MATHEWS

Research Article

Mathews Journal of Nutrition & Dietetics

Functional And Pasting Properties of Mechanically Dehulled Toasted African Breadfruit (*Treculia africana*) Seed Flour as Affected by Pretreatments

Akajiaku LO[1],*, Nwabueze TU[2], Onwuka GI[2]

[1] *Department of Food Science and Technology, Federal University of Technology, Nigeria*

[2] *Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike, Nigeria*

ABSTRACT

The study investigated the functional and pasting properties of toasted African breadfruit (*Treculia africana*) seed flour. The *Treculia africana* seeds were soaked with and without *Alum* at different time duration to have 10 samples, toasted, mechanically dehulled and coded: BFA2, BFA4, BFA6, BFA8, BFA10, BFW2, BFW4, BFW6, BFW8, BFW10 and a control sample was toasted and dehulled without pretreatment, coded BFC. The samples were made into flours and their functional and pasting properties were determined using standard methods. The functional properties result of the flour samples showed that BD, WAC, OAC, FC, SI and GT ranged from 0.68g/ml–0.94g/ml, 1.80ml/g–2.08ml/g, 1.44–1.74 ml/g, 18.03–23.41%, 1.27–1.61% and 72.11–82.41°C, respectively. Functional properties were significantly $p<0.05$ elevated in the soaked samples without *alum* relative to the *alum*-soaked samples and untreated sample. The flour samples had peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature ranged from 257.08 RVU to 474.83 RVU, 183.67 RVU to 266.08 RVU, 71.83 RVU–212.92 RVU, 311.83 RVU–441.0 RVU, 124.33 RVU and 179.08 RVU, 4.60min and 5.07min and 78.30°C–84.70°C, respectively. Pasting properties were significantly $p<0.05$ higher in the soaked samples with *alum* relative to the soaked samples without *alum* and untreated sample. Toasted African breadfruit flour showed good functional and pasting properties. The results offer valuable insights into the utilization of toasted African breadfruit seed flour and encouraging its adoption within the food industry.

Keywords: Functional Properties, Pasting Properties, Pretreatment, Seed Flour, Toasted African Breadfruit.

INTRODUCTION

African breadfruit (*Treculia africana*) is a versatile food source with various products derived from its seeds. These ranges of products are traditionally derived from it through methods such as soaking, dehulling, grinding, boiling, steaming, frying, or a combination of two or more of these techniques [1]. African breadfruit, with diverse culinary

Vol No: 07, Issue: 01
Received Date: February 12, 2024
Published Date: March 13, 2024

***Corresponding Author**

Mrs. Linda O Akajiaku

Department of Food Science and Technology, Federal University of Technology, P.M.B. 1526, Owerri, Imo State, Nigeria, Phone: +2348034448727

E-mail: lindaoakajiaku@gmail.com

Citation: Akajiaku LO, et al. (2024). Functional And Pasting Properties of Mechanically Dehulled Toasted African Breadfruit (*Treculia africana*) Seed Flour as Affected by Pretreatments. Mathews J Nutr Diet. 7(1):32.

https://doi.org/10.30654/MJND.10032

applications and nutritional benefits, have been processed into various products including flour, porridge, soups, stews, beverages, and oil and used as flavouring for alcoholic drinks [1,2]. According to [3,4], novel food products are also being developed from African breadfruit.

The seeds of African breadfruit can be ground into flour, which serves as a nutritious alternative to traditional flours [5,6] or used as a composite with wheat flour for baked foods [1,6]. Breadfruit flour is rich in carbohydrates, fibre, and essential nutrients [7,8].

Traditional processing treatments such as soaking, fermenting, germinating, and roasting have been utilized for improving the nutritional value of cereals and pulses [9]. Soaking is one of the processing treatments that are basically used to pre-treat legumes prior to processing [10]. In addition to softening the seed coat or hull of seeds with tough or hard-to-remove hulls, making it easier to remove during the dehulling process, soaking seeds, including African breadfruit seeds, with *alum* can offer several other potential advantages. *Alum* treatment has been noted for its capacity to enhance the water absorption of seeds [11], potentially influencing the bioavailability of certain nutrients in the seeds [12]. Moreover, it may impact the texture and overall quality of the final product derived from the seeds. Soaking may also contribute to a reduction in overall processing time [13]. The soaking process is useful in the production of children's food products with high protein digestibility and mineral availability [14]. Roasting or toasting, a common dry heat food processing method, serves distinct purposes to fulfill specific requirements [15]. This process induces significant changes in moisture content, appearance, taste, aroma, and texture. According to Sruthi et al. [16], roasting is a food processing technique that utilizes heat to achieve uniform cooking, improving the digestibility, palatability, and sensory characteristics of foods with beneficial structural alterations in the food matrix. Roasting transforms nutrients for better digestibility, yielding enhanced aroma, flavor, and color in various foods through a high temperature-short time process, while concurrently reducing water activity, improving shelf-life, and modifying antioxidant and functional properties for increased consumer acceptance [16].

Functional properties of foods refer to the specific characteristics or attributes of a food product that affect its behavior, quality and performance during processing, storage and consumption [17].The functional properties of a food material play a crucial role on how it interacts with other components within the food matrix and ultimately determine its suitability for various applications [18]. Consequently, food products with favorable functional characteristics can be easily integrated into other culinary creations, resulting in high-quality and acceptable end products [18].

According to Ocheme et al. [18], the pasting properties of a food are the alterations that happen to the food when heat is applied in the presence of water. These changes impact the food's texture, how easily it can be digested, and how it can be used in various food products. The alterations influence the texture of the food, its digestibility, and its applicability in different food products. Generally, the pasting properties, excluding pasting temperature, reveal a direct correlation between the starch (carbohydrate) content and these properties, while demonstrating an inverse association between protein content and pasting properties [18]. The alterations influence the texture of the food, its digestibility, and its applicability in different food products. As the carbohydrate content decreases, the pasting properties also decrease, but as the protein content increases, the pasting properties decrease. Pasting characteristics are of utmost importance in selecting a variety for industrial use, such as thickening, binding, or other purposes [19].

