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# Functional Properties of Raw and Heat Processed Jackfruit (*Artocarpus heterophyllus*) Flour

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**Abstract:** The functional properties, water and oil absorption, gelation, bulk density, foaming, emulsification and nitrogen solubility were studied. The effects of pH and NaCl concentration on some of these functional properties were also investigated. Emulsification, foam capacity and nitrogen solubility were pH-dependent with minimum values at pH 4. Addition of NaCl up to 0.4 M improved emulsification capacity of both raw and heat processed flours whereas a decrease was observed in foam capacity after 0.2 M. The foam of the raw flour was more stable than that of the heat processed flour. Heat processing of jackfruit flour increased the water and oil absorption capacity but lowered nitrogen solubility, foam capacity and emulsification capacity. Water and oil absorption capacities of raw jackfruit flour were 2.3 ml $g^{-1}$ and 2.8 ml $g^{-1}$, respectively; while heat processed flour sample gave 3.5 ml $g^{-1}$ and 3.1 ml $g^{-1}$. The water and oil absorption capacities of the heat processed jackfruit flour were significantly higher ($p < 0.05$) than those of the raw flour. Least gelation concentration of raw jackfruit flour was found to be 16% and heat processed flour, 18% while bulk densities of 0.61 g $ml^{-1}$ and 0.54 g $ml^{-1}$ were calculated for raw and heat processed flours, respectively.

**Key words:** Jackfruit, moraceae, flour, functionality

## Introduction

Jacktree (*Artocarpus heterophyllus* L.) belongs to the family Moraceae. It grows abundantly in Bangladesh, India and in many parts of Southeast Asia (Rahman *et al*., 1999). It is cultivated in some of the countries in the evergreen forest zone of West Africa (Burkill, 1997). In Nigeria, its cultivation has not been encouraged, though it is found in the south-coastal parts of the country where it grows wild or semi-conserved. Jackfruit, a dicotyledonous compound fruit of the jacktree provides approximately 2 MJ of energy per kg-wet weight of ripe perianth (Ahmed *et al*., 1986). Jackfruit has been reported to contain high levels of protein, starch, calcium and thiamine (Burkill, 1997). In Bangladesh it is commonly referred to as 'the poor man's food' (Rahman *et al*., 1995).

The pulp of the ripe jackfruit may be eaten fresh or incorporated into fruit salad. The seeds are eaten when boiled or roasted. Most staple foods are becoming more expensive in Nigeria. For this reason many people now consume jackfruit which provides an inexpensive source of nutritious edible seed.

Jackfruit occurs naturally in two textural forms; in one the perianth becomes soft and pulpy when ripe while, in the other the perianth remains firm (Rahman *et al*., 1999). The soft variety was used in this study. The composition of jackfruit perianth and seed has been reported (Selvaraj and Pal, 1989; Bobbio *et al*., 1978; Rahman *et al*., 1995; Hossain *et al*., 1990). No systematic work on the functional properties of jackfruit has so far been reported. The present study was undertaken to investigate the functional properties of flour produced from jackfruit seeds to determine its potential in food formulation.

## Materials and Methods

Mature fruits obtained from Umuapu in Imo State of Nigeria, were stored for two days at ambient temperature (Rahman *et al*., 1995). The seeds were separated from the perianths and shelled manually after steeping for 6 hours. The seeds selected for raw flour samples were first sliced with a knife. Raw jackfruit flour was made from seeds, which were dried (60°C, 24 h) and then milled to pass through a 0.5 mm sieve. Heat processed flour was made from seeds which were roasted (120°C, 2 h) and milled to pass through a 0.5 mm sieve. Raw and heat processed flours to be used for determination of functional properties were defatted by solvent extraction using n-hexane. All samples were stored in capped plastic bottles kept in a refrigerator (~ 4°C) until required for use.

### Functional properties

**Water and oil absorption:** Water and oil absorption determinations were carried out as described by Abbey and Ibeh (1988) using 1 g of flour and 10 ml distilled water or refined vegetable oil (Life Brand. Density, 0.89 g $ml^{-1}$). The determinations were carried out in triplicate at room temperature and the values were expressed as ml of water or oil absorbed by 1 g of flour.

