

EFFECT OF STORAGE ON THE PHYSICOCHEMICAL, FUNCTIONAL AND RHEOLOGICAL PROPERTIES OF TARO (*COLOCASIA ESCULENTA*) FLOUR AND PASTE

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Abstract

Recent studies have led to the development of a simple process for the production of precooked taro flour for the preparation of achu (taro paste). The objective of this study was to determine optimal conditions for the preservation of taro flour. For this purpose, flour was produced from boiled taro tubers. Cooked tubers were sun dried using a solar dryer, ground through a 500 µm sieve and further separated by using 250, 150 and 75 µm sieves. Flours were sealed in polyethylene bags and kept at ambient temperature (25°C) and at 4°C. One set of flour not sealed was exposed at 25°C. Flours were stored for 5 months. Physico-chemical and rheological properties of flours and paste were determined monthly. Increases in water content of flours were recorded, especially for exposed flours. Resistant starch increased with storage. Water absorption capacity and water solubility index increased during the first three months and decreased thereafter. Flour color also varied. Angle of repose increased while cohesion decreased. Paste produced from these flours decreased in hardness with storage. The highest value of gumminess was observed in the paste made from flours with particle size above 250 µm. In fact, the degree of variations of each parameter depended mainly on the storage level. This study revealed that flours kept in polyethylene bags at ambient temperature may be stored for three months without significantly ($p < 0.05$) altering their physico-chemical properties whereas 4 to 5 months is the maximum storage in polyethylene bags at 4°C.

Keywords: taro flour, paste, storage, physico-chemical, rheological properties

Introduction

Several products are carried and preserved as flours. Their role in the feed and in food industry is

very important (Nip, 1997). Flours generally have low water and in this way a means for the conservation of tubers. Its consumption became more important in urban areas in most African

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countries like Cameroon (Bricas *et al.* 1997). Trying to produce them from new sources is necessary. Taro flour (*Colocasia esculenta*) makes part of the new types of flour. Some recent studies permitted to establish a simple process to produce taro flour for preparation of achu (Njintang and Mbofung, 2003; Njintang and Mbofung, 2006a; Njintang, Parker, Moates, Mbofung, Smifh and Waldron, 2006b; Aboubakar, 2002). In this process taro tuber are cooked in its skin, peeled, sun dried and ground through 500 μm sieves. Several works have been led to improve the process of production (Njintang *et al.*, 2003; Njintang *et al.*, 2006a). The mechanical analyses done on the dough, give characteristics nearer to the traditional one (Njintang *et al.*, 2006b). However, in spite of importance of results gotten on the production, no work interested at yet, to our knowledge, on the conservation of this flour. Generally, during the storage of flour, physicochemical losses are observed. These losses can be due to the nature of flour's constituent, like autolysis phenomena such as the hydrolysis of the starch and proteins or to the inadequate relation between package, local humidity, extreme temperatures and light exposure (Cheftel and Cheftel, 1977). These modifications will directly influence rheological characteristic. Attempts to preserve these waste of rheological properties, is lead to understand different modifications during storage.

This work was initiated to optimize conservation parameters of the taro flour, specifically, to evaluate physico-chemical and rheological modifications of flours and to study rheological modifications of dough gotten by different reconstituted flours.

Materials and methods

Materials

The red variety of *Colocasia esculenta* corms, locally called «Ibo coco» used in this study were freshly harvested from a farm in Bini town (Ngaoundere-Cameroon). Corms were thoroughly washed in clean water and kept at 4°C until required for used.

Methods

Sample preparation

Cooking of tubers

Cooking was carried out to 15 min under pressure in a pressure cooker capacity 12 L. Cocoyam were plunged in tap water and pressure cooked. Initial trials had shown that 15 min. was the time necessary to cook cocoyam under pressure. Four types of cooking were made: whole steamed tubers (WST), steamed slices (SS), whole boiled tubers in tamarind (WBTT) and lemon (WBTL). Cooked tubers obtained were peeled then cut into slices. The slices were dried using a solar drier.