In recent times, individuals have been consistently modifying their dietary preferences, seeking to enhance their nutritional intake with safe food options while concurrently striving to improve their overall health and well-being. Consequently, experts in the food industry have persistently adapted formulations and ingredients, employing innovative technologies to create food products that not only align with consumers' demands but also offer heightened nutritional value and safety. Therefore, the research focused on determining the functional and pasting properties of toasted African breadfruit flour as affected by pretreatment. The results of this study are anticipated to broaden the range of applications for this nutritious local crop.

MATERIALS AND METHODS

Materials Procurement

Fresh seeds of African breadfruit (*Treculia africana*) were purchased from Relief market in Owerri Municipal L.G.A, Imo State, Nigeria.

Material Preparation

Sample cleaning and pretreatment process

The seeds of African breadfruit (*Treculia africana*) were cleaned to remove defective seeds, stones, and foreign particles. Subsequently, they were washed and divided into three equal portions, each weighing 10kg. These portions were coded as the control sample (BFC), sample soaked with *Alum* (BFA), and sample soaked without *Alum* (BFW). Sample BFC was toasted without soaking. Sample BFA was further divided into five parts. Each part was soaked at interval in distilled water at a ratio of 1:10 (w/v) with 1.0% *Alum* [20] for varying durations-2h, 4h, 6h 8h, 10h, resulting in samples BFA2, BFA4, BFA6, BFA8 and BFA10. Similarly, sample BFW was divided into five portions and subjected to soaking durations in distilled water at a ratio of 1:10 (w/v) without *Alum*-2h, 4h, 6h 8h, 10h, yielding samples BFW2, BFW4, BFW6, BFW8 and BFW10. The steeping method, as modified by [21], was employed for this process. Following steeping, excess water was drained, and the breadfruit samples were subsequently toasted.

Processing of dehulled toasted African bread fruit seed flour

The method described by Ozigbo et al. [22] with modifications was employed. The seeds were toasted for 30 minutes at 130oC. After toasting, the seeds were cooled for 1h before dehulling. The toasted African breadfruit seeds (TABS) were dehulled mechanically, winnowed, processed into flour using a hammer mill (Model: De-Demark Super) and sieved through a 4.25µm sieve as described by Agu et al. [5] with slight modifications. The flour was packaged in airtight container for further studies. The flow chart for processing of the dehulled toasted African bread fruit seed flour is shown in Figure 1.

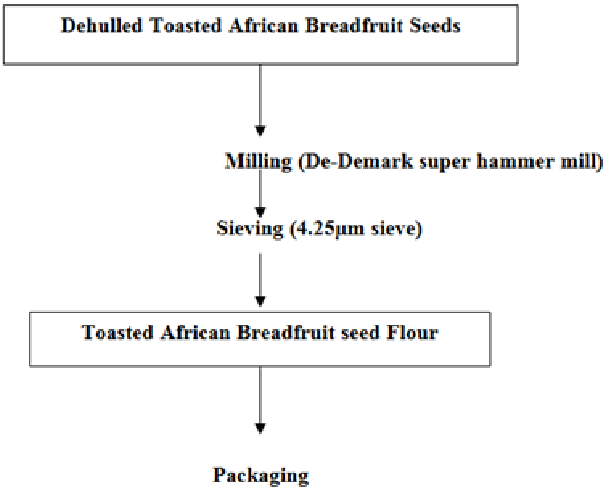

Figure 1. Production of toasted African bread fruit seed flour.

Method of Analyses

Determination of Functional Properties of Toasted African breadfruit seed flour samples

Determination of Bulk Density (BD)

The Bulk Density of the flour sample was determined by the method of [23]. A 10ml capacity graduated measuring cylinder was weighed and filled with the sample to the 10ml mark. The bottom of the cylinder was tapped gently but repeatedly on a laboratory bench until there was no further diminution of the sample level after filling to the 10ml mark. The cylinder with the sample was weighed.

Calculation:

$$\text{BD (g/ml)} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (ml)}} \quad (1)$$

Determination of Water/Oil Absorption Capacity (WAC/ OAC)

The method of [23] was used. From each sample, one (1) gram was weighed into a conical graduated centrifuge tubes and 10ml of water or oil was added to the weighed sample and mixed thoroughly. The sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5000rpm for 30 minutes. After then, the volume of the free water\ oil was read directly from the graduated centrifuge tube. The absorption capacity was expressed as gram of oil or water absorbed per gram of sample.

Calculation:

Water/oil absorption capacity (ml/g) =

(Volume of oil/water used–volume of free oil/water) X 100
(2) Weight of sample 1

Determination of Swelling Index/ Capacity

The method described by [24] was used. Ten (10) grams of the flour sample was measured into a 300ml clean, graduated measuring cylinder and the volume noted. Then 150ml of distilled water was added to the flour sample; the cylinder was swirled and allowed to stand for four hours. The final volume after swelling was recorded. The percentage swelling was calculated as;

% Swelling capacity = Final volume–Initial volume X 100 (3)

Initial volume 1

Foam Capacity (FC) and Foam Stability (FS)

Foam capacity and stability of the flour samples were determined according to the method described by [23]. Two (2) grams of the flour sample was blended with 100ml distilled water in a blender and the suspension was whipped at 1600rpm for 5 minutes. The whipped mixture was transferred into 250ml measuring cylinder. The blender was rinsed with 10ml distilled water and then gently added to the measuring cylinder. Percentage increase in volume of foam after whipping was expressed as the foam capacity while volume of foam at 15, 30, 60 and 120 seconds after whipping were recorded and used to determine foam stability. These were expressed using the formula as follows:

Foam capacity (% volume increase) =

Volume after whipping–volume before whipping X 100 (4)

Volume before whipping 1

Foam stability (%) = Foam volume after time 't' X 100 (5)

Initial foam volume 1

Gelatinization Temperature

The method of [23] was adopted in the determination of gelatinization temperature. Ten (10) grams of the flour sample was dispersed in distilled water in a 250ml test tube and made up to 100ml flour suspension. The aqueous suspension was heated in a boiling water bath with continuous stirring. The heating and stirring continued until the suspension began to gel. Then 30 seconds after the gelatinization was noticed, the corresponding temperature was recorded as the gelatinization temperature.

