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Physicochemical changes occurring during post-harvest hardening of trifoliate yam (*Dioscorea dumetorum*) tubers

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Abstract

Processing of *Dioscorea dumetorum* tubers into flour could be a means of adding a longer-term value to this tropical plant with a high nutritional potential but which presents a post-harvest hardening problem. This study was carried out in order to investigate the effect of storage under prevailing tropical ambient conditions (19–28 °C, RH 60–85%) for 56 days on the physicochemical characteristics of flours produced from hardened tubers. With the exception of bulk density, the results showed that all the physicochemical properties measured (water absorption capacity, oil absorption capacity, water solubility index, hydrophilic–lipophilic index, swelling capacity and least gelatinising concentration) were significantly influenced by tuber storage time ($P < 0.05$). In general, the physicochemical indices increased with storage in at least two phases, from days 2 to 21 and from days 28 to 56. Since sprouting of most tubers was observed after 28 days of storage, the results suggest that post-harvest hardening and sprouting influence the above-mentioned indices of flours produced from *D. dumetorum* tubers.

Keywords: *Dioscorea dumetorum*; Physicochemical characteristics; Storage; Hardening; Sprouting

1. Introduction

Dioscorea dumetorum is one of the eight yam species commonly grown and consumed in Cameroon. It is rich in protein (9.6% dry weight basis), fairly balanced in essential amino acids (chemical score of 0.94) and highly digestible, due to its small starch granules with cereal-like structure (Mbome Lape & Trèche, 1994; Robin, 1976). This yam specie is high-yielding (40 t/ha) and may not require staking, thus saving on labour (Lyonga & Ayuk-Takem, 1982). The oval-shape and shallow-growing tubers could permit mechanised harvest.

Despite these qualities, the use of this yam as food is limited by a post-harvest hardening phenomenon that reduces its shelf life. The hardening of *D. dumetorum* begins a few hours after harvest with the tubers being resistant to chewing and cooking, even after long hours of cooking (Sealy, Renaudin, Gallant, Bouchet, & Brillouet, 1985; Trèche & Delpeuch, 1982). Hardened *D. dumetorum* yam tubers maintain a nutritional value superior to that of other yams and comparable to that of cereals (Agbor-Egbe & Trèche, 1995; Trèche, 1989; Trèche & Agbor-Egbe, 1996).

In order to add more value to *D. dumetorum* as an important source of food and energy, Trèche, Mbome Lape, and Agbor-Egbe (1984) developed a scheme for processing of its fresh tubers into instant flour with good organoleptic and nutritional qualities. However, the problem of utilisation of hardened tubers remains crucial. Mbome Lape (1991) started assay of processing hardening tubers into low-bulk gruel, with high nutrient and energy density for infants, by lactic acid fermentation and elimination of fibrous material. But from our experience and literature review, flour obtained directly from hardened tubers have poor organoleptic qualities, such as coarseness in the mouth.

The use of most flours as food ingredients depends to a large extent on their interaction with water or oil during food preparation. To the best of our knowledge,

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physicochemical properties affecting the utilisation of *D. dumetorum* flour as a food ingredient have not been well investigated. In particular, no study has so far been carried out to determine the influence of tuber storage on physicochemical properties of resulting flours.

The present study was therefore carried out to determine the influence of tuber storage on the water absorption capacity (WAC), oil absorption capacity (OAC), water solubility index (WSI), hydrophilic–lipophilic index (HLI), least gelatinising concentration, bulk density and swelling capacity (SC) of the flour.

2. Materials and methods

2.1. Materials

The trifoliate yams (*D. dumetorum*) tubers (yellow cultivar) were randomly harvested at maturity from a farm at Esse in the Centre Province of Cameroon. They were immediately transported to the laboratory and stored under prevailing tropical ambient conditions (19–28 °C, 60–85% RH) for a period of 56 days. No growth of mould was observed during the storage period. Hardening during storage was characterised by a rough and fluffy surface of peeled tubers as opposed to the smooth and moist surface of freshly harvested ones. The sprouting of most tubers was observed after 28 days of storage.

2.2. Sample preparation

Samples of stored tubers were collected at fixed time intervals (days 0, 2, 5, 7, 14, 21, 28, 42 and 56). They were thoroughly washed with water, peeled, chopped into chips of 0.5 cm thickness, dried at 35 °C in a ventilated oven for 24 h and stored at –21 °C. Prior to analysis, the dried chips were ground into flour in a Hammer mill (Campsas 82370, Labastide St-Pierre, France) to pass through a 500 μm sieve.