**Bulk density:** This was determined by the method of

Narayana and Narasinga Rao (1984). A calibrated centrifuge tube was weighed and flour samples were filled to 5 ml by constant tapping until there was no further change in volume. The contents were weighed and from the difference in weight the bulk density of the sample was calculated.

**Foam capacity and stability:** Foam capacity and stability were determined by the method of Lawhon *et al.* (1972) with slight modifications. The flour (2 g) was suspended in distilled water (100 ml) and stirred at room temperature for 5 min using a magnetic stirrer at 10 Ruhrer speed (Phywe, Gottigen, Germany). The contents along with the foam were immediately poured into a 250 ml measuring cylinder. Volume of foam (ml) after mixing was expressed as the foam capacity and then volume over a time period of 20-120 min as foam stability for the respective time periods. Foam capacity measurements were also made using NaCl solutions of 0.2-1.0 M concentrations and pH between 1 and 12. Measurements were made in triplicate and averaged.

**Emulsification capacity:** Emulsification capacity was determined according to the procedure of Beuchat *et al.*, (1975) at room temperature. A 2 g flour sample and 23 ml of distilled water or NaCl (0.2-1.0 M) solution were mixed for 30 s using a Phywe magnetic stirrer at 10 Ruhrer speed. After complete dispersion, refined vegetable oil (Life Brand, density 0.89 g $ml^{-1}$) was added continuously (in ml portions) from a burette and blending continued at room temperature until the emulsion breakpoint was reached, when there was separation into two layers. Emulsification capacity was also determined in the pH range of 1-12 and the values are expressed as milliliters of oil emulsified by 1 g of flour.

**Nitrogen solubility:** This was determined as described by Narayana and Narasinga Rao (1982). Nitrogen solubility of both raw and heat processed jackfruit flour was determined in the pH range of 1-12, using 1 g flour, with a meal: water ratio of 1:60 and shaking for 2 h at room temperature. The pH of the suspension was adjusted by the addition of 2 M HCl or 2 M NaOH. After extraction, the suspension was centrifuged for 20 min at 400 rpm at room temperature, and nitrogen in the supernatant was estimated by the micro-Kjeldahl method (Pearson, 1976). Nitrogen extracted was expressed as percentage of the flour nitrogen content. Analyses were performed in triplicate.

**Gelation capacity:** Least gelation concentrations for raw and heat processed jackfruit flours were determined using the method of Coffman and Garcia (1977) as modified by Abbey and Ibeh (1988). Flour samples were mixed with 5 ml of distilled water in test tubes to obtain suspensions of 2-20% (w/v) concentration. The test tubes were heated for 1 h in a boiling water bath, cooled rapidly under running tap water and further cooled for 2 h in a refrigerator at 4°C. The least gelation concentration was regarded as that concentration at which the sample from the inverted test tube did not fall or slip.

## Results and Discussion

**Gelation:** Least gelation concentrations for the raw and heat processed jackfruit flour were determined to be 16% and 18% (w/v), respectively. These values are identical to those reported for raw (16%) and heat processed (18%) cowpea flour (Abbey and Ibeh, 1988) but lower than the values reported for raw (10%) and heat processed (12%) African breadfruit flour (Odoemelam, 2000). The least gelation concentration reported for other flours such as lupid seed is 14% (Sathe *et al.*, 1982) and fluted pumpkin is 36% (Fagbemi and Oshodi, 19991). Variations in the gelling properties of different flours may be due to variations in the ratios of different constituents such as carbohydrates, lipids and proteins that make up the flours. Abbey and Ibeh (1988) have suggested that interactions between such constituents may have a significant effect on functional properties of flour. The gelling capacity of flours has been attributed to denaturation, aggregation and thermal degradation of starch (Enwere and Ngoddy, 1986). Since gelation involves the swelling of starch granules on heating, the low gelation concentration of raw jackfruit flour could be attributed to higher level of total available carbohydrate than in the heat-processed flour. Data on least gelation concentration show that jackfruit flour is a good gelling agent and may be useful in food systems such as puddings, sauces, soup and 'moi-moi'.