Determination of pasting properties of Toasted African breadfruit seed flour samples

Rapid Visco-Analyzer (RVA) General Pasting Method as described by [25] was used. Three (3) grams of the toasted African breadfruit flour sample was weighed using a sensitive weighing balance and placed in a clean beaker. Additionally, twenty five (25) millilitres of distilled water was measured using a graduated cylinder. Gradually, the distilled water was poured into the beaker containing the flour. The flour and water were mixed using a stirring rod to ensure the creation of homogeneous slurry without any lumps. The RVA software was initiated on the connected computer, and the required testing parameters, including temperature profile and test duration was set accordingly. The prepared flour-water slurry was carefully transferred into the RVA canister. The RVA canister was inserted into the instrument. The test was initiated according to the predetermined parameters in the RVA software. Throughout the test, the RVA automatically controlled the temperature and stirring of the sample as per the set profile. Data on the viscosity and other pasting properties of the flour sample were continuously recorded. As the test progressed, the RVA software generated a graphical representation of the viscosity curve. This curve included key points such as the peak viscosity, breakdown viscosity, trough viscosity, final viscosity, setback viscosity, peak time and pasting temperature. The pasting properties were recorded.

Statistical analysis

Data obtained were subjected to a one-way Analysis of Variance (ANOVA) and significant differences among means were identified using Duncan's multiple range test. Statistical significance of mean differences was assessed at a 5% probability level. All statistical analyses were performed using Statistical Package for Social Scientists (SPSS) software, version 21.0.

RESULTS AND DISCUSSION

Effect of pre-toasting treatment on the functional properties of Toasted African breadfruit seed flour samples

The functional properties obtained from toasted African breadfruit seeds flour samples are shown in Table 1. The bulk density of the flour samples were found to be between 0.68g/ml and 0.94g/ml. Sample BFA6 had the highest bulk density (0.94g/ml) while sample BFW8 had the least

(0.68g/ml). There were no significant differences among samples BFC, BFA2, BFA6, BFA8 and BFW10, and also among samples BFW2, BFA4, BFA8, BFA2, BFC and BFW10. In this study, it was observed that soaking with or without *Alum* did not reduce/affect the bulk densities of the flour samples. The values obtained were found to be slightly higher than the range (0.61– 0.67 g/ml) reported by [25] for maize-soyabean-pumpkin flour blends, slightly higher than the range (0.543g/ml–0.816g/ml) for different legume flours reported by [26] and higher than the value of 0.35 g/ml for maize-bambara groundnut flour blend by [27]. Bulk density is a determinant of flour expansion and an indicator of the porosity of food products [28]. An increase in bulk density offers better packaging advantage since more flour can be kept in a given space [25] but nutritionally, low bulk density is advantageous because it brings about consumption of more quantity of the lighter food item and this translates into more nutrients for the consumer [18]. Presence of fibre also contributes to bulkiness in a flour sample [29].

The water absorption capacity of the flour samples in this study ranged from 1.80ml/g–2.08ml/g. The highest value was observed in sample BFW8 (2.08ml/g) while the lowest value was sample BFC (1.80ml/g). Soaking was observed to increase the water absorption capacity of the samples. A similar finding was recorded by [30] for soaked chick pea flour. All the samples differed significantly ($p<0.05$) from one another. It was observed that samples soaked without *Alum* had higher water absorption capacity than samples soaked with *Alum* and in both cases, the WAC values increased with increase in duration of soaking. It was also observed that the water absorption capacity increased with increase in protein and fibre contents. According to [26], the protein quality of legume flours also affects their water absorption capacity. Again, [31] reported that legume flours containing several water-loving components like polysaccharides generally have high water absorption capacity. The water absorption capacity of flours plays an important role in the food preparation process because it influences other functional and sensory properties [26]. The values obtained in this study were found to be slightly higher than the range (1.12–1.89g/g) reported by [26] for different legume flours, higher than the range (0.90–1.14g/g) reported by [18] for wheat: groundnut concentrate flour blends, lower than the range (131.50–147.50ml/100g) reported by [30] for Quality protein maize based complementary flours and lower than the range (369–375ml/100g) reported by [30] for control, soaked and germinated chick pea flours. The water absorption capacity of legume flours greatly influences the type of food made from legume-cereal flours [26].

OAC of the flour samples ranged from 1.44–1.74 ml/g and the highest value was observed in sample BFW8 (1.74ml/g), followed by sample BFW6 (1.69ml/g), sample BFC had the lowest value (1.44ml/g). There were significant differences ($p<0.05$) among all samples. It was observed that samples soaked without *Alum* had higher oil absorption capacity than samples soaked with *Alum*. Again, all soaked samples had higher values than the sample without pretreatment (sample TC). This suggests that soaking increased the oil absorption capacity of the samples. A similar finding was recorded by [30] for soaked chick pea flour. The values obtained in this study were found to be slightly higher than the range (0.93–1.38g/g) reported by [26] for different legume flours, lower than the range (379–386ml/100g) reported by [20] for soaked and germinated chickpea flours, lower than the range (3.03–3.60g/g) reported by [32] for soybean, mung bean and red bean flours, lower than the range (88.75–108.50ml/100g) reported by [30] for Quality protein maize based complementary flours and lower than the range (379–386ml/100g) reported by [30] for control, soaked and germinated chick pea flours. Oil absorption capacity of legume flours is important for improving the mouth texture and maintaining the flavour of food products [26].

Foam capacity in this study ranged from 18.03–23.41%. The highest foam capacity was observed for sample BFW10 (23.41%) and lowest for sample BFA4 (18.03%). Similarly, the highest foam stability was observed for sample BFW10 (85.26%) and lowest for sample BFA4 (71.37%). It was observed that samples soaked without *Alum* had higher foam capacity than samples soaked with *Alum* and in both cases, the foam capacity values decreased with increase in duration of soaking. A similar result was obtained for foam stability of the samples. The foam capacity values obtained in this study were found to be higher than the range (5.25–9.20%) reported by [18] for wheat: groundnut protein concentrate flour blends. Generally, it was observed that the high protein content of the samples had influence on the foaming capacity. According to Brou et al. [33], foaming capacity is positively correlated with protein content.