2.3. Moisture and ash determination

Moisture and ash contents were determined using Association of Official Analytical Chemist approved methods 925.10 and 920.87, respectively (AOAC, 1990).

2.4. Water absorption capacity and water solubility index

Water absorption capacity and water solubility index were determined as described by Philips, Chinnan, Brach, Miller, and McWatters (1988) and Anderson, Conway, Pfeifer, and Griffin (1969). About 1 g (M_0) of the sample was mixed with 10 ml of distilled water and shaken for 30 min in a KS10 agitator. The mixture was centrifuged at 4500 rpm for 30 min on a desktop centrifuge (Bioblock scientific MLWT.62.1) and the resulting sediment (M_2) was weighed and then dried at 105 °C to constant weight (M_1). The WAC was then calculated as follows:

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

while the WSI was calculated using the following equation:

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

2.5. Oil absorption capacity and hydrophilic–lipophilic index

Oil absorption capacity was estimated by centrifuging a known quantity of flour saturated with oil as described by Sosulski (1962), while HLI was determined as the ratio of WAC to that of OAC.

2.6. Least gelatinisation concentration

The least gelatinisation concentration was estimated according to the method of Coffman and Garcia (1977). Flour dispersions of 4–14% (w/v) were prepared with distilled water in test tubes and mixed for 2 min on a vortex mixer, the mixtures were then boiled for one hour and cooled. The least gelatinisation concentration (i.e. the lowest concentration that gives a stable gel when test tube is inverted) was determined.

2.7. Bulk density and swelling capacity

The bulk density of the paste obtained after mixing 100 g of flour with a given quantity of water to obtain a water content of 60% was first determined according to the method described by Okezie Onuma and Bello (1988). A 10 ml measuring cylinder, previously tarred was gently filled to mark with the paste sample. The sample was then parked by gently tapping the cylinder on the bench top until there was no further drop of the sample below the 10 ml mark. The weight of the filled cylinder was taken and the bulk density calculated as the weight of sample per unit volume of sample (g/ml). Swelling capacity was then calculated using the following equation:

$$\mathrm{SC} = \frac{d_0 + d_i}{d_0 \times d_i} \times 100, \quad (3)$$

where d_0 is the initial density and d_i the density after whipping the paste during 10 min.

2.8. Statistical analysis

All measurements were carried out in triplicate and data obtained were subjected to analysis of variance to evaluate the effects of storage factors on the properties measured. Duncan's multiple range test was used to classify these factors whenever there was a significant difference. All these analyses were carried out using the SPSS (1995) statistical package for Windows.

3. Results and discussion

3.1. Moisture and ash analysis

The moisture content of the yam tubers decreased from 77.6% to 71.8% (Fig. 1), representing 5.8% moisture loss during the 56 days of storage. Tuber dehydration is relatively low compared to that recorded by Sefa-Dedeh and Afoakwa (2002) who observed moisture loss of about 8% in the yellow cultivars of *D. dumetorum* stored under tropical ambient conditions (28 °C, 62–100% RH) after only 72 h of storage. Our results are comparable to those obtained by Trèche and Agbor-Egbe (1996) who reported moisture loss of about 8.6% within 110 days of harvesting in the yellow cultivars of *D. dumetorum*. The slow dehydration observed could be in line with the hypothesis of Trèche and Delpeuch (1982) who suggested that hardening of *D. dumetorum* tubers is associated with thickening of the cellular membrane which constitutes a natural protection against dehydration.

The ash content of yam significantly increased ($P \leqslant 0.05$) after 56 days of storage (Fig. 2). This result is in agreement with the first studies (Trèche, 1989; Trèche & Agbor-Egbe, 1996) which showed that, despite the absence of significant variation of individual mineral content during storage of *D. dumetorum* tubers, there is a significant increase of ash content. This increase of ash content is a result of tuber moisture decrease during storage (Fig. 1).