Production of flour

After drying slices were milled in a hammer mill equipped with a 500 μm sieve. The flours obtained were divided into three particle sizes as follow: 75, 150 and 250 μm . The flours of each particle size were stored according to three modes of storages: - storage in open polyethylene bag at ambient temperature (SOBAT) - storage in sealed polyethylene bag at ambient temperature (SSBAT) - storage in a sealed polyethylene bag in a refrigerator at 4°C (SSBRT). Flours of each particle size and of each storage regime were prepared in 5 lots and conserved in corresponding to each month of storage.

Achu preparation

Achu was prepared following two different methods: firstly following the traditional method, which entails cooking and pounding of taro corms to obtain traditional *achu* and secondly by reconstituting taro flour into *achu*. For traditionally prepared *achu*, the corms from *Ibo coco* were cooked in a pressure cooker (SEB, France) until soft, peeled and pounded in a mortar to obtain a smooth *achu*. For the preparation of *achu* from taro flour, the flours were mixed with distilled water at 25% solids contents and cooked while stirring to obtain a paste.

Proximate composition of flours

Flours were analysed for moisture (air oven method), fat (Soxhlet) and ash (direct method) contents, following AACC standard methods (1990). Total protein (Nx6.25) was analysed using

approved methods of Kjeldahl (AACC, 1990) in semi automatic machine (GEHARDT, Paris, France). The total resistant starch content were analyzed essentially as described by Goni *et al.* (1996). Samples were mixed with water and protease was added before heating in the boiling water bath. The amount of RS was then determined by digestion with amyloglucosidase after solubilisation in 2M KOH and the sugar determined as previously described (Njintang *et al.* 2003). Available carbohydrate was determined essentially as described by Njintang *et al.* (2000). Precisely, 1.5 g of flour sample was suspended in 10 ml of 1.5 N sulphuric acid and heated for 20 min after which 10 mL of a 10% NaOH solution was added to the mixture and the volume adjusted to 100 mL. The solution obtained was used for the spectrophotometric determination of reducing sugars generated from the hydrolysis of carbohydrates (Bernfeld, 1955). A 0.25 mL solution was mixed with 0.5 mL distilled water and 0.25 mL of a dinitrosalicylic acid solution and heated in a water-bath for 5 min at boiling temperature (98°C). During heating, alkaline 3,5-dinitrosalicylic acid (DNS) forms a red-brown reduction product, 3-amino-5-nitrosalicylic acid, in the presence of a reducing sugar. The intensity of the colour developed at 540 nm is proportional to the quantity of reducing sugars.

Functional properties

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

WAC and WSI were evaluated according to Phillips *et al.* (1988) and Anderson *et al.* (1969) methods, respectively. Exactly 0.1 g flour was mixed with a 10 mL of distilled water in a centrifuge tube, kept in a water-bath (30°C) for 30 min, centrifuged (Ditton LAB centrifuge, UK) at 5000 rpm for 15 min and the weight of the pellets determined. The excess water absorbed by the flour was expressed as the percentage water bound by 100 g sample. For the estimation of water solubility index, the supernatant was dried in an oven set at 105°C for 48 h and the soluble matter expressed per 100 g of flour.

Blue value index (BVI)

BVI was evaluated by the modified amylose/iodine method of Birch and Prietly (1973). Flour (0.1 g) was suspended in 10 mL distilled water, mixed for one hour in a shaking water bath (Kottermann, Germany) and centrifuged at 5000 rpm for 30 min. The supernatant was recuperated and 1 mL was mixed to 2 mL of I₂/KI (0.075%; 0.75%) reagent and the absorbance read at 620 nm on a Spectronic Genesys 2PC spectrophotometer.

Powder Characteristics

Angle of repose, angle of spatula, compressibility, density and cohesion of precooked flour were determined using Powder Characteristics Tester (model PT-N, Hosokawa Micron Corporation, Osaka, Japan). These five parameters were then converted into flow ability indices for numerical evaluations of flour flow properties.