**Water and oil absorption:** The results of water and oil absorption are presented in Table 1. The water absorption capacity of raw jackfruit flour (2.3 ml $g^{-1}$) was found to be significantly lower ($p<0.05$) than the value of 3.5 ml $g^{-1}$ obtained for the heat-processed flour. This result showed that heat processing affected the water absorption capacity of the native protein of jackfruit flour. The values reported here are similar to the values of 2.4 g $g^{-1}$ and 3.6 g $g^{-1}$ reported for raw and heat processed cowpea flours, respectively (Abbey and Ibeh, 1988).

Heat processing increased water absorption by about 52%. Heat processing has been reported to increase the water absorption capacity of African yam bean flour (Eke and Akobundu, 1993), winged bean flour (Narayana and Narasinga Rao, 1982), sunflower proteins (Lin *et al.*, 1974) and cowpea flour (Abbey and Ibeh, 1988; Giami, 1993). Proteins consist of subunit structures that dissociate on heating. Narayana and Narasinga Rao (1982) have suggested that the subunits may have more water binding sites than the oligomeric protein. This could be the reason for the observed higher water

Table 1: Water and oil absorption capacity of raw and heat processed jackfruit flour

| Sample | Water absorbed (ml $g^{-1}$) | Oil absorbed (ml $g^{-1}$) |
|---|---|---|
| Raw flour | 2.3±0.2 | 2.8±0.3 |
| Heat processed flour | 3.5±0.1 | 3.1±0.2 |

Mean ± SD of triplicate determinations

Table 2: Bulk density, foam capacity and stability of raw and heat processed jackfruit flour

| Jack fruit Flour sample | Bulk density (g $ml^{-1}$) | Foam Capacity (g $ml^{-1}$) | Foam volume (ml) after time (min) 20 | 40 | 60 | 80 | 100 | 120 |
|---|---|---|---|---|---|---|---|---|
| Raw flour | 0.61±0.03 | 7.1±0.3 | 4.0 (0.4) | 3.5 (0.3) | 3.0 (0.5) | 2.3 (0.3) | 2.2 (0.3) | 2.0 (0.2) |
| Heat processed flour | 0.54±0.04 | 6.0±0.4 | 3.6 (0.5) | 3.2 (0.3) | 2.5 (0.2) | 1.9 (0.2) | 1.8 (0.5) | 1.3 (0.4) |

Mean ± SD of triplicate determinations SD in parentheses

Table 3: Effect of NaCl concentration on foam capacity and emulsification capacity of raw and heat-processed jackfruit flour

| NaCl concn Mol $dm^{-3}$ | Foam Raw flour | Capacity ml $g^{-1}$ Heat processed flour | Emulsification capacity, ml $g^{-1}$ Raw flour | Heat processed flour |
|---|---|---|---|---|
| 0.0 | 7.1 ± 0.3 | 6.0 ± 0.4 | 3.2 ± 0.1 | 1.6 ± 0.2 |
| 0.2 | 9.5 ± 0.2 | 6.8 ± 0.3 | 4.0 ± 0.3 | 1.7 ± 0.3 |
| 0.4 | 9.3 ± 0.4 | 5.7 ± 0.5 | 4.5 ± 0.2 | 2.0 ± 0.1 |
| 0.6 | 9.3 ± 0.5 | 5.5 ± 0.3 | 3.6 ± 0.4 | 2.0 ± 0.1 |
| 0.8 | 8.9 ± 0.3 | 5.2 ± 0.3 | 3.0 ± 0.1 | 1.8 ± 0.3 |
| 1.0 | 8.4 ± 0.6 | 5.0 ± 0.2 | 2.8 ± 0.2 | 1.7 ± 0.2 |

Mean ± SD of triplicate determinations

absorption by the heat processed jackfruit flour. Carbohydrates also play important role in water absorption. Narayana and Narasinga Rao (1982) have reported that during heat processing, gelatinization of the carbohydrates and swelling of the crude fibre occur which could also lead to increased water absorption.

Fat absorption is an important property in food formulations because fats improve the flavour and mouthfeel of foods (Kinsella, 1976). Heat processing increased the oil absorption capacity of jackfruit flour from2.8 ml $g^{-1}$ flour to 3.1 ml $g^{-1}$ flour. The values reported here are similar to those reported for raw (2.8 g $g^{-1}$) and heat processed (3.1 g $g^{-1}$) cowpea flour (Giami, 1993) but are, however, lower than the values reported for raw (1.4 g $g^{-1}$) and heat processed (2.2 g $g^{-1}$) winged bean flour (Narayana and Narasinga Rao, 1982). Narayana and Narasinga Rao (1982) have attributed the increased oil absorption of heat processed flours to the denaturation and dissociation of the constituent proteins that may occur on heating which unmasks the non-polar residues from the interior of the protein molecule. The oil absorption capacity of jackfruit flour suggests that it may find useful application in food systems such as ground meat formulations.