3.2. Other physicochemical properties

The use of flours in the preparation of gruel is dependent to a large extent on their interaction with

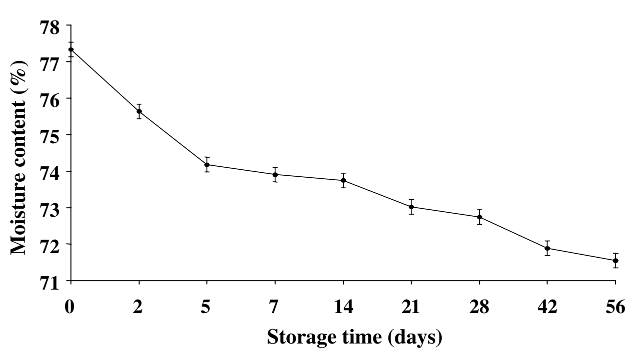

Fig. 1. Changes in moisture of *D. dumetorum* tubers during storage.

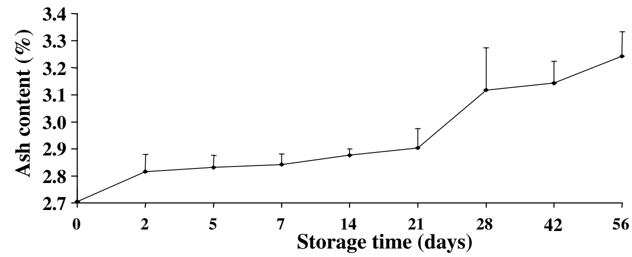

Fig. 2. Changes in ash contents of *D. dumetorum* tubers during storage.

water in the process of rehydration. In this study, it was observed that WAC and WSI of resulting flours of *D. dumetorum* tubers were significantly influenced ($P \leqslant 0.05$) by tuber storage duration (Table 1). However, these two physicochemical indices did not follow the same pattern with storage duration. Water absorption capacity increased with tuber storage in three phases, from days 0 to 2, days 5 to 21 and days 28 to 56, suggesting that storage of *D. dumetorum* tubers increases water affinity of resulting flour. On the other hand, WSI decreased from days 2 to 21 and then increased from day 28 to reach a value on day 42 comparable to that of fresh tuber. This suggests that post-harvest hardening, as well as sprouting (since sprouting of most tubers was observed after 28 days of storage), influences WSI of flours produced from *D. dumetorum* tubers. This could be due to the mobilisation of soluble substances at the beginning of hardening and the liberation of others during sprouting. Similar observations were made by Njintang, Mbofung, and Waldron (2001) who observed a significant increase in WSI of flour from germinated red bean (*Phaseolus vulgaris*).

Analysis of variance indicated that storage time of the tubers significantly affects ($P \leqslant 0.05$) the OAC of *D. dumetorum* flours. Oil absorption capacity increased with tuber storage in two phases, from days 2 to 21 and days 28 to 56 (Table 1), suggesting that post-harvest hardening and sprouting affect the OAC of flour.

Similarly, changes in HLI of *D. dumetorum* flours were markedly affected by storage time and sprouting (Table 1). There was a general increase in HLI levels. The values obtained in this study are higher than those reported by Njintang et al. (2001) for cowpea (about 1.12), suggesting that *D. dumetorum* flour has more affinity for water than for oil.

Tuber storage caused significant increase in SC of the paste obtained by *D. dumetorum* flours (Fig. 3). Peak values were observed on day 5 (about 27% of increase), day 28 (about 33%) and day 56 (about 40%). This increase could be a combined effect of post-harvest hardening and sprouting of tubers. Since swelling is associated with incorporation of air in the paste (Halling, 1981), this result suggests that post-harvest

Table 1
Effect of tuber storage duration on some physicochemical properties of flours produced by *D. dumetorum* tubers

	Storage time (days)								
	0	2	5	7	14	21	28	42	56
WAC (%)	182.3 ± 4.1^{a}	231.2 ± 8.9^{b}	290.9 ± 13.0^{c}	290.4 ± 22.8^{c}	$290.7\ 26.2^{c}$	325.6 ± 39.3^{c}	363.5 ± 9.0^{d}	385.7 ± 13.2^{d}	390.7 ± 4.4^{d}
WSI (%)	15.0 ± 0.1^{c}	12.0 ± 0.4^{a}	12.7 ± 1.3^{ab}	12.8 ± 0.6^{ab}	13.0 ± 0.5^{ab}	13.1 ± 0.2^{ab}	13.2 ± 0.5^{b}	14.6 ± 0.1^{c}	14.8 ± 0.4^{c}
OAC (%)	72.3 ± 1.9^{a}	85.9 ± 0.1^{b}	85.3 ± 0.6^{b}	85.5 ± 3.0^{b}	87.9 ± 3.9^{bc}	88.6 ± 0.6^{bc}	90.4 ± 3.3^{c}	90.5 ± 1.7^{c}	94.8 ± 2.4^{d}
HLI (%)	2.5 ± 0.1^{a}	2.7 ± 0.1^{a}	3.4 ± 0.1^{b}	3.4 ± 0.2^{b}	3.3 ± 0.5^{b}	3.7 ± 0.5^{b}	4.1 ± 0.1^{c}	4.3 ± 0.2^{c}	4.1 ± 0.1^{c}
Bulk density (g/ml)	1.02 ± 0.08	0.94 ± 0.09	0.93 ± 0.09	0.93 ± 0.09	0.94 ± 0.08	0.95 ± 0.09	0.94 ± 0.10	0.93 ± 0.07	0.95 ± 0.09