The value of swelling index ranged from 1.27–1.61% and was found highest for sample BFC (1.61%) and lowest for samples BFW2 and BFW10 (1.27%). It was observed that un-soaked sample (sample TC) had higher swelling index than all soaked samples. The swelling capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations [34]. Again, samples soaked without *Alum* had higher values than samples soaked with *Alum*. There was no significant difference (p>0.05) between samples BFW2 and BFW10. All other samples differed significantly (p<0.05) from one another. The values obtained in this study were found to be lower than the range (4.82-10.52 g/g) reported by [32] for soybean, mung bean and red bean flours, the range (9.91–12.71%) reported by [18] for wheat: groundnut protein concentrate flour blends and the range (400.00–480.29%) reported by [25] for maize–soya–pumpkin flour formulations. Swelling capacity is related to protein and starch contents in foods [25]. According to Ratnawati et al. [32], swelling power is also influenced by the size of starch granules. Thus high swelling power can indicate that an ingredient can be applied to improve the characteristics of baked products [32].

The gelation temperature obtained ranged from 72.11–82.41°C. The highest G.T. was recorded for sample BFW10 (82.41°C), followed by sample BFC (sample without pretreatment) (81.41°C) and lowest for sample BFA2 (72.11°C). It was observed that in samples soaked with *Alum*, gelation temperature increased with increase in soaking duration while in samples soaked without *Alum*, the gelation temperature decreased with increase in soaking duration.

Table 1. Functional properties of toasted African breadfruit seed flour samples

Parameters/ Sample	BD g/ml	WAC ml/g	OAC ml/g	FC %	FS %	SI %	GT ºC
BFC	0.92 ± 0.10^{ab}	1.80 ± 0.01^{h}	1.44 ± 0.01^{j}	20.05 ± 0.01^{e}	80.11 ± 0.01^{c}	1.61 ± 0.01^{a}	81.41 ± 0.01^{b}
BFA2	0.92 ± 0.01^{ab}	1.83 ± 0.01^{g}	1.49 ± 0.01^{h}	18.86 ± 0.01^{i}	74.21 ± 0.02^{f}	1.58 ± 0.01^{b}	72.11 ± 0.02^{k}
BFA4	0.86 ± 0.01^{bc}	1.91 ± 0.01^{e}	1.56 ± 0.01^{f}	18.03 ± 0.01^{j}	71.37 ± 0.01^{j}	1.51 ± 0.02^{c}	74.61 ± 0.01^{j}
BFA6	0.94 ± 0.01^{a}	1.81 ± 0.01^{h}	1.47 ± 0.01^{i}	19.54 ± 0.01^{f}	75.22 ± 0.01^{e}	1.53 ± 0.01^{c}	75.75 ± 0.02^{h}
BFA8	0.90 ± 0.01^{ab}	1.87 ± 0.01^{f}	1.51 ± 0.01^{g}	19.21 ± 0.01^{g}	73.48 ± 0.01^{h}	1.51 ± 0.02^{c}	75.11 ± 0.01^{i}
BFA10	0.82 ± 0.01^{cd}	1.93 ± 0.02^{d}	1.61 ± 0.02^{d}	19.02 ± 0.02^{h}	71.61 ± 0.01^{i}	1.47 ± 0.01^{d}	76.21 ± 0.01^{g}
BFW2	0.86 ± 0.02^{bc}	1.90 ± 0.01^{e}	1.58 ± 0.01^{e}	22.82 ± 0.01^{b}	82.31 ± 0.02^{b}	1.27 ± 0.02^{f}	80.12 ± 0.02^{c}
BFW4	0.80 ± 0.01^{d}	1.97 ± 0.01^{c}	1.63 ± 0.01^{c}	21.43 ± 0.02^{c}	80.12 ± 0.02^{c}	1.36 ± 0.01^{e}	78.91 ± 0.02^{d}
BFW6	0.73 ± 0.01^{e}	2.03 ± 0.01^{b}	1.69 ± 0.01^{b}	20.65 ± 0.02^{d}	77.35 ± 0.01^{d}	1.48 ± 0.01^{d}	78.22 ± 0.02^{e}
BFW8	0.68 ± 0.01^{e}	2.08 ± 0.01^{a}	1.74 ± 0.01^{a}	20.03 ± 0.01^{e}	73.68 ± 0.01^{g}	1.58 ± 0.01^{b}	76.81 ± 0.02^{f}
BFW10	0.91 ± 0.01^{ab}	1.84 ± 0.02^{g}	1.52 ± 0.01^{g}	23.41 ± 0.01^{a}	85.26 ± 0.01^{a}	1.27 ± 0.01^{f}	82.41 ± 0.02^{a}

Values are means ±SD of triplicate determinations. Means with same superscript in the same column are not significantly different at (P>0.05). BD = bulk density; WAC = water absorption capacity; OAC = oil absorption capacity; FC = foam capacity; FS = foam stability; SI = swelling index; GT = gelation temperature.

Key: BFC= African breadfruit seeds toasted without pretreatment (control), BFA2 = African breadfruit seeds soaked with *Alum* for 2h before toasting, BFA4 = African breadfruit seeds soaked with *Alum* for 4h before toasting, BFA6 = African breadfruit seeds soaked with *Alum* for 6h before toasting , BFA8= African breadfruit seeds soaked with *Alum* for 8h before toasting , BFA10 = African breadfruit seeds soaked with *Alum* for 10h before toasting, BFW2 = African breadfruit seeds soaked without *Alum* for 2h before toasting, BFW4 = African breadfruit seeds soaked without *Alum* for 4h before toasting, BFW6 = African breadfruit seeds soaked without *Alum* for 6h before toasting, BFW8 = African breadfruit seeds soaked without *Alum* for 8h before toasting, BFW10 = African breadfruit seeds soaked without *Alum* for 10h before toasting.

