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Evaluation of breadfruit (*Artocarpus communis*) in traditional stiff porridge foods

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Abstract

Process parameters for producing the best breadfruit flours for stiff porridges were determined. Physical properties, chemical composition, and storage properties of the flours; and sensory properties of stiff porridges of the flours were determined. Chips of dimensions 1.0 x 1.5 x 1.5 cm of the pulp of unripe, but matured breadfruit, dried at 80°C for 18 hours produced the best flour. Concentrations of the chemical components of pre-cooked pulp flour were higher than that of the raw pulp flour, with the exception of starch, while flour from the mixture of pulp and core contains higher percentages of ash, fat, protein and fibre compared with either the raw or pre-cooked pulp flours. Flours from the core were brown, while the other breadfruit parts, including pulp with core, produced cream-coloured flours. Viscosity of flour pastes increased rapidly as from flour concentration of 30 g kg^{-1}. Sugar content increased, while swelling power and paste viscosity decreased during storage of breadfruit flour. Flour of raw pulp cooked at 300 g kg^{-1} flour concentration resembled breadfruit stiff porridge best, while pre-cooked flour at 350 g kg^{-1} flour concentration produced a porridge comparable with stiff porridge of freshly cooked and pounded breadfruit pulp in terms of hardness, stickiness and mouldability.

Key words: Breadfruit flour, stiff porridges, physical, chemical, sensory, storage properties.

Introduction

The breadfruit belongs to the Mulberry family Moraceae [1]. The plant is called by three different botanical names *Artocarpus communis, Artocarpus altilis and Artocarpus incisa*, which are used interchangeably [2]. The plant grows in the Tropics, where the fruits are used in a variety of food preparations. The fruit has been used to make cakes, syrup, jam, vinegar, and starch, cooked into puddings, and porridges, or baked, roasted, or fried as chips [1]. In Nigeria, the breadfruit is regarded as the poor man's substitute for yam (*Dioscorea esculenta* and *D. cayenensis*), because it is used in several traditional food preparations of yam, but costs less than one-third the cost of procuring yam at the market. It is used in soft and stiff porridge dishes, boiled as boiled yam, fried as chips, and roasted as roast yam The breadfruit has been made into flour and evaluated in bakery products [3,4] , but it has not been evaluated into traditional yam flour like products. Currently, the two types of yam flour products manufactured in Nigeria are the yam flour 'elubo', which is traditionally made by parboiling yam chips at about 80°C till the chips are pliable, then the chips are sun-dried and ground into flour. The yam flour is reconstituted by in boiling water and cooked with continuous stirring until a thick brown or grey-coloured smooth paste is formed, which is consumed with sauce [5]. Pounded-yam flour, which is a modern invention to simplify the tedious traditional process of preparing pounded yam, is the other manufactured yam product in the flour form. The traditional process for the preparation of pounded yam is a tedious process, which involves pounding cooked slices of yam in a mortar using a pestle to a smooth dough consistency. However pounded yam flour is manufactured by drying cooked yam chips in the oven, then pulverising the dried chips into flour. The flour, when reconstituted, produces a white to creamy-white smooth dough, similar to the yam pounded in the mortar. The breadfruit (*Artocarpus communis*) has not been used to produce yam flour or pounded-yam flour-like products. The objective of this study was to evaluate breadfruit in traditional stiff porridge foods.

Experimental

A preliminary experiment was conducted to determine the sensory preferences of the breadfruit producing and consuming populations of Ile-Ife and surrounding towns of Nigeria for yam flour and pounded yam products. The people described their preferences for colour, taste, flavour and texture, for both products, which is presented in Table 1. These organoleptic preferences formed the basis on which the yam flour and pounded yam flour products of breadfruit were developed. Thereafter, the effects of maturity and stage of ripeness of the fruit, of peeling and coring on flour quality were investigated. The effect of sulphating on the colour of the flours was also evaluated. Pulp from unripe mature and ripe mature fruits was processed into flour. Flour from uncooked pulp, and mixture of pulp and core, were evaluated for the breadfruit paste, while flour from cooked pulp and cooked mixture of pulp and core were evaluated for pounded breadfruit stiff porridges. Process variables evaluated for breadfruit flours included chip sizes and shapes, duration of boiling in water at 100°C (6, 8, 10 and 12 minutes), drying temperatures and duration (65°C for 24 hours, or 80°C for 15 – 24 hours) of the fruits. The dried chips were ground to pass through 0.8, 1.0, and 1.2 mm screen openings to determine the most acceptable particle size.