Texture evaluation

Texture of different achu was evaluated by subjecting each sample to a compression test using a computer interfaced universal testing machine (Lloyd Model LRX-2500 N, Lloyd Instrument Ltd. Fareham, Hans, UK) equipped with a 500 N load cell. Achu pastes were compressed in a single-cycle compression–decompression test, using a flat plate (50 mm diameter) at a cross-head speed of 20 mm/min. One measurement was been made per paste, three pastes were tested per treatment, and their average values taken to represent the mean texture value of test samples. From the gathered force-deformation curve, the following parameters were obtained.

$$\text{Cohesiveness} = A_2/A_1$$

where A_1 is the area under first compression and A_2 is the area under second compression.

$$\text{Adhesiveness} = A_3 \text{ (N mm)}$$

where A_3 is area under curve, due to adhesion.

$$\text{Springiness} = \text{Displacement (mm) under the curve} / A_2$$

$$\text{Hardness} = \text{Peak force of first compression (N)}$$

Statistical analysis

Variations during storage of all component analysed, were fitted in the form of the kinetic. The

general rate of kinetics of food products is expressed as follow (Labuza and Riboh, 1982; Van Boekel, 1996):

$$d[C]/dt=k[C]^m \quad (1)$$

Where [C] represents the quantitative value studied;

k, the rate constant of reaction;

m order of the reaction.

For a first order reaction, equation (1) can be integrated as follow:

$$\ln[C]_t/[C]_0 = kt$$

[C]₀ and [C]_t, were the initial and the concentration at time t (month) of studied component.

Table 1. Chemical composition of taro (*Colocasia esculenta*) flours

Parameters Size (µm)	Dry mater (%)	Ash (%)	Proteins (%)	Total sugar (%)	Fat (%)	Resistant starch (%)
75	7.56±0.18	5.37±0.03	1.47±0.01 ^b	92.31±0.56	0.146±0.01 ^a	1.99±0.09 ^a
150	7.42±0.33	5.46±0.03	1.31±0.02 ^a	89.67±0.92	0.224±0.01 ^b	2.11±0.3 ^a
250	7.99±0.07	5.52±0.01	1.28±0.02 ^a	89.71±0.7	0.221±0.003 ^b	2.26±0.09 ^b

Means±SD ; n=3 ; values in a rows followed by different superscripts are significantly (p<0.05) different.

Similar observations were made by Wang and Flores (1999) on tortilla flours. Others authors (Lamberts *et al.*, 2005) working with rice have reported similar observations which they attributed to the same fact that, proteins were not homogeneously distributed in the endosperm of rice. Fat content on its part did not correlate with the flour particle size. The 150 µm fraction had highest fat content (0.224±0.01%), while 75µm fraction had the lower (0.146±0.01%). Resistant starch decreased with decrease in flour size from 2.26±0.09 for 250µm to 1.99±0.09 for 75 µm. The decrease of resistant starch was attributed to the damage of starch during the process. These results are in agreement with those of who found that the damage starch decreased, with the increase in flour particle size.

Figure 1 shows the general pattern of moisture absorption under the different storage conditions. These flours were characterised by rapid water

Results and discussion

The result of proximate composition of flours of different particle sizes is presented in table1. No differences were observed in dry matter, ash and total sugar among flours. But changes in proteins, fats and resistant starch are reported. In addition, flour with 75 µm size, showed a highest level of protein (1.47±0.01%) while those with 250 µm particle size had the lowest (1.28±0.02%). On the contrary, highest levels of fats and resistant starch were observed in flours with 250 µm size. These results indicate that the starch granules were released from the protein matrix during milling.

uptake during the first three months. Similar patterns were reported by Pilosof *et al.* (1985), for bean flour, soybean and corn starch and for drum dried banana by Borges and Calvidal (1994).

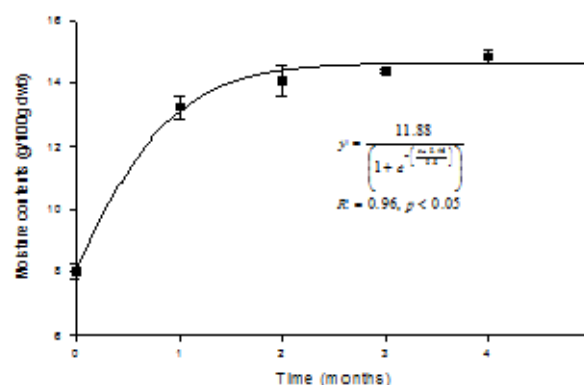


Figure 1. Moisture contents kinetic of SOBAT, SSBAT and SSBRT flours during storage respectively

Hydration profile is characterised by the increasing of the plot to a constant derived from the empirical

equation giving as follow: $Y = a \ln(t) + b$. The rate constant and the time where half the quantity of

water have been absorbed ($t_{1/2}$) are given in table 2.

