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Browning, Viscosity and Moisture Sorption Characteristics of Fresh and Stored African Breadfruit Kernel Flour

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Abstract Flour was prepared from African breadfruit seeds and was stored in tin can and polyethylene bag at ambient temperature (30 °C) for 5 months. The browning index, viscosity and moisture sorption characteristics of the fresh and stored flour samples were evaluated. The equilibrium moisture content (EMC) slightly increased at low water activities but increased sharply at high water activities. The adsorption sorption isotherms of the fresh and stored samples were sigmoidal in shape (type 11 isotherm). The critical moisture content and surface area of ABKF were 5.4g H_2O/100g and 1.8mg-1, respectively. At a constant shear rate, the viscosity was dependent on the ABKF concentration. Heated and Unheated flour dispersions exhibited shear thinning. The browning index of the floor increased while the viscosity decreased on storage. The moisture sorption characteristic of the flour in both packaging materials were not significantly (p>0.05) affected in storage. The tin can provided better keeping quality for the flour than polythene bag.

Keywords African breadfruit, flour, isotherm, packaging, storage, viscosity

Introduction

Recently, the search for cheap and abundant plant protein foods has increased because animal protein is more expensive and is beyond the reach of many people in developing countries. Thus, utilization plant protein sources such as legumes and oilseeds are receiving considerable research attention. African breadfruit (*Treculia africana*) is a tropical tree belonging to the family *Moraceae.* The tree grows in the humid zone of West Africa either as wide or cultivated specie. A mature tree produces about 700-3500kg fruit per annum [1] (.The mature and ripe fruits are fermented to extract the edible seeds. The seeds are highly nutritious and have the potential of replacing most leguminous crops in food formulations [2] (. The chemical composition of the seed has been documented in some reports [3-6] where it was reported that the crude protein and fat contents of the seed ranged from 19-23% and 17-20%, respectively. The seed is also a good source of vitamins and minerals that are essential for human nutrition [5]. In Nigeria, the seeds are dehulled, boiled and eaten as a main dish or as part of dish. The seeds may be roasted and eaten as snack. Raw and toasted seeds are widely used as emulsifiers and thickeners in traditional foods.

With increasing awareness of the potential food and industrial value of African breadfruit seeds, research efforts towards enhancing its food and industrial utilization have equally increased. Some studies have shown that the seeds are potential raw materials for many cottage and commercial food products [7-9]. In order to increase the utilization of the seeds, the storage properties of the flour need to be determined.

Powdery foods adsorption water when packaged and stored under highly humid conditions. This causes deteriorative changes such as microbial degradation, reduced flowability (or caking) and dissolution depending on their physical properties and composition of the foods. The moisture content of food influences texture, storage stability and their susceptibility to microbial spoilage. These changes affect the acceptability of the products. Most micro-organisms have specific water activities below which they will not grow. The relationship between moisture content and water activities is expressed as moisture sorption isotherm. Moisture sorption isotherms are useful thermodynamic tools that are used for determining interactions of water and food substances and provide information for assessing food processing operations such as drying, mixing, packaging and storage [10]. Moisture sorption isotherms can also be used to investigate structural features of food products such as specific surface area, pore volume, pore size distribution and crystallinity [10]. Such data can be used for selecting appropriate storage conditions and packaging systems that optimize or maximize retention of aroma, colour, texture, nutrient and biological stability [10]. Information on the moisture sorption characteristics of African breadfruit kernel flour is lacking in the literature. For effective packaging of African breadfruit kernel flour, knowledge of the critical equilibrium moisture content and relative humidity are needed. Such information can be obtained from the sorption isotherms. Similarly, knowledge of the influence of storage on the viscosity and browning of the ABKF would be useful as the flour is used as thickener and emulsifier in soups. Information is scanty on the changes in the quality of African breadfruit kernel flour in storage.

The objectives of this study were to determine the non enzymic browning index, viscosity and moisture sorption characteristics of African breadfruit kernel flour and to investigate the influence of storage on these parameters.

Materials and Methods

African breadfruit *(Treculia africana)* seeds were purchased from a local market in Nsukka Township, Enugu State, Nigeria. The seeds were cleaned of extraneous materials, parboiled (100°C, 5min) in aluminium pot with a lid. The seeds were drained within 5min, cooled for 2min and dehulled manually. The kernels were washed in tap water, sun dried (30°C, 10-12h), and milled to pass through 60 mesh sieve (0.1 mm) (British standard).