Flour preparation: A flow chart for the preparation of breadfruit flours is presented in Fig. 1. Freshly harvested matured but unripe breadfruit was obtained from Ile-Ife, Oshun state, Nigeria. The fruits were washed in clean water from the mains to remove adhering latex and dirt. Then the fruits were peeled manually, and samples consisting of the whole fruit, pulp plus core, and core alone, were diced into 1.0 x 1.5 x 1.5-cm pieces with a stainless steel knife. The pulp chips for the cooked flour were cooked in boiling water for 10 min, then, dried in a forced air oven at 80°C for 18 hours. The dried chips were ground in a hammer mill to pass through 0.8 mm screen opening. Uncooked pulp dices and other diced parts were treated similarly. The ground samples were packed into 200 ì m-thick polyethylene bags and sealed for storage in the laboratory at ambient temperature (25-30°C).

Material balance: acid method of Dubois et al. [9].

Flour storage properties: Flours packed and sealed in 200ì m thick, polyethylene bags were stored in the laboratory at ambient temperatures (25-30°C) for fifteen weeks. Aliquot samples were extracted weekly and evaluated for swelling power, viscosity and sugar content. The bags were re-sealed tightly after the samples had been extracted.

Physical and functional properties of flour: Bulk density was determined as the ratio of the mass of flour and the volume it occupies in a graduated cylinder. Water-binding capacity of flours was determined using the method of Medcalf and Gilles [10]. Flour (2 g) was suspended in 15 mlL of distilled water for 10 minutes and centrifuged at 2500 rpm for minutes. Swelling power of 0.2 g of flour in 18 mlL of distilled water, was determined according to the method of Leach et al [11]. Temperature intervals of 5° C, from 65 to 100°C were used in the determination. Flour suspensions (10 – 100g kg^{-1} solids dry weight), were heated at 100°C for 30 minutes in a water bath, then cooled to room temperature. Viscosity of the resultant pastes were measured using a Baroid-280 rheometer (Baroid Division NL Inc.) at 600 and 300 rpm for 15 sec. Apparent paste viscosity was calculated as half the dial reading at 600 rpm while plastic viscosity was calculated as the difference between the dial readings at 600 and 300 rpm respectively.

Reconstitution of flour and sensory evaluation of stiff porridges *:* Flour from raw pulp chips was reconstituted into paste at 250,300, and 350 g kg^{-1} solids dry weight in 1L of boiling water over a low gas flame with continuous stirring for 1 min. Flour from cooked chips was treated similarly, but at concentrations of 300, 350 and 400g kg^{-1} solids dry weight, respectively. Texture of the stiff porridges in terms of hardness, mouldability and stickiness, were evaluated by an 18-member panel of judges using the texture characteristics described by Szczesniac [12]. Texture of the stiff porridge from the reconstituted raw pulp flour was assessed by a rank order test using the hedonic scale preference analysis described by Larmond [13], while texture preference between cooked and pounded breadfruit pulp and the reconstituted cooked breadfruit pulp flour porridges were determined by multiple comparison test. Scores were based on a 9-point hedonic scale, where 9 was extremely liked; 5 was neither like nor dislike and 1was extremely disliked. Also the taste panel members were asked to rate the colour and flavour as indices of the overall acceptability of the porridges. Variances in the means of the scores were determined [14] and separated using Duncan's new multiple range test [15].