Table 2. Kinetic constants of water uptake of taro flours of different particle sizes stored under different conditions.

Storage	Size(μm)	Constants		
		k(month ⁻¹)	$t_{1/2}$ (month)	R ²
SOBAT	75	0.287±0.07	2.41	0.84
	150	0.21±0.027	3.3	0.96
	250	0.179±0.013	3.87	0.98
SSBAT	75	0.462±0.1	1.5	0.86
	150	0.332±0.1	2.08	0.84
	250	0.296±0.073	2.34	0.77
SSBRT	75	0.667±0.029	1.04	0.99
	150	0.634±0.038	1.09	0.97
	250	0.809±0.083	0.809	0.97

In general, flour stored in open bags at ambient temperature (SOBAT) exhibited a higher rate of water uptake than SSBAT and SSBRT. The rate of water absorb decreases during storage ($p < 0.05$). On the other hand, the water absorption capacity (WAC) increased as a Gaussian plot with maximum levels in the third month (Figure 2). After this period all WAC decreased. Small particle size (75 μm) flours absorbed more water than larger ones (150 and 250 μm). Similar plots were obtained with WSI. These results agreed with the study of Hogan *et al.*, 1968, who explained it by the fact, that, small particle has more water binding sites.

The variation in resistant starch is represented in Figure 3. Resistant starch formation increased with storage time and the rate of resistant starch formation was highest in flours with 250 μm particle size.

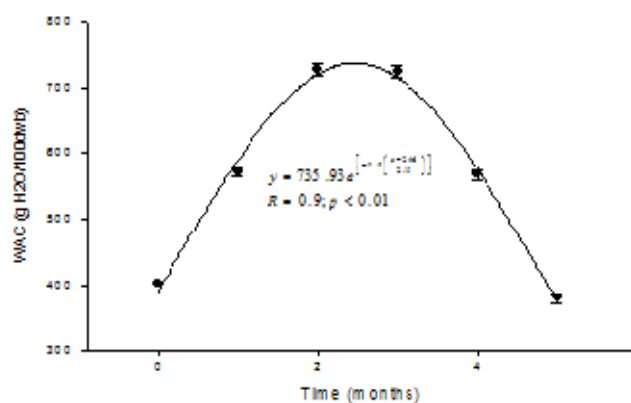


Figure 2. WAC kinetic of SOBAT, SSBAT and SSBRT flours during storage respectively

This increase was more apparent in SSBRT ($2.05 \pm 0.134 \text{ month}^{-1}$) flours than SOBAT and SSBAT flours (0.223 ± 0.04 and $0.389 \pm 0.2 \text{ month}^{-1}$). Highest values of resistant starch were obtained in SOBAT flours ($5.78 \pm 0.15 \text{ g/100 g d.b.}$).

These observations were attributed to the effect of cooking techniques and storage condition by means of retrogradation. These results were similar to observation made by many authors Asp, 1995; Englyst and Hudson, 1996; Englyst *et al.*,

1992; Goni *et al.*, 1996; Siljestrom *et al.*, 1989; Muir and O’Dea, 1992; on some products as bread, breakfast cereals, biscuits, boiled rice and potatoes, parota and wheat flour, oats, banana respectively.

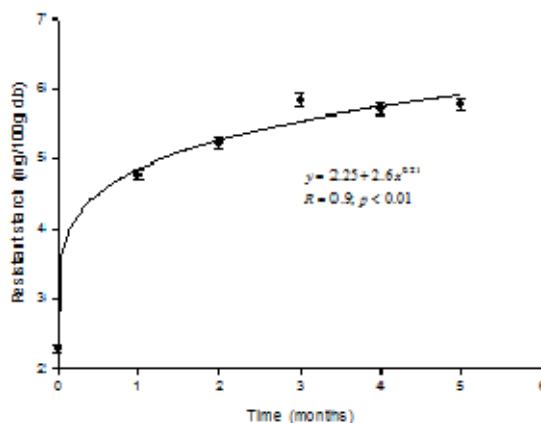


Figure 3. Resistant starch kinetic of SOBAT, SSBAT and SSBRT flours during storage respectively

Table 3. Kinetic constants of resistant starch of taro flours of different particle sizes stored under different conditions.