Effect of pre-toasting treatment on the pasting properties of Toasted African breadfruit seed flour samples

Table 2 shows the effect of pre-toasting treatment on the pasting properties obtained from toasted African breadfruit seeds flour. The peak viscosity obtained ranged between 257.08 RVU and 474.83 RVU. Peak viscosity (PV) is the ability of starches to swell freely before their physical breakdown and indicates the strength of the pastes formed during gelatinization [35]. Sample BFW6 had the highest peak viscosity (474.83 RVU) while sample BFW2 had the lowest peak viscosity (257.08 RVU). Sample BFA2 (African breadfruit seeds soaked with *Alum* for 2h before toasting) had higher peak value of 291.83 RVU compared to its counterpart sample BFW2 (African breadfruit seeds soaked without *Alum* for 2h before toasting) (257.08RVU). Similarly, samples BFA4 (349.67RVU), BFA8 (382.50RVU) and BFA10 (342.42RVU) had higher values than their counterpart samples BFW4 (290.92RVU), BFW8 (279.17RVU) and BFW10 (339.17RVU) respectively. The relatively high peak value of the flours probably indicates that the flour will form a thick paste hence, may be suitable for products requiring high gel strength and elasticity [36]. Aside sample BFW2, sample BFW8 had the lowest peak viscosity (279.17RVU) and this may be due to lower carbohydrate content, highest protein content and in addition highest fat content of the flour sample. Protein content in legume flours can inhibit starch granule swelling and reduce viscosity; in addition high fat content in flour also affects viscosity [26; 37]. It was observed that peak viscosity decreased with decrease in carbohydrate content and increase in protein content of the flour samples. Ocheme et al. [18] stated that reduction in peak viscosity could be attributed to a lowering of the starch as well as interactions between the starch, fat, and protein contents of the flour samples. High protein content in flour may cause the starch granules to be embedded within a stiff protein matrix which subsequently limits the access of the starch to water and restricts the swelling power [38]; thus swelling power of flours is related to their protein and starch contents. According to Sanni et al. [39], peak viscosity has been reported to be correlated with water binding capacity of starch which takes place at equilibrium point between swelling which causes an increase in viscosity while rupturing and realignment cause its reduction. The peak viscosity values obtained in this study were similar to the peak viscosity values (272.47 RVU, 322.88 RVU and 377.83 RVU) which have been reported for plantain, yam and cocoyam respectively by [40]; compares favourably with the peak viscosity values (468 BE and 560 BE) reported by [41] for chickpea flour and wheat flour respectively; lower than the range (913RVU to 1492RVU) reported by [18] for wheat-groundnut protein concentrate flour blends; lower than peak viscosity of mung bean (909 cP) and red bean flour (827.67 cP) and higher than soybean flour (19.17 cP) reported by [32]; higher than the range (96.2 RVU to 216.8 RVU) reported by [26] for legume (lentil, pinto bean, lima bean, chick pea, mung bean, red kidney bean, black eye bean, navy bean, etc) flours and the values (65.0 RVU and 67.5 RVU) reported by [25] for maize-soaked and maize-unsoaked soya bean flours respectively.

The trough viscosity obtained ranged from 183.67 RVU to 266.08 RVU. Sample BFA6 had the highest trough viscosity (266.08 RVU) while sample BFA2 had the lowest trough viscosity (183.67RVU). Trough viscosity measures the ability of paste to withstand breakdown during cooling [42]. It was observed that samples soaked with *Alum* had higher trough viscosity values than samples soaked without *Alum* and in both cases, the trough viscosity values increased with increase in duration of soaking. Generally, all the flour samples exhibited relatively high trough viscosity (i.e. high-holding periods). This indicates that they can withstand high-heat treatments during processing. Asaam et al. [25] reported that high trough values may represent low cooking losses and superior eating quality. The trough viscosity values obtained in this study were higher than the values (61.50RVU and 60.0RVU) reported by [25] for maize-unsoaked and maize-soaked soya bean flours respectively and also higher than the values (90.1RVU to 140.6RVU) reported by [26] for flours from different legumes.

The breakdown viscosity obtained ranged between 71.83 RVU and 212.92 RVU. Sample BFW6 had the highest trough viscosity (212.92 RVU) while sample BFW2 had the lowest trough viscosity (71.83RVU). As reported by [25], the breakdown viscosity of flour is regarded as a measure of the degree of disintegration of starch granules or its paste stability during heating. It was observed that samples soaked with *Alum* had higher breakdown viscosity values than samples soaked without *Alum* and in both cases, the breakdown viscosity values increased with increase in duration of soaking. All the flour samples generally, had high breakdown viscosity which indicates less resistant to heat and shearing during heating. A higher breakdown viscosity value indicates a lower ability of the sample to withstand heating and shear stress during cooking [43]. The breakdown viscosity values obtained in this study were higher than the values (6.0RVU and 5.0RVU) reported by [25] for maize-unsoaked and maize-soaked soya bean flours respectively and also higher than the values (0.2RVU to 79.0RVU) reported by [26] for flours from different legumes. Lower breakdown viscosities suggest that pastes are more stable under hot conditions resulting from lower concentrations of starch in a sample [25].

The final viscosity obtained ranged between 311.83 RVU and 441.0 RVU. Sample BFW6 had the highest final viscosity (441.0 RVU) while sample BFW2 had the lowest final viscosity (311.83RVU). It was observed that samples soaked with *Alum* had higher final viscosity values than samples soaked without *Alum* and in both cases, the final viscosity values increased with increase in duration of soaking. A high-value of final viscosity has been attributed to the aggregation of amylose and a low final viscosity indicates the resistance of the paste to shear stress during stirring [25]. Viscosity of the gel formed during and after heating is an important factor in the selection process [44]. The final viscosity values obtained in this study were higher than the values (115.50RVU and 116.50RVU) reported by [25] for maize-unsoaked and maize-soaked soya bean flours respectively and also higher than the values (118.5RVU to 243.8RVU) reported by [26] for flours from different legumes.

