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Full Length Research Paper

Functional and pasting characteristics of breadfruit (*Artocarpus altilis*) flours

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Breadfruit was processed to obtain whole and pulp flours following removal of the core. The flours were evaluated for proximate analysis, physicochemical, functional and pasting characteristics. The results showed that pulp flour exhibited significantly ($p < 0.05$) higher moisture and protein (11.42 and 5.49%, respectively) but lower crude fibre and carbohydrate contents (5.78 and 79.46%, respectively). The water absorption and oil absorption capacities were significantly ($p < 0.05$) higher in whole flour (267.4 and 139.9%, respectively) than in pulp (154.7 and 81.62%, respectively). The bulk densities were 0.56 g/ml for the pulp and 0.69 g/ml for whole flour. Swelling power and water absorption capacity generally increased with increasing temperature (60 to 90°C). Whole flour demonstrated a greater ability to absorb more water as temperature increased while pulp showed a higher capacity to swell with increasing temperature. The whole flour showed a significantly higher gelatinization temperature (81.4°C) when compared to the pulp (78.3°C). The values of 2714, 2231 and 4712 cP obtained for the peak viscosity, trough viscosity and final viscosity were significantly higher than corresponding values of 768, 686 and 1182 cP recorded for whole flour.

Key words: Breadfruit, pulp flour, water absorption, swelling capacity, pasting properties.

INTRODUCTION

Breadfruit (*Artocarpus altilis*) is a tropical fruit native to Malaysia and countries of the South Pacific and the Caribbean and it is an important food in these areas (Taylor and Tuia, 2007). Breadfruits are found from sea level to about 1550 m elevation. The latitudinal limits are approximately 17°N and S, but maritime climates extend that range to the tropics of cancer and capricorn (Ragone, 2007). The tree has a great productive ability with an average sized tree producing 400 to 600 fruits per year (NTBG, 2009). It has been reported that breadfruit yields in terms of food are superior to other starchy staples such as cassava and yam (Singh, 2009). The mature fruit is a good source of carbohydrate (84%) with starch constituting more than 60% of the total carbohydrate (Oladunjoye et al., 2010).

Breadfruit has been processed into many forms for utilization. After peeling, the fruits are boiled, pounded and eaten with soups just like pounded yam. Processing of breadfruit into starches (Loos et al., 1981) and flour (Olatunji and Akerele, 1978) has also been reported. Although, breadfruit is nutritious, cheap and available in high abundance during its season, it has found limited applications in the food industries (Omobuwajo, 2003). One major factor limiting its availability is its poor storability, as the fruits undergo rapid physiological deterioration after harvesting.

In many food-deficit countries, the need to fully utilize all existing foodstuffs with a view to alleviating poverty and hunger is now receiving considerable attention. One way to minimize post-harvest losses and increase the utilization of breadfruit is through processing into flour, which is a more stable intermediate product. The flour can then be the starting material for processing through reconstitution with hot water to form a paste or dough. The suitability of the flour for use as food or food ingredients will however depend on its functional properties. The objective of this work was therefore to provide information on the chemical, functional and rheological properties of whole breadfruit and pulp flours

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with a view to establishing the full industrial potential of breadfruit flours for utilization as foods and food ingredients.

MATERIALS AND METHODS

Freshly harvested matured but unripe breadfruits were obtained from the fields in Ile-Ife (7° 29 N, 4° 33 E) and adjoining villages in Osun State, Nigeria.

Preparation of breadfruit flour

The fresh fruits were washed in clean water to remove adhering latex and dirt and subsequently peeled. After peeling, the fruits were divided into two portions. The first portion was sliced and the core (heart and stem) was separated while the second portion was sliced without removing the core. Eventually, samples consisting of the whole breadfruit (pulp with core) and pulp were obtained. Each of these samples was then dried in a hot air oven at a temperature of 60°C for 6 to 8 h. The dried samples were then milled using Marlex Excella grinder (Marlex Appliances PVT., Daman). The ground samples were packaged in polyethylene bags and then stored at -4°C for further use.

