using yam « Kponan » flour (25.80 to 13.32 %) during the cooking water of yam tubers.

UNDER PEER REVIEW

Table 3: Evolution of the functional properties of yam flour « Azaguié » during post-harvest conservation of yam tubers

Functional properties	Conservation time (months)			
	0	2	4	6
WAC (%)	265.74 ± 1.91[a]	280.53 ± 2.71[b]	288.86 ± 6.85[c]	302.61 ± 2.16[d]
WSI (%)	40.17 ± 0.25[a]	37.87 ± 0.25[b]	34.23 ± 0.25[c]	30.83 ± 0.40[d]
OAC (%)	35.87 ± 0.45[a]	36.80 ± 0.30[b]	38.10 ± 0.20[c]	40.13 ± 0.40[d]
IHL	8.44 ± 0.12[a]	7.85 ± 0.19[b]	7.36 ± 0.04[c]	6.62 ± 0.11[d]
bulk density (g/cm^3)	1.14 ± 0.02[a]	1.02 ± 0.04[b]	0.91 ± 0.04[c]	0.76 ± 0.01[d]
wettability (sec)	50 ± 2[a]	60 ± 3[b]	72 ± 3[c]	87 ± 2[d]
Foaming capacity (%)	24.41 ± 0.94[a]	21.42 ± 0.46[b]	20.09 ± 0.25[c]	18.80 ± 0.63[d]

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter are significantly ($P \leq 0.05$) different between them according to Duncan test.

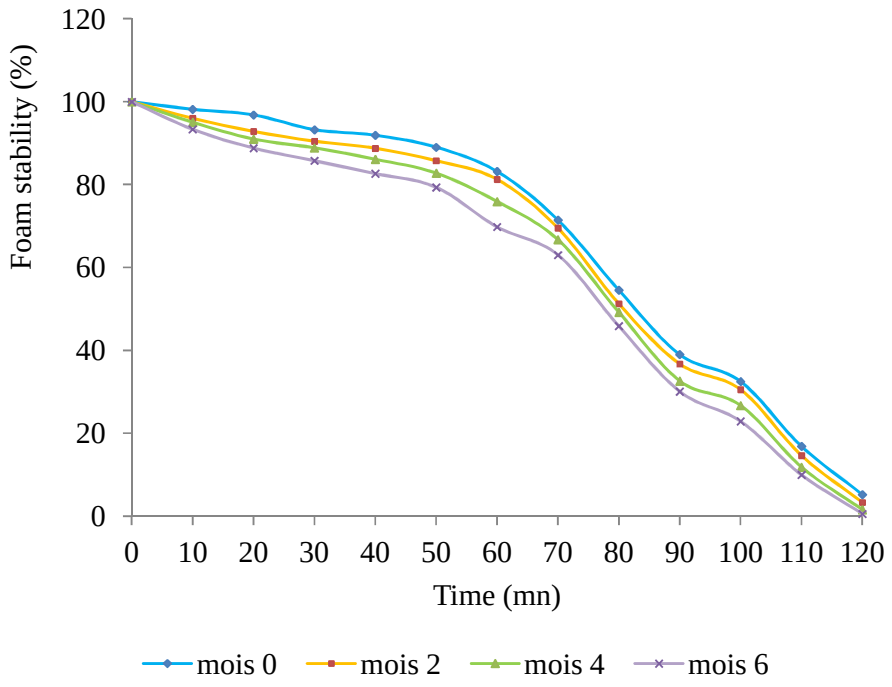

Figure 1: Evolution of the foam stability of yam flour « Azaguié » during post-harvest storage of yams tubers

UNDER PEER REVIEW

CONCLUSION

After this study, it appears that except for lipids, the post-harvest conservation of yams variety « Azaguié » tubers has a significant influence on the biochemical parameters and functional properties of flour. In general, the dry matter, total and reducing sugars contents increase with the post-harvest conservation time. In contrast, protein, starch, phenolic compound, ash and minerals contents of yam flour decrease with the post-harvest conservation time of yams tubers. In addition, the water absorption capacity and oil as well as the wettability of flour increase. Conversely, bulk density, index of solubility, foaming capacity and foam stability flour decrease with the post-harvest conservation time of yam tubers. The results suggest that, for the use of yam « Azaguié » flour as ingredient in food formulation, it is necessary to take into consideration the state of the tubers

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UNDER PEER REVIEW

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UNDER PEER REVIEW

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UNDER PEER REVIEW

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UNDER PEER REVIEW

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