Storage Stability

The flour samples (200g) were stored in polyethylene bags (15cm x 10cm) of 0.77mm thickness and tin cans on a laboratory bench. Samples were analysed at monthly intervals for changes in browning index, viscosity and moisture sorption characteristics for 5months.

Non Enzymic browning index (NEBI)

The NEBI was determined as alcohol extractable colour as described by Harvey et al[11]. Five gram of the flour was soaked in 95% ethanol with occasional shaking for 24h. The mixture was filtered through No 4 Whatman filter paper and the optical density of the filtrate was read at 420nm using Spectronic 20. The NEBI was calculated as optical density/weight of sample x100.

Determination of viscosity

The flour dispersions (5%, w/v) were prepared with distilled water at 30°C and hydrated for 2h with continuous stirring. Some portions of the dispersions were heated in water bath (30-80°C). Viscosities of the heated and unheated dispersions were measured with Brookfield viscometer [12]. Appropriate spindles were used for all readings which were recorded in 3 replicates.

Moisture Sorption Studies

Moisture sorption isotherms of the fresh and stored flours were determined by the gravimetric method at ambient temperature (30 ^{o}C) as described by Mohammed et al[13]. Saturated salt solutions for the required humidity were prepared by saturating the salts in 20ml distilled water at 30°C. The salts used were Magnesium chloride (a_w=0.33). Calcium chloride (a_w=0.35), Potassium carbonate (a_w =0.40), Magnesium nitrate (0.55), Sodium nitrate (a_w =0.64), Sodium chloride (a_w =0.75), Ammonium sulphate (a_w = 0.80) and Barium chloride (a_w =0.90). Sulphuric acid was used to prepare water activities (a_w) of 0.11 and 0.19 as described by *Gevaudan et a l*[14]. The flour samples (1g) in 3 replicates were placed over the saturated salt solutions in desiccators at ambient temperature (30°C). In order to inhibit fungal growth at high water activities (0.8-0.9), flours were treated with 0.15% (w/v) sodium benzoate. The samples were weighed daily using a digital meter balance and when two consecutive weighing were fairly constant, it was assumed that equilibrium condition was reached. The moisture contents of the equilibrated samples were determined by drying the samples in a hot air oven at 105°C to fairly constant weight [12]. The sorption moisture isotherm was obtained by plotting the equilibrium moisture content of the flours against water activity. The monolayer moisture values of the flours were calculated using the equation given by Labuza [15] as:

$$\frac{aw}{a_1 - a_w} = \frac{1}{M_0 C} + \frac{C-1}{M_0 C_w^a}$$

Where a_w=water activity, a=water content (gH_2O, dry matter), Mo=monolayer and C=a constant. A plot of a_w/a (1-a_w) versus a_w (BET plot) gives a straight line from where the slope and intercept were obtained and used to calculated the monolayer value as 1/y- intercept + slope .The monolayer value was used to calculate the apparent surface area of the flour (So) as outlined by Demertzis *et* al[16]: So =1/MH_2O No AH_2OMo (Mg^{-1} solid) where MH_2O is the relative molecular mass of water, No is the Avogadro's Number ($6.023x10^{23}$ molecules mol^{-}) and AH_2O is the apparent surface area of one water molecule ($1.05x10^{-15}M^2$).

Statistical analysis

The data were analyzed by analysis of variance in completely randomized design using the Special Product for Service Solution (SPSS) software version 17, 2007. Significantly different means were separated by the least significant difference (Lsd) test. Significance was accepted at $P<0.05$.