Chemical analysis

Protein content of samples was determined by the modified Lowry method (Markwell et al., 1978). Moisture, lipid, ash and crude fibre contents of samples were determined by standard methods of analysis (AOAC, 1990). Carbohydrate content was determined by difference.

Physicochemical and functional properties analyses

Bulk density

Bulk density was determined by the method of Okezie and Bello (1988). A 10 ml graduated cylinder, previously tared, was gently filled with the sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/ml).

pH

The pH was measured by making a 10% w/v suspension of the sample in distilled water. The suspension was mixed thoroughly in a Sorex blender and the pH was measured with a Hanna checker pH meter (Model HI1270).

Water absorption capacity (WAC)

The WAC was determined at room temperature and at temperatures ranging between 60 to 90°C using a combination of the AACC (1995) method and those of Sosulski (1962) and Rutkowski and Kozlowska (1981). A 2 g sample was dispersed in 20 ml of distilled water. The contents were mixed for 30 s every 10 min using a glass rod and after mixing five times, centrifuged at 4000 g for 20 min. The supernatant was carefully decanted and then the contents of the tube were allowed to drain at a 45° angle for 10 min and then weighed. The water absorption capacity was expressed as percentage increase of the sample weight.

Oil absorption

Oil absorption capacity of the flour samples was determined by the centrifugal method elicited by Beuchat (1977) with slight modifications. One gram of sample was mixed with 10 ml of pure canola oil for 60 s, the mixture was allowed to stand for 10 min at room temperature, centrifuged at 4000 g for 30 min and the oil that separated was carefully decanted and the tubes were allowed to drain at a 45° angle for 10 min and then weighed. Oil absorption was expressed as percentage increase of the sample weight.

Gelling concentration (GC)

The method of Sathe and Salunkhe (1981) was employed for the determination of gelling concentration. Sample suspensions of 1, 3, 5, 7, 9, 11, 13, 15, 17 and 20% (w/v) were prepared in 5 ml distilled water and the test tubes were heated in a boiling water bath for 1 h followed by rapid cooling under running cold tap water. The test tubes were further cooled for 2 h at 4°C. Least gelling concentration was determined as that concentration when the sample from the inverted test tube did not fall down or slip.

Swelling capacity (SC)

Swelling capacity was determined using the method elicited by Takashi and Sieb (1988) with slight modifications. Briefly, 3 to 5 g samples were weighed into tared 50 ml centrifuge tube. About 30 ml distilled water was added and mixed gently. The slurry was heated at a constant temperature (60, 70, 80, and 90°C) in a water bath for 15 min. During heating, the slurry was stirred gently to prevent clumping of the starch. On completion of the 15 min, the tube containing the paste was centrifuged at 3000 g for 10 min. The supernatant was decanted immediately after centrifugation. The tubes were dried at 50°C for 30 min, cooled and then weighed (W_2). Centrifuge tubes containing sample alone were weighed prior to adding distilled water (W_1). Swelling capacity was calculated as follows:

Swelling capacity = $[W_2\ (g) - W_1\ (g)]/$ Weight of sample (g)

Pasting characteristics

The pasting characteristics of flour samples were determined using a Rapid Visco Analyser (Newport Scientific Pty Ltd. Warriewood NSW 2102, Australia) hooked on to a workstation (Figure 3)

The moisture content of the sample was first determined to obtain the correct sample weight and amount of water required for the test. An aqueous suspension of sample was then made and spun at 75 rpm. The temperature-time conditions included a heating step from 50 to 95°C at 6°C/min (after an equilibration time of 1 min at 50°C), a holding phase at 95°C for 5 min, a cooling step from 95 to 50°C for 2 min. Readings were displayed on the monitor in a numerical and graphical form. Viscosities were expressed in centipoises.

Statistical analysis

All experiments were conducted in triplicate. Data reported are averages of three determinations. The mean values were compared Using Paired-samples T test procedure of SPSS version 13.0 (SPSS, Chicago, IL, USA).

Table 1. Chemical composition (%) of breadfruit whole and pulp flours.