The setback viscosity obtained ranged between 124.33 RVU and 179.08 RVU. Sample BFW6 had the highest setback viscosity (179.08RVU) while sample BFC (sample without pretreatment) had the lowest setback viscosity (124.33RVU). This suggests that soaking (with or without *Alum*) had influence on the setback viscosity. This is in agreement with the findings of [25] for soaked and un-soaked soya bean flours, where the soaked sample had higher setback value than the un-soaked sample. It was observed that samples soaked without *Alum* had higher setback viscosity values than samples soaked with *Alum* and in both cases, the setback viscosity values increased with increase in duration of soaking. Setback viscosity is the viscosity that occurs due to a decrease in temperature so that the starch molecules retrograde or reconnect and it correlates with the texture of various products [32]. According to Sandhu et al. [45], setback viscosity is an index of retrogradation tendency of a paste prepared from a starchy food. According to Asaam et al. [25], fibre is known to be a good water absorption food component that gives good stabilizing effects on foods. A high amount of dietary fibre (6.49% to 9.82%) was obtained for toasted African breadfruit seed flour in this study and the increasing setback viscosity in these flours could be attributed to high-fibre content. Asaam et al. [25] reported a similar finding for composite flours with pumpkin pulp flour substitutions. The setback viscosity values obtained in this study were higher than the values (54.0RVU and 56.50RVU) reported by [25] for maize-unsoaked and maize-soaked soya bean flours respectively and also higher than the values (28.3RVU to 103.2RVU) reported by [26] for flours from different legumes.

Table 2. Pasting properties of toasted African breadfruit seed flour samples

Parameters / Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final visc. (RVU)	Setback viscosity (RVU)	Peak Time (min)	Pasting Temp. (°C)
BFC	290.17	208.67	81.50	333.00	124.33	5.07	83.15
BFA2	291.83	183.67	108.17	317.08	133.42	4.73	82.35
BFA4	349.67	223.50	126.17	365.33	141.83	4.87	80.05
BFA6	404.92	266.08	138.83	419.75	153.67	5.00	78.30
BFA8	382.50	251.83	130.67	386.33	134.50	5.00	79.20
BFA10	342.42	215.50	126.92	344.08	128.58	4.93	81.55
BFW2	257.08	185.25	71.83	311.83	126.58	4.93	82.35
BFW4	290.92	192.42	98.50	339.42	147.00	4.73	80.65
BFW6	474.83	261.92	212.92	441.00	179.08	4.87	79.90
BFW8	279.17	194.42	84.75	333.25	138.83	5.00	84.70
BFW10	339.17	203.67	135.50	348.75	145.08	4.60	79.90

Final visc. = final viscosity

Key:

BFC= African breadfruit seeds toasted without pretreatment (control)

BFA2 = African breadfruit seeds soaked with *Alum* for 2h before toasting

BFA4 = African breadfruit seeds soaked with *Alum* for 4h before toasting

BFA6 = African breadfruit seeds soaked with *Alum* for 6h before toasting

BFA8 = African breadfruit seeds soaked with *Alum* for 8h before toasting

BFA10 = African breadfruit seeds soaked with *Alum* for 10h before toasting

BFW2 = African breadfruit seeds soaked without *Alum* for 2h before toasting

BFW4 = African breadfruit seeds soaked without *Alum* for 4h before toasting

BFW6 = African breadfruit seeds soaked without *Alum* for 6h before toasting

BFW8 = African breadfruit seeds soaked without *Alum* for 8h before toasting

BFW10 = African breadfruit seeds soaked without *Alum* for 10h before toasting

The peak time obtained ranged between 4.60min and 5.07min. Sample BFC (sample without pretreatment) had the highest peak time (5.07min) while sample BFW10 had the lowest peak time (4.60min). This suggests that soaking (with or without *Alum*) had influence on the peak time and is in agreement with the findings of [25]. Peak time represents the total time taken by each sample to attain its respective peak viscosity [25]. It was observed that samples soaked with *Alum* had higher peak time values than samples soaked without *Alum*; in the former, the peak time values increased with increase in duration of soaking while in the latter, the peak time values decreased with increase in duration of soaking. The peak time values obtained in this study were lower than the values (6.84min and 7.0min) reported by [25] for maize-soaked and maize-unsoaked soya bean flours respectively and higher than the peak time (4.28min to 4.49min) reported by [46] for maize-soybean flour blends.

Pasting temperature is the temperature required by starch granules to begin to swell [32]. The pasting temperature of the flour samples ranged between 78.30°C and 84.70°C. Sample BFW8 had the highest pasting temperature (84.70°C) while sample BFA6 had the lowest (78.30°C). The pasting temperature was found to increase with decrease in peak viscosity and increase in protein content of the flour samples. The high pasting temperature of flour may be due to the higher resistance to swelling and rupture of its starch [26,47] and its high content of protein. According to Mohammed et al. [41], proteins in flours restrict starch granules swelling and also reduce the viscosity. Also, high lipid content of flours can lead to a decrease in their viscosity function through the formation of lipid-amylose complexes. Most legume starches have been reported to exhibit restricted swelling viscosity pattern [48]. The temperature at which the viscosity of the stirred starch/flour slurry begins to rise is the pasting temperature [40]. Similarly, [31,49] stated that pasting temperature is the minimum temperature required to cook or gelatinize flour. It was observed that samples soaked without *Alum* had higher pasting temperature values than samples soaked with *Alum* and in both cases, the pasting temperature values decreased with increase in duration of soaking. The pasting temperature values obtained in this study were similar to the range (73.2oC to 83.0°C) reported by [26] for flours from different legumes and in range with the values (76.5°C and 77.0°C) reported by [25] for maize-unsoaked and maize-soaked soya bean flours respectively.

The pasting properties of toasted African breadfruit seed flour in this study were generally higher than values reported for maize-soybean flour blends (peak 27.71–31.16, trough 23.82–26.19, breakdown 5.31–5.41, final 55.65–56.69, setback viscosity 29.95–31.39 RVU, peak time 4.28– 4.49 min) by [46] and the values reported for maize-soyabean-pumpkin flour blends by [25], suggesting that toasted African breadfruit seed flour will be useful in the food industry. Thus, pasting characteristics play an important role in the selection of a variety for use in the industry as a thickener, binder or for any other use [19].