Results and Discussion

Preliminary work shows that there was no need to sulphite in breadfruit pulp to prevent browning during the processes of peeling, coring and dicing, which lasted about one hour. Akinpelu (unpublished) reported that 3% sulphite prevented browning of breadfruit during processing, and Onayemi and Potter [16] suggested peeling the fruit under water for the same purpose. However except for the pulp from incompletely peeled fruit, which turned green, and the core, which turned brown, the colour of the pulp was creamy white to cream after boiling or drying. Optimum boiling time of the chips at 100°C was 10 min after which the material disintegrated in the boiling water. Optimum drying size was 1 x 1.5 x 1.5 cm. Excessive shrinkage and case hardening occurred in samples of greater dimensions at the drying temperatures employed in this study. Akinpelu (unpublished) suggested a thickness not greater than 1.5 cm with other dimensions ranging between 2.5 to 2.7 cm, while Loos et al [17] and Graham and DeBravo [4] suggested 1 cm^3 as optimal for uniform heat transfer during dehydration of breadfruit. Breadfruit pulp pieces dried at 65°C were sweet due to hydrolysis of starch into sugar at the relatively low drying temperature, and were not suitable for producing either of the two flour products. Pulp dried at 80°C for more than 18 h was scorched and unsuitable for the pounded yam-like flour. Therefore the samples were dried at 80°C for 18 hours (Fig. 1). Drying temperatures ranging from 60 to 80 °C have been used by various workers [3,4,18] for drying breadfruit with varying physicochemical properties of the flours. However, where a bland taste is desirable, and starch gelatinisation does not adversely affect product quality, it may be necessary to use a high enough initial temperature to inactivate the amylolytic enzyme before drying at a lower temperature to prevent hydrolysis of starch to sugar.

Material balance: The peel, core and pulp are in the ratio 10:13:77 respectively on a wet basis and 34:25:40 on dry weight basis (Table 2). Moisture content of the various parts ranged from 718 g kg^{-1} in the pulp to 826 g kg^{-1} in the core. Flour yield on dry weight basis was lowest in the core and highest in the pulp in relation to the moisture content of the parts.

Proximate chemical composition: Proximate chemical composition of the breadfruit flours (Table 3) shows that ash concentration was highest in the peel and lowest in the pulp. The crude fibre, fat, and protein were highest in the core and lowest in the pulp. Thus all the essential nutrients, with the exception of ash, which is highest in the peel, and starch, which is highest in the pulp, were concentrated in the core of breadfruit, indicating the desirability of incorporating breadfruit core in breadfruit dishes. However, the tendency of the core to turn brown after boiling and drying makes the inclusion of the core undesirable in certain foods where cream or white colour is preferred, such as in the pounded yam-like breadfruit product. Boiling increased the other components of the pulp significantly ($p \leq 0.05$) by reducing the starch content. Starch was reduced to sugar by enzyme hydrolysis during boiling of the pulp, as indicated by the increase in sugar and a decrease in the starch content of the cooked pulp. Flour prepared from peeled fruit not cored, contained greater amounts of ash, fat, and protein, compared to the raw or cooked pulp flours (Table 2). Breadfruit is a very valuable food resource on account of its higher ash, fat and protein contents as compared with cassava and yam flours [19]. The main minerals of breadfruit are iron, sodium, zinc and potassium, while the main vitamins are niacin, riboflavin, and ascorbic acid [4]. The lower starch contents of the flours from the peel and the core, compared with flour from the pulp, may be due to the greater fibre contents of these flours. The starch contents of the raw and cooked pulp flours were within the range of 680 to 770 g kg^{-1} starch reported for breadfruit flour [4,17,18]. The sugar content of the raw pulp was similar to the value (47 g kg^{-1}) reported by Ogazi [20] for plantain flour. A high sugar content results in faint sweetness in breadfruit flour products [18], which is undesirable in either yam flour or pounded yam or pounded breadfruit flour stiff porridge products.

Table 1. Desired sensory attributes of breadfruit stiff porridge and pounded breadfruit stiff porridge.

Sensory Attributes	Breadfruit Stiff Porridge	Pounded Breadfruit Stiff Porridge
Colour	Grey yellow/Cream	Pale yellow/ Creamy white
Taste	Bland	Bland
Flavour	Breadfruit peculiar flavour	Breadfruit peculiar flavour
Texture	Smooth paste, slightly sticky	Smooth dough, elastic and comparatively less sticky

Table 2. Mean[1] material balance of breadfruit.