Storage	Size(μm)	Constants		
		k(month ⁻¹)	t _{1/2} (month)	R ²
SOBAT	75	0.223±0.09	3,107	0.81
	150	0.396±0.12	1,75	0.85
	250	0.572±0.1	1,21	0.89
SSBAT	75	0.389±0.2	1,78	0.87
	150	0.454±0.1	1,526	0.88
	250	0.523±0.1	1,325	0.92
SSBRT	75	0.818±0.19	0,847	0.98
	150	0.913±0.07	0,759	0.86
	250	2.05±0.13	0,338	0.98

Several factors determine the proportion of dietary starch that becomes resistant starch. Important factors are starch source, granular structure of starch, degree of processing and presence of other nutrients like protein, fat and fibre (Annison and Topping, 1994; Muir and O’Dea, 1992; Siljestrom *et al.*, 1989). High resistant starch content in flours reflects the presence of starch with the A and B type crystal structure, which is resistant to enzymatic digestion (Annison and Topping, 1994). Thus, it is possible that the processing conditions (precooking), used in the preparation of taro flours in this study favour the formation of retrograded starch. This could have an implication on blue value index (BVI). Indeed, the rate of blue value index decreased with storage time (Figure 4).

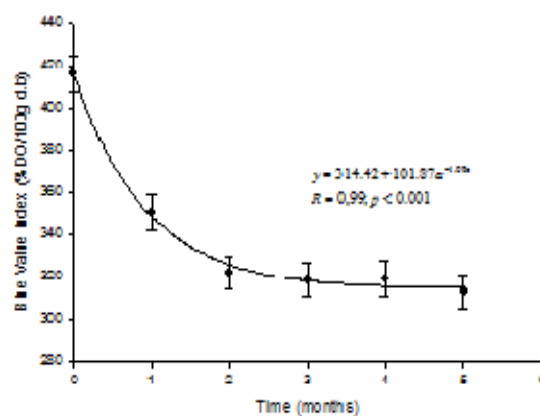


Figure 4. BVI kinetic of SOBAT, SSBAT and SSBRT flours during storage respectively

The BVI decreased during the first two months for all flours sizes. This decrease was intense (320%

DO/100 g) for big particle sizes (150 and 250 μm) and moderate for the small particle size (75 μm). There was a positive correlation ($R=0.82$; $p<0.005$) between the BVI and particle size of flours. Similar interactions ($R=0.85$, $p<0.05$) were also observed between BVI and storage month. Indeed, during the storage big particle sizes flours crystallized quickly under the effect of retrogradation to give a glycolipidic complex or resistant starches. A positive correlation ($R=0.59$, $p<0.05$) were fitted between resistant starch and BVI. These agree with previous observations made by Njintang and Mbofung, 2003 using taro flours.

Levels of reducing sugar in the flours were generally higher at the end of storage period. Figure 5 shows variations in reducing sugars contents of flours with storage. The level of reducing sugar were influenced by flour particle size ($p<0.05$). Flours with large particle sizes (250 μm) had higher reducing sugar content than those with a smaller particle sizes (75 μm). This observation could suggest that, more water had

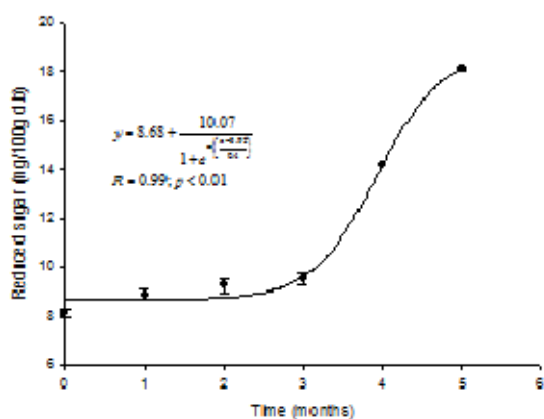


Figure 5. Reduced sugar kinetic of SOBAT, SSBAT and SSBRT flours during storage respectively

been absorbed by large particle size flour. This absorption induced the hydrolysis of long chain sugars. Shaller, 1978 made similar observation on American foods. Simultaneously, storage method influenced too the level of reduced sugar. All time SOBAT has shown an increasing closely of 20%. This means that, flours stored in this condition hydrolysis quickly. This result was lower than that obtained by Rasiklal *et al.*, 1970. Those authors showed an increase of reducing sugar of close to 18% in 4 months of wheat flours stored in 23, 30 and 37°C.