CONCLUSION

This study showed the impact of pre-toasting treatments with and without *Alum* on the functionality of toasted African breadfruit seed flour samples. The functional and pasting properties of toasted African breadfruit seed flour samples in this study were generally higher than values reported for flours from other materials by other researchers. These unique attributes have the potential to create opportunities for the improved utilization and application of toasted African breadfruit seed flour in various food products. Overall, toasted African breadfruit flour showed good functional and pasting properties indicating that it can be used in the production of baked products as biscuits, bread, cakes, pancakes, and others. It is therefore recommended that toasted African breadfruit seed flour be used in food formulations.

AUTHOR CONTRIBUTIONS

The work was a joint collaboration among all Authors. Author ALO: writing—original manuscript draft, investigation, methodology, data curation, statistically evaluated the data obtained, and writing review. Authors NTU and OGI: supervision, project administration, conceptualization, investigation, methodology, data curation and review and editing original draft. All authors read and approved the final manuscript.

ETHICAL STATEMENT

On behalf of all coauthors, I, Mrs. Akajiaku, Linda .O, declare that this article has not been published in part or whole elsewhere. Neither is it under consideration for publication in another journal.

FUNDING

This research received no external funding.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

1. Ojimelukwe PC, Ugwuona FU. (2021). The traditional and medicinal use of African breadfruit (*Treculia africana* Decne): an underutilized ethnic food of the Ibo tribe of South East, Nigeria. Journal of Ethnic Food. 8(21):1-13.
2. Ugwoke FN, Agbo AE, Ali NC, Attah CP, Ekwueme JI. (2003). A Note on African Breadfruit (*Treculia africana* Decne.) Unpublished Report Submitted in Partial Fulfillment of CSC 341, Department of Crop Science, University of Nigeria, Nsukka, Nigeria. pp.18.
3. Onweluzo JC, Nnamuchi OM. (2009). Production and Evaluation of porridge Type Breakfast product from *Treculia Africana* and Sorghum Bicolor fours. Pakistan Journal of Nutrition. 8(6):731-736.
4. Adeniran HO, Ajifolokun OM. (2015). Microbiological studies and sensory evaluation of breadfruit and cassava into garri analogue. Elsevier-Food Webs Journal. 10(33):39-47.
5. Agu HO, Ayo JA, Paul AM, Folorunsho F. (2007). Quality characteristics of biscuits made from wheat and African breadfruit (*Treculia africana*). Nigerian Food Journal. 25(2):19-27.
6. Onyekwelu JC, Stimm B. (2008). *Treculia africana*. In book: Enzyklopädie der Holzgewächse. Ed: 50. Editors: Roloff A, Weisgerber H, Lang U, Stimm B, Wiley-VCH, Weinheim. pp. 1-12.
7. Osabor VN, Ogar DA, Okafor PC, Egbung GE. (2009). Profile of the African breadfruit (*Treculia africana*). Pakistan Journal of Nutrition. 8(7):1005-1008.
8. Enibe SO, Akubuo CO, Mbah BN, Onweluzo JA, Enibe DO, Oduro I, et al. (2013). Progress in agronomic, nutritional and engineering development research on *Treculia africana* tree crop. *Paper presented at the 3rd International Conference on Neglected and Underutilized Species (NUS): for a Food Secure Africa*, Accra, Ghana. pp. 198-214.
9. Chauhan D, Kumar K, Ahmed N, Thakur P, Rizvi QUEH, et al. (2022). Impact of soaking, germination, fermentation, and roasting treatments on nutritional, anti- nutritional, and bioactive composition of black soybean (*Glycine max L.*). Journal of Applied Biology and Biotechnology. 10(5):186-192.
10. Yahaya D, Seidu OA, Tiesaah CH, Iddrisu MB. (2022). The role of soaking, steaming, and dehulling on the nutritional quality of Bambara groundnuts (*Vigna subterranea* (L) Verdc.). Front Sustain Food Syst. 6:1-10.
11. Shittu AT, Awonorin SO, Raji AO. (2004). Evaluating Some Empirical Models for Predicting Water Absorption in African Breadfruit (*Treculia Africana*) Seeds. International Journal of Food Properties. 7(3):585-602.
12. Fernandes AC, Nishida W, Proença RPC. (2010). Influence of soaking on the nutritional quality of common beans (*Phaseolus vulgaris L.*) cooked with or without the soaking water: A review. *International Journal of Food Science and Technology.* 45(11):2209-2218.
13. Balasubramanian S, Borah A, Singh KK, Patil RT. (2012). Effect of selected dehulled legume incorporation on functional and nutritional properties of protein enriched sorghum and wheat extrudates. J Food Sci Technol. 49(5):572-579.
14. Eltayeb LF, Mohamed MAS, Fageer ASM. (2017). Effect of soaking on nutritional value of sorghum (*Sorghum bicolor L*). International Journal of Scientific Research. 6(11):1360-1365.
15. Bhattacharya, S. (2014). Roasting and Toasting Operations in Food: Process Engineering and Applications. Chapter

10. Book Editor(s): Suvendu Bhattacharya. Available at: https://doi.org/10.1002/9781118406281.ch10

16. Sruthi NU, Premjit Y, Pandiselvam R, Kothakota A, Ramesh SV. (2021). An overview of conventional and emerging techniques of roasting: Effect on food bioactive signatures. Food Chem. 348:129088.

17. Awuchi CG, Igwe VS, Echeta CK. (2019). The Functional Properties of Foods and Flours. International Journal of Advanced Academic Research, Sciences, Technology and Engineering. 5(11):139-160.

18. Ocheme OB, Adedeji OE, Chinma CE, Yakubu CM, Ajibo UH. (2018). Proximate composition, functional, and pasting properties of wheat and groundnut protein concentrate flour blends. Food Sci Nutr. 6(5):1173-1178.

19. Kaur M, Kaushal P, Sandhu KS. (2013). Studies on physicochemical and pasting properties of Taro (*Colocasia esculenta L.*) flour in comparison with a cereal, tuber and legume flour. J Food Sci Technol. 50(1):94-100.

20. Olapade AA, Umeonuorah UC. (2014). Chemical and sensory evaluation of African breadfruit (*Treculia africana*) seeds processed with *Alum* and trona. Nigerian Food Journal. 3(1):80-88.