	Peel	Core	Pulp
Weight (g kg^{-1})	101 ± 4	132 ± 6	767 ± 14
Moisture content (g kg^{-1})	742 ± 15	826 ± 11	718 ± 17
Flour Yield (g kg^{-1})	297 ± 11	205 ± 14	337 ± 6

[1.]Means and Standard deviation of 5 determinations on wet weight basis

Table 3. Mean [1,2] chemical composition of breadfruit flours (g kg-1).

f Flour	Moisture	Ash	Crude Fibre	Crude Protein	Crude Fat	Starch	Sugar
Pulp (Raw)	37d	24d	75e	43e	18d	755a	48b
Pulp (Pre-cooked)	41c	27d	86de	57d	19d	718b	52a
Peel	53a	59a	128ab	73b	33ab	619d	36d
Core	48b	48b	146a	97a	34a	583e	44c
Pulp plus Core	45b	41c	103cd	64c	25c	674c	48b
Whole Fruit	47b	45b	107b	66c	28bc	666c	42c

[1]Means of three replicates.

[2]Means with the same letters in a column are not significantly (p ≤ 0.05) different.

Table 4. Mean [1,2] physical and functional properties of breadfruit flours.

Sample	Colour (Flour)	Colour (Porridge)	Texture (Flour)	Texture (Porridge)	Bulk Density (kg m^{-3})	Water Binding Capacity(%)	Swelling Power (cP) [3]	Apparent Viscosity (cP) [3]	Plastic Viscosity
Pulp (Raw)	Creamy-white	Grayish-cream	Fine	Hard, Pasty	.380c	181.0a	17.4a	84.0a	55.0a
Pupl (Pre -cooked)	Creamy	Creamy white	Coarse	Hard and fragile	.706a	154.5c	13.8c	61.0b	46.0b
Core	Brown	Dark brown	Fine	Soft and fragile	.439b	172.0b	14.5bc	51.0c	36.5d
Pulp plus Core	Creamy white	Grayish cream	Fine	Hard and fragile	.429b	178.5a	15.2ab	54.0c	40.0c

[1]Data are means of three replicates.; [2]Means with the same letters in a column are not (p ≤ 0.05) different;

[3]Viscosity of Flour at 60g Kg-1 flour concentration.

Table 5. Mean [1,2] scores of sensory attributes of breadfruit stiff porridges.

	Breadfruit flour Stiff Porridge			Pre-cooked Breadfruit flour Stiff Porridge		
	Flour Concentration (g kg^{-1})					
Sensory Attributes	250	300	350	300	350	400
Hardness	5.50b	7.25a	5.00b	5.38a	5.88a	3.75b
Mouldability	5.50b	7.00a	4.88b	5.13a	5.75a	3.75b
Stickiness	5.63b	7.38a	4.88b	5.25a	6.00a	3.88b
Overall Acceptability	4.63b	7.00a	3.75b	4.75b	6.75a	4.24b

[1] Means with the same letters for each attribute within a product are not different (p≤0.05).; [2]Means of 18 scores.

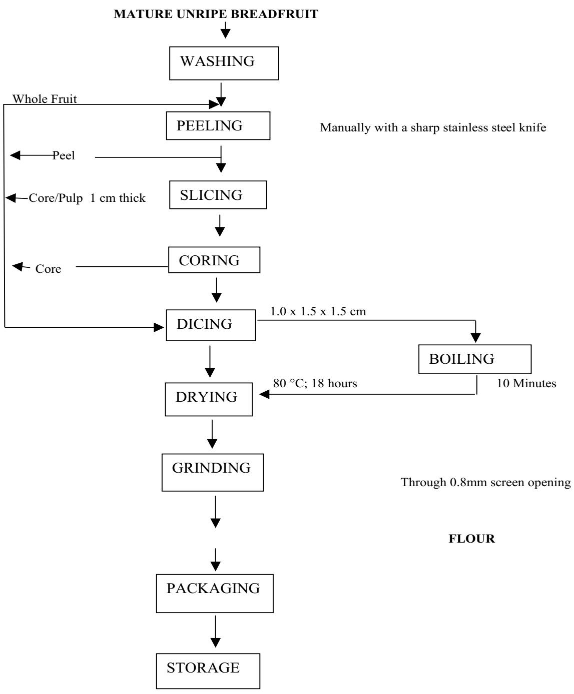

Figure 1. Flow chart of breadfruit flour processing.