The color of flour samples measured using the $L^*a^*b^*$ color space (CIELAB space) are presented in figure 6, 7. The difference between color value were significant ($p<0.05$).

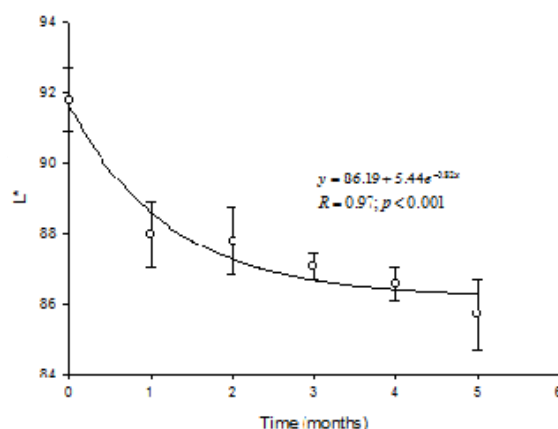


Figure 6. Lightness (L^*) kinetic of SOBAT, SSBAT and SSBRT flours during storage respectively

The L^* values (Figure 6), of flour decreased with storage time. This decrease is very important in flour with large particle size (2.65%) than in those of small particle sizes (2.35%). The decrease of the luminescence (L^*) would be related to the darkness of the flour. This accounts to the increase of parameter value a^* (Redness) and b^* (yellowness).

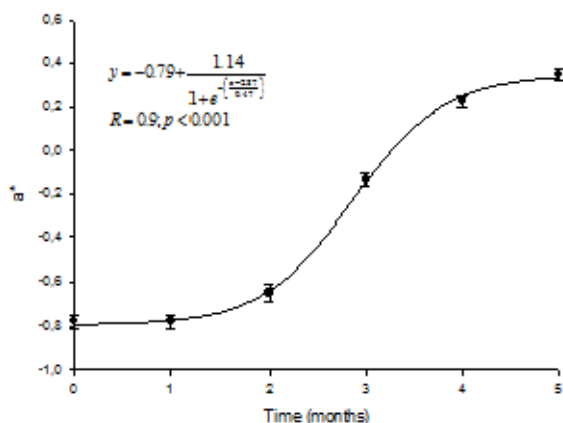


Figure 7. Redness (a^*) kinetic of SOBAT, SSBAT and SSBRT flours during storage respectively

Besides, the statistical analyses show a combined significant influence of the type of storage and the particle size on parameters a^* and b^* ($p < 0.05$). Parameters a^* and b^* increased with the time of

storage. There equally was observed a good correlation ($R=0.87$, $p < 0.05$) between the parameter a^* and reduced sugar. Reduced sugar and free amino acids are important factors of the browning phenomenon. In fact, this result is in agreement with the one gotten by Jamin and Flores, 1998 that explain the increase of the value of a^* by a presence of important value of sugar and proteins in the flour of corn. It clearly justifies the implication of parameters in the no enzymatic browning to the fading of flour. Kerr *et al.*, 2000 have also made this observation on the flour of *Vigna unguiculata*.

Physical characteristics of powder were evaluated using a Powder Characteristics Tester. The variation in the angle of repose (Figure 8 a, b, c) is a function of the time of storage and the type of storage.

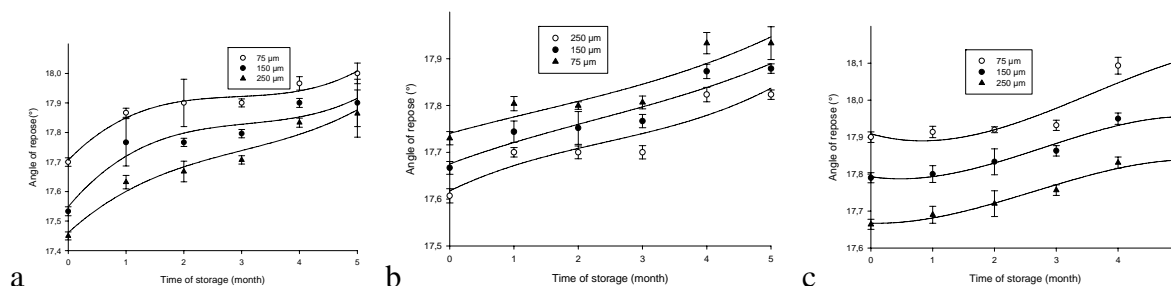


Figure 8 a, b, c. Variation of angle of repose of SOBAT, SSBAT and SSBRT flours during storage respectively