**Bulk density:** Heat processed jackfruit flour had a lower bulk density (0.54 g $ml^{-1}$) than the raw flour (0.61 g $ml^{-1}$) (Table 2). Heat processing reduced the bulk density of jackfruit flour by 11.5%. Roasting is one of the traditional methods of processing jackfruit for consumption. It is therefore recommended as the traditional method of choice when low bulk flour is desired.

**Foam capacity and foam stability:** Heat processing considerably decreased the foam capacity and foam stability of jackfruit flour (Table 2). A similar effect of heat processing on foam capacity and stability of cowpea flour (Giami, 1993) and winged bean flour (Narayana and Narasinga Rao, 1982) has been reported. The foamability of flours has been shown to be related to the amount of native protein (Lin *et al*., 1974). Yasumatsu *et al*. (1972) have reported that native protein gives higher foam stability than the denatured protein. Since proteins are heat labile, the reduced foam capacity and stability of heat-processed flours can be explained on the basis of protein denaturation. Hence the raw jackfruit flour gave higher foam stability than the heat-processed flour.

Data on the effect of NaCl concentration on foam capacity are presented in Table 3. The addition of NaCl, up to 0.2 M concentration, increased the foam capacity of raw and heat processed jackfruit flours; higher concentrations of NaCl decreased it considerably. Narayana and Narasinga Rao (1982) have reported that low concentrations of NaCl enhance protein solubility

Table 4: Effect of pH on foam capacity of raw and heat processed jackfruit flour

| pH | Foam capacity ($ml\ g^{-1}$) | |
|---|---|---|
| | Raw flour | Heat processed flour |
| 1 | 7.4 ± 0.2 | 5.8 ± 1.1 |
| 2 | 6.4 ± 0.4 | 5.1 ± 0.3 |
| 4 | 4.2 ± 0.1 | 3.4 ± 0.2 |
| 6 | 5.0 ± 0.2 | 4.0 ± 0.3 |
| 8 | 6.2 ± 0.5 | 5.0 ± 0.2 |
| 10 | 7.8 ± 0.3 | 6.2 ± 0.4 |
| 12 | 8.2 ± 0.3 | 6.6 ± 0.3 |

Mean ± SD pf triplicate determinations

Table 5: Effect of pH on emulsification capacity of raw and heat processed Jackfruit flour

| | Emulsification capacity ($mlg^{-1}$) | |
|---|---|---|
| pH | Raw flour | Heat processed flour |
| 1 | 6.4 ± 0.4 | 5.2 ± 0.3 |
| 2 | 5.5 ± 0.3 | 4.8 ± 0.2 |
| 4 | 4.8 ± 0.5 | 3.4 ± 0.1 |
| 6 | 7.0 ± 0.2 | 4.6 ± 0.3 |
| 8 | 8.6 ± 0.3 | 6.1 ± 0.4 |
| 10 | 9.8 ± 0.4 | 8.5 ± 0.3 |
| 12 | 10.0 ± 1.2 | 8.8 ± 0.6 |

Mean ± SD of triplicate determinations

Table 6: Effect of pH on nitrogen solubility of raw and heat processed jackfruit flour

| | | Nitrogen solubility (%) |
|---|---|---|
| pH | Raw flour | Heat processed flour |
| 1 | 35.2 ± 0.5 | 31.2 ± 1.1 |
| 2 | 32.5 ± 0.2 | 28.3 ± 0.6 |
| 4 | 30.2 ± 0.4 | 24.2 ± 0.4 |
| 6 | 36.4 ± 0.3 | 30.1 ± 0.5 |
| 8 | 38.7 ± 0.5 | 33.5 ± 0.4 |
| 10 | 40.6 ± 0.4 | 35.2 ± 0.8 |
| 12 | 35.8 ± 0.5 | 32.5 ± 0.3 |

Mean ± SD of triplicate determinations

while high concentrations decrease it. Since foam capacity is due to solubilized proteins (Narayana and Narasinga Rao, 1982), the decreased foam capacity observed for the heat-processed flour could be explained on the basis of smaller amount of solubilized protein available at higher NaCl concentrations.