Composition	Whole flour	Pulp flour
Moisture	7.78 ± 0.49^a	11.42 ± 0.62^b
Protein	3.79 ± 0.19^a	5.49 ± 0.22^b
Fat	1.09 ± 0.01^a	1.49 ± 0.08^a
Ash	2.10 ± 0.23^a	2.06 ± 0.20^a
Crude fibre	5.78 ± 0.07^a	2.93 ± 0.11^b
Carbohydrate	79.46 ± 3.29^a	76.61 ± 1.26^b

Values with similar letters within the same row are not significantly ($p < 0.05$) different.

Table 2. Physicochemical and functional properties of breadfruit whole and pulp flours.

Property	Whole flour	Pulp flour
WAC (%)	267.4 ± 0.29^a	154.7± 0.75^b
OAC (%)	139.9 ± 1.02^a	81.62 ± 0.94^b
LGC (%)	10.00 ± 0.57^a	8.00 ± 0.61^b
BD (g/ml)	0.69 ± 0.01^a	0.56 ± 0.02^a
pH	5.67 ± 0.05^a	6.07 ± 0.02^b

WAC, Water absorption capacity; OAC, oil absorption capacity; LGC, least gelling concentration; BD, bulk density. Values with similar letters within the same row are not significantly ($p < 0.05$) different.

RESULTS AND DISCUSSION

Proximate composition

The results of proximate analysis are presented in Table 1. The moisture and protein contents of the pulp flour (11.42 and 5.49%) were significantly ($P < 0.05$) higher than those of the whole flour (7.78 and 3.79%). The moisture values obtained for both flours are comparable to that of bambarra groundnut flour (Sirivongpaisal, 2008) but lower than that reported for sweet potato flours (Osundahunsi et al., 2003). Carbohydrate, crude fibre, ash and fat were higher in whole flour than in pulp. The protein contents of the pulp and whole flour were lower than the protein content of the African breadfruit kernel of 17.1% reported by Akubor et al. (2000), higher than cassava protein (2.45%), compare favourably with maize protein (5.2%) (Ibanga and Oladele, 2008) and were within the range of values reported for breadfruit pulp, skin and stem and heart by Graham and De-Bravo (1981). While the ash and the fat contents of breadfruit whole flour and pulp were higher than those of cassava and maize flours, the carbohydrates were lower than those reported for cassava and maize by Ibanga and Oladele (2008).

Physicochemical and functional properties

The results of bulk density, pH, water absorption capacity, oil absorption capacity and least gelling concentration are presented in Table 2. The bulk density was between 0.56 g/ml for the pulp and 0.69 g/ml for the whole flour. The high volume per gram of flour material is important in relation to its packaging. Increase in bulk density is desirable in that it offers greater packaging advantage, as a greater quantity may be packed within a constant volume (Fagbemi, 1999). The aqueous solutions of both flours were acidic but whole flour was more acidic (pH 5.67) than the pulp (pH 6.07). This implied that the core probably contained some organic acid. The pH of flour suspension is important since some functional properties such as solubility, emulsifying activity and foaming properties are affected by pH.

The water and oil absorption capacities of the whole flour (267.4 and 139.9%, respectively) were higher than for pulp (154.7 and 81.62%, respectively). Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food. It is desirable in food systems to improve yield and consistency and give body to the food (Osundahunsi et al., 2003). There was a significant difference between the water absorption capacities of the whole flour (267.4%) and pulp (154.7%). The difference may be attributed to the difference in their carbohydrate contents. The water absorption capacity of breadfruit flours (whole and pulp) was higher than those reported for native red (24%) and white (26%) sweet potato flour (Osundahunsi et al., 2003), yam flour (88.48%) by Jimoh and Olatidoye (2009) but lower than those reported for fermented maize flour (271.7%) and