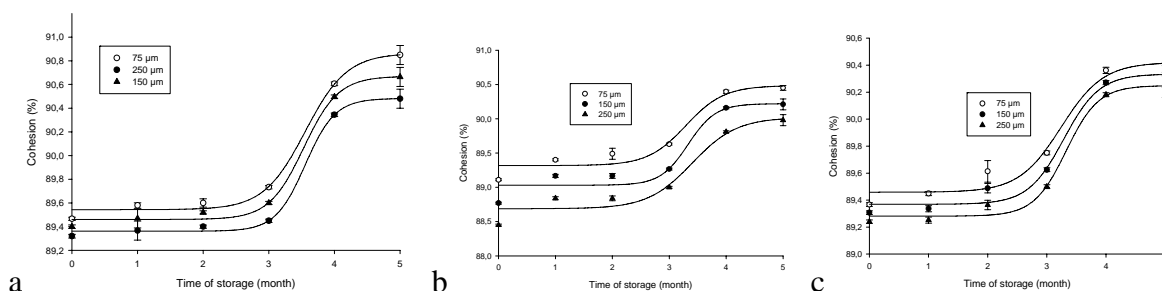


Figure 9 a, b, c. Variation of cohesion of SOBAT, SSBAT and SSBRT flours during storage respectively

This increase of cohesion could be explained by the fact that during storage, the flours absorb water and increase by particle size. A significant correlation was observed between moisture contents and cohesion ($R=0.65$, $p < 0.05$). This phenomenon is similar with that observed by Richefeu, 2004 which showed that when the particles absorbed water, their cohesion increased.

This suggests a fall of flowability of flours during storage.

Analysis of the textural profile made it possible to obtain as a completely two positive curves and two negative curves. The peak of the first cycle of compression is regarded as hardness. Figure 10 (a, b, c) shows that the highest hardness is observed in paste produced with 250 µm flour (3.03 N) and softness is traditional paste (1.88 N).

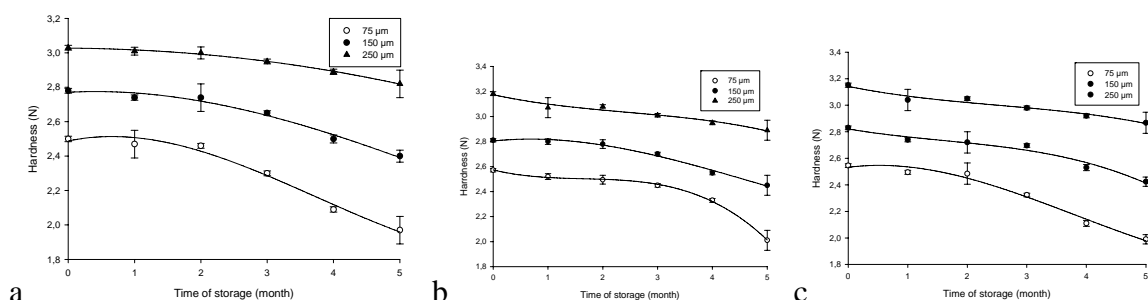


Figure 10 a, b, c. Variation of hardness of SOBAT, SSBAT and SSBRT flours during storage respectively

The hardness of all the pastes decreases considerably with storage. This fall starts slowly the first three months of storage and is accentuated beyond this period. The plastic structure changes gradually to a rigid structure of low hardness. This transformation is higher in the case of the pastes produced from SOBAT flours than that of SSBAT

flour. [Rahman and Al-Farsi, 2005](#) which had made similar study on the pastes of dates observed similar results. Though the paste of taro is not a rigid structure, it would be more important to measure energy necessary to transform it into a structure ready to be swallowed; this structure is the gumminess (Figure 11a, b, c).