The effect of pH on foam capacity of raw and heat-processed jackfruit flour is presented in Table 4. Minimum foam capacity of 4.2 ml $g^{-1}$ flour was observed for raw jackfruit flour at pH 4 while that of the heat-processed flour was 3.4 ml $g^{-1}$ flour. Beyond this pH, foam capacity increased to a maximum at pH 12. Compared to heat-processed jackfruit flour the raw flour had higher foam capacity at all pHs studied. The foamability of cowpea flour has been shown to be a desirable characteristic for the production of several cowpea-based food products (McWatters, 1985). Perhaps the foamability of jackfruit flour may enhance its utilization as a functional ingredient in certain fabricated foods in Nigeria.

**Emulsification capacity:** The effect of NaCl on emulsification capacity was determined using NaCl solutions of 0.2-1.0 M concentration. Raw jackfruit flour had higher emulsification capacity in salt solution than the heat-processed sample. The observed reduction in emulsification capacity could be attributed to thermal denaturation of protein caused by heating. Incorporation of NaCl up to 0.4 M increased emulsification capacity of the raw flour from 3.2 ml $g^{-1}$ flour to 4.5 ml $g^{-1}$ flour; higher concentrations of NaCl reduced it considerably. There was no significant change in emulsification capacity of the heat-processed flour with increasing salt concentration. A similar observation in the case of African yam bean has already been reported (Eke and Akobundu, 1993).

The effect of pH on emulsification capacity was determined over the pH range 1-12 (Table 5). An emulsification capacity of 6.4 ml $g^{-1}$ flour was observed for the raw flour sample at pH 1. Emulsification capacity gradually decreased to 4.8 ml $g^{-1}$ flour at pH 4, which is also the pH of minimum nitrogen solubility. With the progressive increase of pH on the alkaline side, emulsification capacity increased to a maximum (10.0 ml $g^{-1}$ flour) at pH 12.

Heat-processing considerably decreased the emulsification capacity of jackfruit flour at all the pHs studied (Table 5). At pH 1 the emulsification capacity of heat-processed flour was 5.2 ml $g^{-1}$ flour compared to 6.4 ml $g^{-1}$ flour for raw flour sample. The same trend was observed between pH 2-10. At pH 12 an emulsification capacity of 8.8 ml $g^{-1}$ was observed for heat-processed flour as against 10.0 ml $g^{-1}$ for raw flour. A similar observation has been reported in the case of raw and heat-processed winged bean flour (Narayana and Narasinga Rao, 1982).

**Nitrogen solubility:** Nitrogen solubility of the raw and heat-processed flours studied is shown in Table 6. Nitrogen solubility was found to be pH-dependent. Minimum nitrogen solubilities of 30.2% and 24.2% were recorded for raw and heat-processed samples, respectively at pH 4. Below and above this pH, nitrogen solubility increased considerably. Maximum nitrogen solubility of 40.6% was observed at pH 10 in the case of raw flour. Thereafter it dropped to 35.8% at pH 12. The solubility behaviour was similar to that reported for cowpea flour which also had a minimum nitrogen solubility at pH 4 (Giami, 1993).

Heat-processed jackfruit flour exhibited lower solubility values in the pH range 1-12 investigated compared to the raw flour. At pH 1 nitrogen solubility of 31.2% was observed compared to 35.2% with the raw flour. At pH12, it was 32.5% compared to 35.8% with raw flour. Heat processing resulted in a 17.3% reduction in nitrogen solubility of jackfruit flour at pH 6, compared to the raw flour. Reduction in nitrogen solubility due to heat processing has been reported in the case of conophor nut flour (Odoemelam, 2003) and cowpea flour (Giami, 1993). Perhaps, heat processing denatures the proteins in flours and reduces their solubility in water at different pHs.

**Conclusion:** This study has shown that jackfruit flour has a great potential as a functional agent in food systems. The functional properties were affected by pH, NaCl concentration and heat treatment.

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