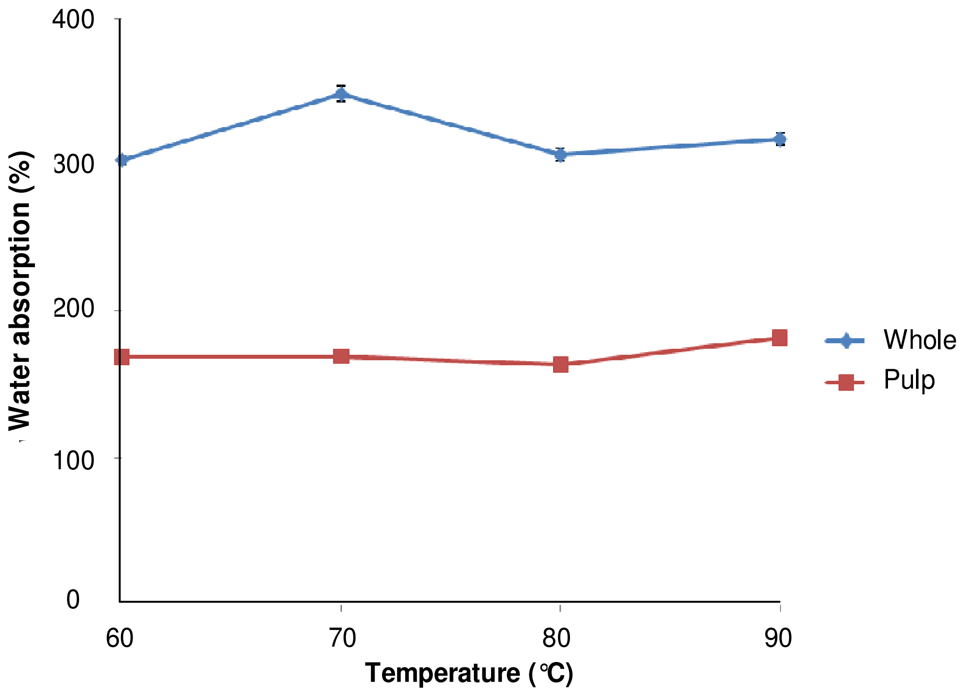

Figure 1. Water absorption capacity of breadfruit whole and pulp flours as a function of temperature.

bambarra groundnut flour (227%) by Fasasi et al. (2007) and Sirivongpaisal (2008), respectively. These results suggest that breadfruit flour may find useful applications in food formulations especially those involving dough handling such as fufu (fermented cassava dough).

The oil absorption capacity followed a similar pattern with the whole flour exhibiting significant oil absorption capacity. The oil absorption capacity of breadfruit flour was lower than the values reported for raw (230%) and heat processed (350%) jackfruit flour (Odoemelam, 2005) and fermented maize flour (Fasasi et al., 2007) but compared favourably with that of bambarra groundnut flour (Sirivongpaisal, 2008). Fat absorption is an important property in food formulations because fats improve the flavour and mouthfeel of foods (Odoemelam, 2003).

The pulp exhibited superior gelling power by forming a stable gel at 8% flour concentration when compared to the whole flour which formed a stable gel at 10% flour concentration. The least gelling concentrations obtained for whole breadfruit flour and pulp compared well with the value reported for fermented maize flour (10%, w/v) by Fasasi et al. (2007), lower than those of *Dioscorea alata* varieties (30 to 50%, w/v) reported by Udensi et al. (2008) and lupin seed (14%, w/v) (Sathe et al., 1982). The difference in gelling concentration of the whole flour and pulp may be attributed to the relative ratios of different constituents such as proteins, carbohydrates and lipids that make up the flours and the interactions between such components (Sathe et al., 1982).

Effect of temperature on water absorption and swelling capacities

The result of water absorption capacity as influenced by temperature for whole flour and pulp is shown in Figure 1. The water absorption capacity of whole flour was found to increase between 60 and 70℃ and then decreased between 80 and 90℃. The water absorption capacity of pulp flour increased with increasing temperature. However, the whole flour showed significant higher capacity to absorb water and swell at all temperatures of investigation in this study. The water absorption capacity for the whole flour ranged between 303.9 to 348% with the highest amount of water being absorbed at 70℃. The water absorption capacity of the pulp on the other hand varied between 169.42 to 182.16%. Increase in water absorption capacity of flour as a result of increase in temperature is in conformity with earlier reports for red and white sweet potato (Osundahunsi et al., 2003) and for fermented maize flour (Fasasi et al., 2007). The higher carbohydrate content in whole flour may be responsible for its higher water absorption capacity. Water absorption capacity ranging from 149.1 to 471.5% is considered critical in viscous foods such as soups, gravies (Aletor et al., 2002), hence the flours may find use as functional ingredients in soups, gravies and baked