Results and Discussion

Sorption studies

The relationship between equilibrium moisture contents and water activities of the fresh and stored African breadfruit kernel flour (ABKF) in polyethylene bags and tin cans at ambient temperature (30°C) is shown in Table 1. Equilibrium moisture content (EMC) increased slightly at low water activities but showed a rise at high water activities. The time for the flour to reach equilibrium varied from 6 to 14 days and was shorter at low water activities. The equilibrium time agreed with the predictions of COST (Cooperation in the field of scientific and technical research in Europe) i.e 7 days for $a_w<0.6$ and 14 days for $a_w>0.6$ [14]. At low and intermediate water activities, water is mainly held by physical adsorption on polymeric compounds [16]. At high water activities; sugar dissolves and causes the step increase in moisture [17]. Egwujeh *et al* [18] reported that products with high contents of protein and fat exhibited gradually small rise in water activity suggesting that this region is a zone of highest instability with respect to spoilage. The increase in the EMC with increase in water activity makes the flour more susceptible to microbial spoilage [19]. Fig.1 shows the adsorption moisture isotherm of the fresh ABKF. Those for the flours stored in both polyethylene bags and tin cans were not represented as they were similar to that of the fresh flour. Each point on the isotherm curve represents the average of three replicates. The curve showed a sigmoid shape, which is described as a Type 11 isotherm according to the classification of Branauer *et al* [20]. This type of curve is typical of many food materials [21]. Therefore, ABKF requires careful handling and proper packaging environment to make it stable over long storage period of time. A typical sigmoid sorption isotherm is divided into three parts [22]. The first region is the monolayer ($a_w<0.22$) in which the water is bound by the hydrophilic water-ion or water diploes interactions. The water in this phase is the most strongly adsorbed, immobile and depends on the chemical composition of the products and is also affected by pre-treatment's [23]. The second region corresponds to the linear portion of the isotherm (a_w 0.22 to 0.73) which represents the water held in the matrix [23]. The third region (a_w 0.73 to 1.0) corresponds to the last concave region which represents the least strongly bound water and the most mobile which is designated as bulk water phase [23].

The equilibrium moisture contents data were subjected to analysis as described by Labuza [15]. The monolayer moisture content was calculated from BET plot as 5.4g H_2O/100g DM for the fresh flour. Comparable values of 5.4 and 5.5g H_2O/100g DM were obtained for the flours stored in tin cans and polyethylene bags, respectively. The monolayer moisture content represents the moisture content of the flour when the entire surface is covered with uni-molecular moisture layer [16]. Monolayer value provides an estimate of the water content that would provide maximum stability to a dry food product [16]. This value is related to the stability of foods during storage, since it is corresponds to a minimum amount of water bound onto active sites of a food to give a monolayer coverage (Labuza, 1968). Monolayer moisture values of food vary with composition and processing [16]. Monolayer values that varied from 3.2 to 16g H_2O/100g DM have been reported for starchy foods [16]. The value obtained for ABKF in this study was comparable to 5.0g H_2O/100g DM reported for wheat flour [14]. Moisture gained by a food in excess of its monolayer value represents free water which promotes browning, hydrolysis, caking and other defects [16,24]. The surface area of the ABKF obtained from the monolayer value was $1.89m^2g^{-1}$. This value was lower than $5.01m^2g^{-1}$ reported for raffinose [16]. Storage of ABKF in the cans and polyethylene bags at ambient temperature (30 °C) did not significantly ($p<0.05$) affect its equilibrium moisture content (Table 1). However, equilibrium moisture content was slightly higher for flours packed in polyethylene bags than for those in the tin cans.

Table 1: Equilibrium moisture content (EMC) and water activity (a_w) relationship of African breadfruit kernel flour before and after storage at 30°C for 5 months

Chemical used	**a_w**	**EMC (g/100g DM)**		
		Fresh flour	**polyethylene Packed flour**	**Tincan packed flour**
Sulphuric acid	0.11	4.0^a	4.4^a	4.1^a
Sulphuric acid	0.19	6.0^a	6.3^a	6.0^a
Sulphuric acid	0.33	6.7^a	6.6^a	6.5^a
Magnesium chloride	0.35	8.7^a	8.5^a	8.4^a
Potassium carbonate	0.44	11.5^a	12.0^a	11.8^a
Magnesium nitrate	0.55	12.6^a	12.6^a	12.5^a
Sodium nitrate	0.64	13.3^a	13.2^a	13.1^a
Sodium chloride	0.75	13.6^a	14.0^a	13.5^a
Ammonium sulphate	0.80	16.7^a	16.9^a	16.5^a
Barium chloride	0.9	27.1^a	27.4^a	27.2^a

Values are means of three replications. Means within a row with the same superscript were not significantly different ($p>0.05$)