21. Nwosu JN. (2010). The effects of steeping with chemicals (trona and *alum*) on the functional properties and proximate composition of asparagus bean (*Vigna sesquipedalis*). Journal of Nature and Sciences. 8(9):111-120.

22. Ozigbo ES, Bamgboye AI, Murphy KM. (2015). Determination of the Effects of Parboiling and Frying on the Dehulling Process of African Breadfruit Seeds (*Treculia Africana* Decne). International Journal of Research in Agricultural Sciences. 2(6):281-285.

23. Onwuka GI. (2018). Food Analysis and Instrumentation: Theory and Practice. Second edition. Naphtali prints, Lagos. pp. 343-348.

24. Ukpabi UJ, Ndimele C. (1990). Evaluation of gari production in Imo State. Nigerian Food Journal. 8:105–110.

25. Asaam ES, Adubofuor J, Amoah I, Apeku OD. (2018). Functional and pasting properties of yellow maize–soya bean–pumpkin composite flours and acceptability study on their breakfast cereals. Cogent Food & Agriculture. 4(1):1501932.

26. Du S, Jiang H, Yu X, Jane J. (2014). Physicochemical and functional properties of whole legume flour. LWT- Food Science and Technology. 55(1):308-313.

27. Mbata TI, Ikenebomeh MJ, Ezeibe S. (2009). Evaluation of mineral content and functional properties of fermented maize (Generic and specific) flour blended with bambara groundnut (*Vigna subterranean L*). Afr J Food Sci. 3(4):107-112.

28. Kraithong S, Lee S, Rawdkuen S. (2018). Physicochemical and functional properties of Thai organic rice flour. Journal of Cereal Science. 79:259-266.

29. Akinjayeju O, Ajayi OF. (2011). Effects of Dehulling on Functional and Sensory Properties of Flours from Black Beans. Food and Nutrition Science. 2(4):344-349.

30. Desalegn BB. (2015). Effect of Soaking and Germination on Proximate Composition, Mineral Bioavailability and Functional Properties of Chickpea Flour. Food and Public Health. 5(4):108-113.

31. Kaur M, Singh N. (2005). Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum L.*) cultivars. Food Chemistry. 91(3):403-411.

32. Ratnawati L, Desnilasari D, Surahman DN, Kumalasari R. (2019). Evaluation of Physicochemical, Functional and Pasting Properties of Soybean, Mung Bean and Red Kidney Bean Flour as Ingredient in Biscuit. IOP Conf. Series: Earth and Environmental Science. 251:1-10.

33. Brou K, N'Da-Kouassi A, Kouadio J, Guehi T, N'Guessan K, Gnakri D. (2013). Biochemical characterization and functional properties of weaning food made from cereals (millet, maize) and legumes (beans, soybeans). Journal of Food Chemistry and Nutrition. 1(1):22-32.

34. Chandra S, Samsher A. (2013). Assessment of functional properties of different flours. Afr J Agric Res. 8(38):4849–4852.

35. Sanni LO, Kosoko SB, Adebowale AA, Adeoye RJ. (2004). The influence of palm oil and chemical modification on the pasting and sensory properties of *fufu* flour. International Journal of Food Properties. 7(2):229-237.

36. Abioye VF, Ade-Omowaye BIO, Babarinde GO, Adesigbin MK. (2011). Chemical, Physico-chemical and sensory properties of soy-plantain flour. Afr J Food Sci. 5(4):176-189.

37. Hamid S, Muzaffar S, Wani IA, Masoodi FA. (2015). Physicochemical and functional properties of two cowpea cultivars grown in temperate Indian climate. Cogent Food & Agriculture. 1(1):1-11.

38. Aprianita A, Purwandari U, Watson B, Vasiljevic T. (2009). Physicochemical properties of flours and starches from selected commercial tubers available in Australia. Food Res Int. 16:507-520.

39. Sanni AI, Asiedu M, Ayernor GS. (2001). Influence of processing conditions on the nutritive value of ogi-baba, a Nigerian fermented sorghum gruel. Plant Foods Hum Nutr. 56(3):217-223.

40. Oluwamukomi M, Akinsola O. (2015). Thermal and Physicochemical Properties of Some Starchy Foods: Yam (*Dioscorea rotundata*), Cocoyam (*Xanthosoma sagittifolium*) and Plantain (*Musa paradisiaca*). Food Science & Technology. 3(1):9-17.

41. Mohammed I, Ahmed AR, Senge B. (2014). Effects of chickpea flour on wheat pasting properties and bread making quality. J Food Sci Technol. 51(9):1902-1910.

42. Tharise N, Julianti E, Nurminah M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. International Food Research Journal. 21(4):1641-1649.

43. Adebowale YA, Adeyemi A, Oshodi AA. (2005). Variability in the physicochemical, nutritional and antinutritional attributes of six Mucuna species. *Food Chemistry.* 89(1):37-48.

44. Aryee FNA, Oduro I, Ellis WO, Afuakwa JJ. (2006). The physicochemical properties of flour samples from the roots of 31 varieties of cassava. Food Control. 17:916-922.

45. Sandhu KS, Singh N, Malhi NS. (2006). Some properties of corn grains and their flours I: Physicochemical, functional and chapati-making properties of flours. Food Chemistry. 101(3):938-946.

46. Edema MO, Sanni LO, Sanni AI. (2005). Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria. African Journal of Biotechnology. 4(9):911-918.

47. Singh N, Kaur M, Sandhu KS, Guraya HS. (2004). Physicochemical, thermal, morphological and pasting properties of starches from some Indian black gram (*Phaseolus mungo L.*) cultivars. Starch–Stärke. 56(11):535-544.

48. Hoover R, Ratnayake WS. (2002). Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada. Food Chemistry. 78(4):489-498.

49. Shimelis E, Meaza M, Rakishit S. (2006). Physicochemical properties, pasting behaviour and functional characteristics of flours and starches from improved bean (*Phaseolus vulgaris L*) varieties grown in East Africa. Agricultural Engineering International. 3(1):1-18.