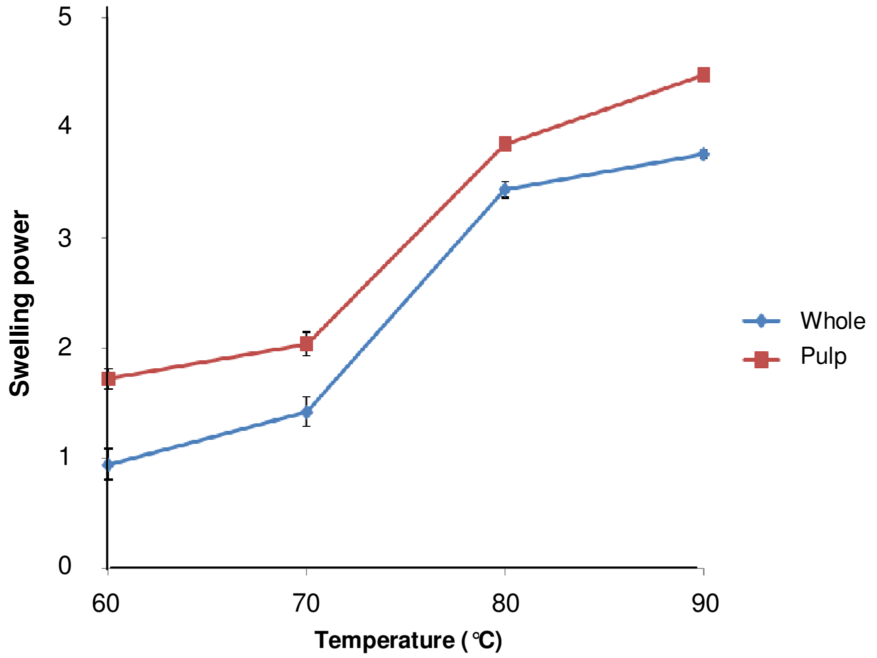

Figure 2. Swelling power of breadfruit whole and pulp flours as a function of temperature.

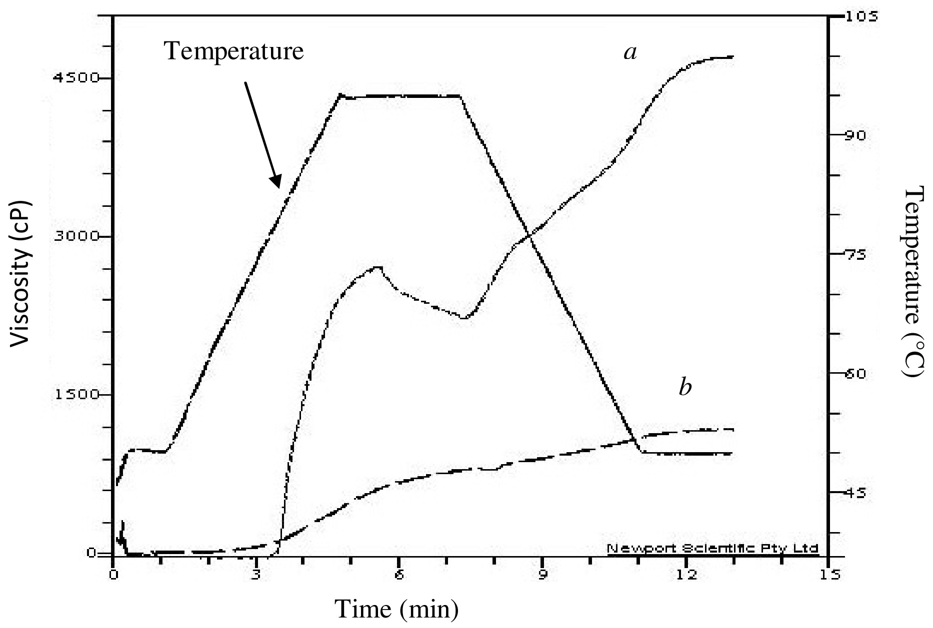

Figure 3. Rapid visco analyzer pasting profiles of breadfruit whole flour (b) and breadfruit pulp flour (b).