Mean ± SD, $n = 3$.
Means on the same line with different superscripts are significantly different ($P < 0.05$) according to Duncan's multiple range test.
WAC, water absorption capacity.
WSI, water solubility index.
OAC, oil absorption capacity.
HLI, hydrophilic–lipophilic index.

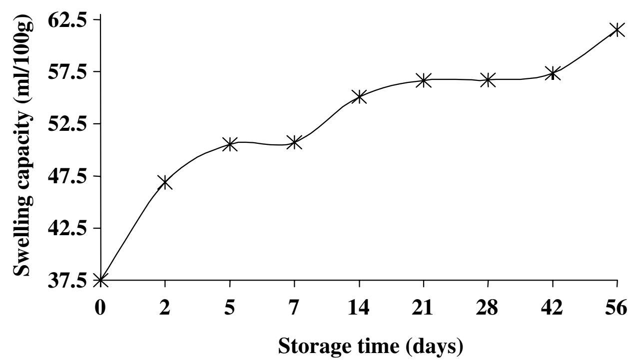

Fig. 3. Effect of *D. dumetorum* tuber storage on swelling capacity of resulting flour.

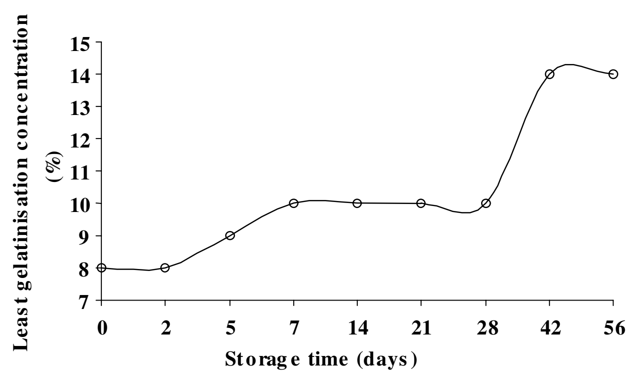

Fig. 4. Effect of *D. dumetorum* tuber storage on least gelatinisation concentration of resulting flour.

hardening and/or sprouting of *D. dumetorum* tubers increase the aptitude of the resulting flour paste to incorporate and retain air.

In contrast to the trends observed for SC during tuber storage, the bulk density of *D. dumetorum* flour paste was not significantly affected ($P \leqslant 0.05$) by tuber storage time. It varied only slightly from 1.02 to 0.93 g/ml (Table 1).

The least gelatinisation concentration of *D. dumetorum* flour increased with the tuber storage duration (Fig. 4). This concentration was 8% for fresh and 2 day-old tubers, 9% after 5 days of storage, 10% after 7–28 days and 14% from day 42 to 56. ANOVA results indicated that storage time and sprouting had significant effects ($P \leqslant 0.05$) on the least gelatinisation concentration. This result suggested that strength of the gel formed after cooking of *D. dumetorum* flour decreases with tuber storage duration. In this connection, Mbome Lape (1991) observed decrease of viscosity of gruels prepared from hardened tuber flours compared to those prepared from fresh tuber flour and suggested that this reduction is due to the increase of both α and β amylase activities in the tubers with storage time. This result was confirmed by Afoakwa and Sefa-Dedeh (2002).

4. Conclusion

D. dumetorum tubers undergo physicochemical changes as a result of post-harvest hardening and sprouting of the tubers. With the exception of bulk density, the physicochemical properties of flours produced from *D. dumetorum* tubers increased with tuber storage duration. These changes occur in two main phases from days 2 to 21 and days 28 to 56. The results suggest that, for the use of *D. dumetorum* flour as ingredient in food formulation, it is necessary to take into consideration the state of the tubers, which can be fresh, hardened or hardened and sprouted.

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