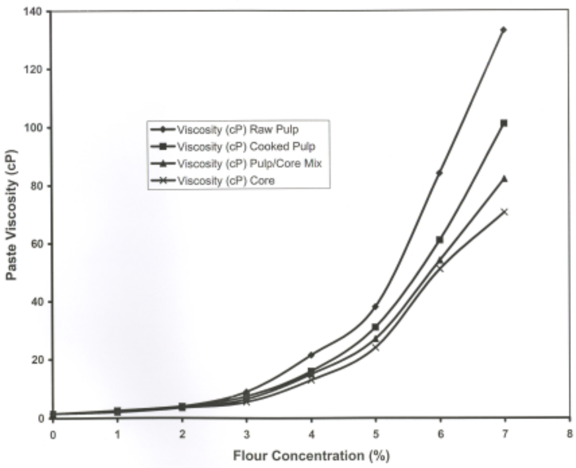

Figure 2. Viscosity of breadfruit pastes at different flour concentrations.

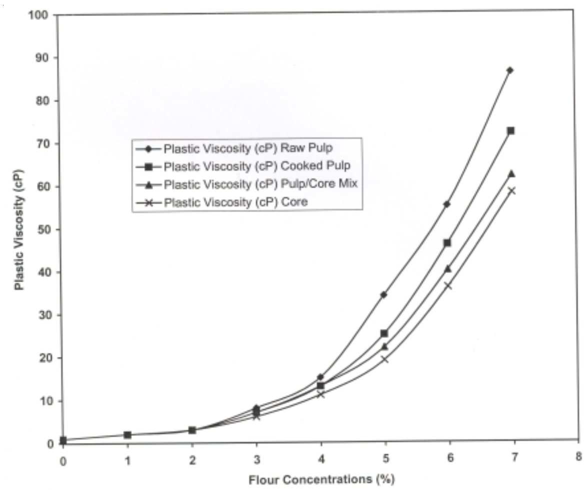

Figure 3. Paste viscosity at different concentrations of breadfruit flours.

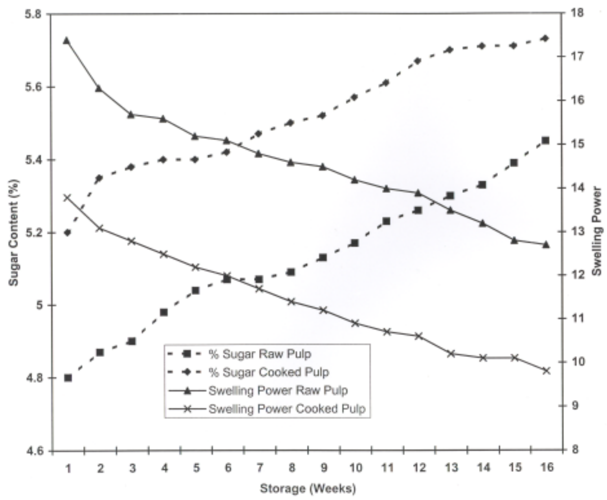

Figure 4. Changes in swelling power and sugar content during storage of beadfruit flour.