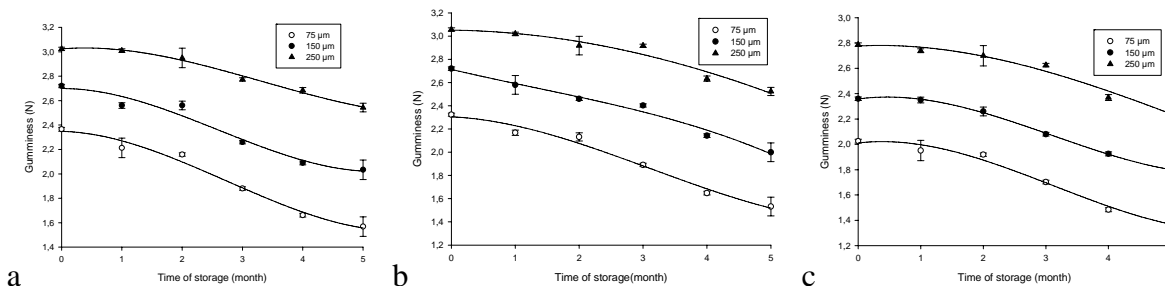


Figure 11 a, b, c. Variation of gumminess of SOBAT, SSBAT and SSBRT flours during storage respectively

The highest value was observed in pastes of flours with large particle sizes (250 µm) (2.788 N) and the low value in the traditional pastes (1.377 N). The adhesiveness is a very important parameter in the evaluation of gumminess foods. It measures work necessary to exceed gravitational attraction between the surface of the paste and the surface of the instrument at which paste is putted in contact (adhesiveness) (Figure 12 (a, b, c). Traditional paste had higher values (-76.895 N.s) than the

pastes resulting from the flours (-155.3 N.s). It was observed that, particle size had no significant effect on the adhesiveness. The figures show an increase in adhesiveness with storage. This increase is important after the third month of storage. This observation means that, during storage starches of taro flour were hydrolysed [Njintang, Mbofung and Kesteloot \(2007\)](#) working on taro paste observed similar reduction in adhesiveness with increase in particle size.

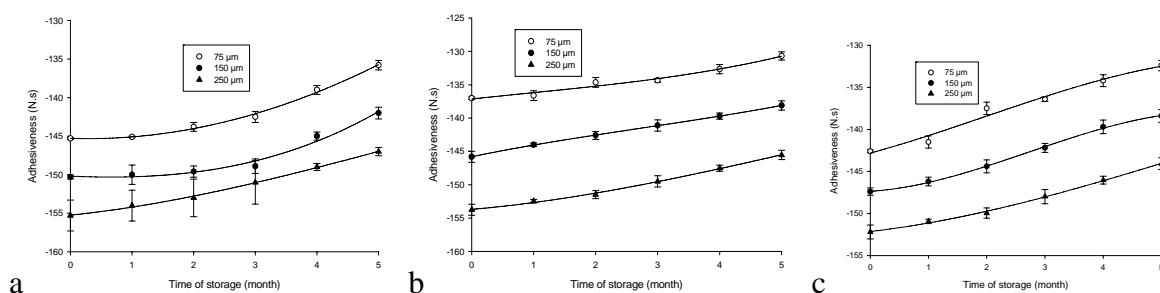


Figure 12 a, b, c. Variation of adhesiveness of SOBAT, SSBAT and SSBRT flours during storage respectively

Conclusions

The results obtained showed some differences on the physico-chemical and rheological properties of flours and pastes. The study revealed that during five months of storage, variations in water content of flours were recorded, especially for exposed flours. In addition, resistant starch increased. Water absorption capacity and water solubility index increased during the first three months and decreased thereafter. Colours of flours also varied. The lightness decreased, while redness and yellowness increased. Angle of repose was increasing while cohesion was decreasing. The hardness of all the pastes decreased considerably with storage. The highest value of gumminess was observed in the pastes of the flours with large particles sizes. It was observed high values of adhesiveness in the traditional paste than the pastes resulting from flours. This result showed that the date line of storing taro flour can not exceed 3 month for flours kept in polyethylene bags at ambient temperature. To keep good physico-chemical and rheological parameters, flours have to be stored in a sealed polyethylene bag.

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