products. It could also be used as thickeners in liquid and semi liquid foods since the flour has the ability to absorb water and swell for improved consistency in food. The result of swelling power as a function of temperature is depicted in Figure 2. Generally, the swelling power was observed to increase with increase in temperature with the pulp exhibiting significant ability to swell when compared with the whole flour. The swelling capacity of

Table 3. Pasting properties of breadfruit flour samples.

Property	Whole flour	Pulp flour
PV (cP)	768 ± 5.69^a	2714± 3.12^b
TV (cP)	686 ± 1.35^a	2231± 2.06^b
BV (cP)	82 ± 3.98^a	483 ± 7.06^b
FV (cP)	1182 ± 4.54^a	4712 ± 6.28^b
SV (cP)	496 ± 2.06^a	2481 ± 1.71^b
P_{Temp} (℃)	81.04 ± 0.48^a	78.30 ± 0.72^b

PV, Peak viscosity; TV, trough viscosity; BV, breakdown viscosity; FV, final viscosity; SV, setback viscosity; $P_{Temp,}$ pasting temperature. Values with different letters in the same row are significantly ($p < 0.05$) different.

the pulp varied between 1.72 and 4.48. The minimum and maximum swelling power for the pulp was obtained at 60 and 90℃ respectively. A sharp increase in swelling power was observed between 80 and 90 ℃. The swelling power for the whole flour ranged between 0.95 (60℃) and 3.76 (90℃). The increase in swelling power followed a similar pattern with a sharp rise in swelling power between 80 and 90℃. The swelling power of breadfruit flour was significantly lower than the swelling power of its native and modified starches obtained in our laboratory. The higher protein content in pulp may have contributed significantly to its higher swelling capacity.

Pasting properties

The transition from a suspension of starch granules to a paste, when heat is applied, is accompanied by a large increase in viscosity. The pasting properties of whole flour and pulp from Artocarpus communis are presented in Table 3. The pasting temperature of the whole flour (81.4℃) was significantly higher than that of the pulp (78.3℃). The pasting temperature provides an indication of the minimum temperature required to cook a given sample and also indicate energy costs. The pasting temperatures of breadfruit flours were higher than the gelatinization temperature of 70.5℃ reported for Ogi (fermented maize) flour by Oluwamukomi et al. (2005), higher than 66.7 and 67.2℃ for white and red sweet potato flours, respectively (Osundahunsi et al., 2003) and compared well with the value (80.5℃) reported for bambarra groundnut flour (Sirivongpaisal, 2008).

The pulp also exhibited significant higher peak and trough viscosities (2714 and 2231 cP) when compared to the whole flour (768 and 686 cP). The higher peak viscosity of the pulp might be related to the proportion of starch in the flour, the ratio of amylose to amylopectin and the resistance of its starch granules to swelling. The presence in higher amounts of other non starchy constituents in the whole flour may also be a contributing factor.

The breakdown viscosity (BV) which is a measure of the cooked flour to disintegration was found to be significantly higher for pulp (483 cP) than for whole flour (82 cP). This implies that the whole flour is more stable to heat and mechanical shear than the pulp. Final viscosity (indicates the ability of the flour to form a viscous paste) ranged between 1182 and 4712 cP for whole flour and pulp, respectively. The increase in viscosity which occurs as a result of cooling is mainly due to re-association between starch molecules, especially amylose. The results of the final viscosity suggest that the proportion of starch and by extension the amylose content of the whole flour is considerably lower than that of the pulp. The lower setback value obtained for whole flour suggested a reduction in retrogradation tendency.

Conclusion

In view of high water and oil absorption capacities of breadfruit whole flour and greater swelling capacity of the pulp, breadfruit flours may serve as useful ingredients in food formulations such as in dough, soups, gravies and baked products.

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