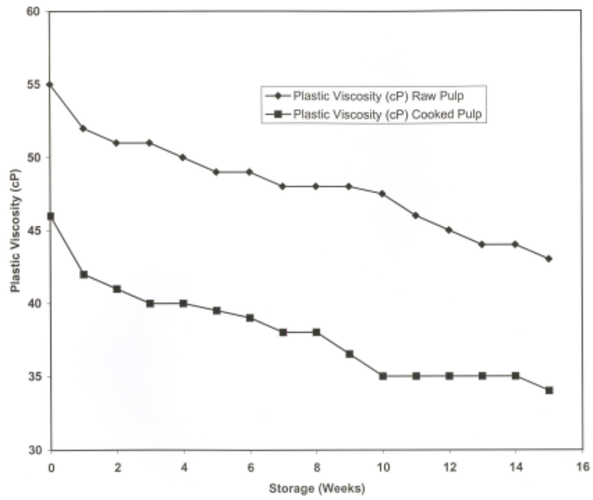

Figure 5. Changes in plastic viscosity of stored beadfruit flour.

Physical and functional properties of breadfruit flours: Flour from the core, which contained higher protein and sugar contents, turned brown during drying due to Maillard oxidative reaction [21]. However, the activity of polyphenoloxidase seemed to have been confirmed by colours of the pastes of the raw pulp and the raw pulp plus core flours, which turned grey, while the paste from the cooked pulp, with the enzyme destroyed, maintained the creamy white colour of the cooked flour. The grey tinge must have been developed during drying due to the lower dry heat of drying the flour compared with the higher moist heat (100°C) of boiling used for the cooked pulp, which must have destroyed the enzyme. Thus, depending on the use intended for the flours, sulphiting might be necessary to prevent polyphenoloxidase activity. However, sulphiting was not necessary for the preparation of either of the flours for the products of this study. Grey colour is characteristic of pastes of both yam and cassava flours [5].

Flour texture: All the flours, except flour of the cooked pulp, had fine grain texture. Flour of the cooked pulp was coarser because cooked pulp turned mealy and upon drying produced flour that was coarser than that produced from the more friable dry uncooked chips. Stiff porridge from the raw pulp flour was pasty and slightly sticky, which are characteristic of yam flour, cassava, or breadfruit flour stiff porridges. Stiff porridge of flours from the core, pulp and core and the cooked pulp flours were less sticky and more fragile and resembled the pounded yam or pounded breadfruit stiff porridge in texture. However, the colour of the stiff porridge from the core was dark brown, and the texture was soft. These two characteristics might preclude the use of flour from the core for pounded breadfruit stiff porridge. The grey colour of the stiff porridge of the core with pulp flour is also unacceptable for the pounded breadfruit product. Softness of the stiff porridge of flour from the core was due to the lower starch content of this flour (Table 3).

Bulk density: Bulk density of flour from cooked pulp was greater than the bulk density of flours of the uncooked breadfruit parts (Table 4) because cooking consolidated the pulp into a meal, displacing the air spaces in the material. Thus grinding the dry meal into flour particle size produced particles with little or no internal air spaces, which were denser than particles of the more friable dry chips from the uncooked breadfruit parts. It is possible that during boiling of the pulp for 10 minutes, the amylose component of the starch granules leached out, thus binding the granules together. This agrees with Itiola's [22] suggestion that fragmented starch particles have higher inter-particulate bonding, which facilitate closer packing, resulting in higher bulk density.

Water binding capacity of flours: Flour from the raw pulp flour had the highest water binding capacity that was comparable ($p \leq 0.05$) to the water binding capacity of flour of raw pulp and core (Table 4). This would have been due to the higher contents of undamaged starch granules in this flour compared with the cooked pulp and the raw core fractions (Table 3). Though the flour from cooked pulp had higher starch content than flour from the pulp plus core, the damage to the starch through moist heat and enzyme hydrolysis during boiling, as indicated by the higher sugar content, reduced the water binding capacity of this flour. The lower water binding capacity of cooked pulp flour was due to starch damage due to cooking, drying and milling [23]. The higher sugar content of flour from the cooked pulp would also reduce its water binding capacity. Flour from the core had the lowest starch, but the highest crude fibre content (Table 3). Fibre has a high water binding capacity and is recommended in diets for this purpose. The high water binding capacity of crude fibre is displayed in the high water holding capacity of flour from the core.

Swelling power and paste viscosity:The swelling power and paste viscosity of the flours, which are starch properties, followed the same trend as the starch content except for the flour of cooked pulp, where the starch had been damaged. Swelling power of the cooked flour was the lowest, in agreement with the report by Leach et al. [11], while the effect of starch concentration was evident in the viscosity of the flours. The swelling of the flour in this study (4-17-fold) was lower than swelling reported by Loos et al [17] and Adewusi et al [18] for purified isolated breadfruit flours. The lower swelling power of the flours in this study compared with reports on isolated starch granules [17,18] was due to restrictions imposed on the free swelling of starch by the surrounding cell walls [24]. However part of the observed depression of swelling power may be attributed to dilution of starch concentration by sugar, ash protein and fat components of the flour and the solute effect of sugar which reduced starch swelling.

Storage property of flours : Sugar content of the flours increased during storage of the flours for fifteen weeks (Fig 5). This indicates the continued activity of starch hydrolysing enzymes even at the low moisture of storage of the flours (Table 2). Ihedioha et al [25] reported a similar trend for stored cassava flour. There was an initial difference in the sugar content of the flours due to boiling, otherwise, pre-heating did not appear to have had any effect on the activity of the enzyme which continued at the same rate in the pre-cooked and the raw flour samples. Both samples had been dried at 80°C for 18h, which should have destroyed the enzyme, but which apparently did not. The swelling power and plastic viscosity were reduced with increasing length of storage and increasing sugar content. The conversion of starch to sugar reduces the swelling power of starch. Also increasing sugar concentration reduced starch concentration and reduces starch swelling through the solute effect.

Storage properties of breadfruit flours : The sugar content of the flours increased by 14.6% and 9.6% for raw and cooked flours respectively at the end of 15-week storage at ambient temperature (Fig. 4). Though the increase of the sugar contents were lower than 7%, which gave a faint sweetness to reconstituted pounded-yam products [26], the resultant decrease in the swelling power of the flours was ($p \leq 0.05$) significant at the end of the storage period. Swelling power of the raw pulp decreased by 37%, while that of the cooked pulp decreased by 27.8% at the end of 15-week storage. These reductions of the swelling power of the flours are bound to reduce hardness, mouldability, and increase in the stickiness of the stiff porridges of the flours. The increase in sugar content and the reduction of the swelling power and plastic viscosity of the flours all indicate that the amylolytic enzyme of breadfruit was still active during flour storage. The greater percent increase of sugar of the raw flour indicated greater enzyme activity of the flour. To preserve breadfruit flours over long storage periods with little or no loss to the textural quality of stiff porridges derived from the flours, processing methods to inactivate the enzyme(s) would have to be devised.

Sensory evaluation of stiff porridges: Sensory scores of the texture of stiff porridges of breadfruit flours are presented in table 5. The paste of the raw pulp flour at 300 g solids kg $^{-1}$ flour suspension concentration was rated significantly better in hardness, mouldability and stickiness than pastes of 250 and 350 g solids kg $^{-1}$ flour suspension, and resembled the paste of reconstituted traditional yam flour best. For the stiff porridge of the cooked pulp flour, which was an analogue of the traditional pounded yam or pounded breadfruit, the hardness, mouldability and stickiness of 30 and 35% flour solids in water were rated similar, and better than the stiff porridge of 40% flour solids. However the stiff porridge containing 350g solids kg $^{-1}$ content was the most acceptable overall of the three concentrations evaluated, and was rated to be very similar to the texture of the stiff porridge obtained by cooking and pounding fresh breadfruit.

Conclusions

Unripe mature breadfruit was processed into flours, which on reconstitution in boiling water, produced yam flour-like and pounded yam or pounded breadfruit-like stiff porridges. These flours, which were well accepted for sensory texture, and flavour can alleviate hunger and reduce the tedium of cooking, particularly for the poor population of the breadfruit growing and consuming areas of Nigeria. However, the flour did not store well because of the activity of starch hydrolysing enzymes present in the fruit, which were not deactivated during processing. More research is needed on the preservation of the quality of breadfruit flour during storage.

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