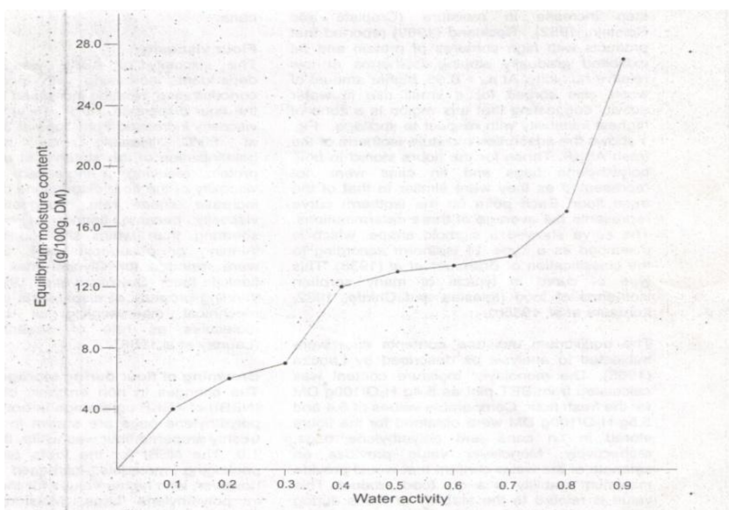

Figure 1: Moisture sorption isotherm of fresh African breadfruit kernel flour at ambient temperature

Flour viscosity

The viscosity of African breadfruit kernel flour was concentration dependent; increasing with increase in flour concentration (Data not shown). Heating increased the viscosity of the flour dispersion. At 5% (w/v) flour level, the viscosity increased from 5cps at 30°C to 680cps at 80 °C (Table 2). Heating may have caused gelatinization of the starch and denaturation of protein, resulting in increased viscosity. The viscosity of the flour dispersions decreased with increased shear rate (Data not shown), suggesting that the viscosity became thinner at higher rate of shearing than when sheared slowly (shear thinning or pseudoplasticity). Similar trends were reported for *Glycine* max and *Mucuna flaellipe* flours [25]. The shear thinning property of dispersions is attributed to mechanical disentangling of chains within molecules as rate of shearing increased [26].

Table 2: Effect of heating temperature on the viscosity of African breadfruit kernel flour

Temperature (^oC)	Viscosity(cps)
30	5^f
40	150^e
50	420^d
60	582^c
70	602^b
80	680^a

Valves are means of three replications. Means within a column with the same superscript were not significantly different (p>0.05)

Changes in viscosity during storage

There viscosity of the flours stored in both packaging materials significantly (p<0.05 decreased during storage (Table 3). The decreases were greater in the polyethylene packed flour than in the flour stored in tin can. Structural changes may have occurred in the protein and starch molecules of the flour during storage. This changes may have restricted the hydration of the flours which probably led to less extension of the molecules and hence, the decrease in viscosity [6]. Similar decrease in viscosity was reported for *Mucuna flaellipe* flour in storage by Onweluzu et al [25].

Table 3: Effect of packaging material and storage time on viscosity of African breadfruit kernel flour

Storage time	Viscosity(cps)	
(Month)	Polyethylene packed flour	Tin can packed flour
0	5.0a	5.0a
1	4.9a	5.0a
2	4.5ab	4.8a
3	4.3b	4.6ab
4	4.0bc	4.2b
5	3.5c	4.0b

Values are means of three replications. Means within a column with the same superscript were not significantly different (p>0.05)

Browning of flour during storage

The changes in non enzymic browning index (NEBI) of African breadfruit kernel flour on storage in both tin cans and polyethylene bags are shown in Table 4.The freshly prepared flour was white, the NEBI being 1.0. The NEBI for the flours packed in both packaging materials increased on storage, however, with higher increases for the flour packed in polyethylene bags. For instance, the NEBI increase from 1 to 14.2 for the polyethylene packed flour and from 1 to 10.2 for the tin can packed flour at the end of the 5 months storage. Moisture picked up through the polyethylene bags might have accelerated the rate of browning. The moisture content (8%) of the tin can packed flour remained constant while that of the flour in the polyethylene bags (9-10%) fluctuated on storage. The presence of reducing sugars in stored foods greatly increased rate of non enzymic browning (NEBI) reactions [11,25]. The pH of the stored flour ranged between 5.8 and 6.3. The slightly acidic conditions of the flours may have contributed to the observed low NEBI [11].

Table 4: Effect of packaging material and storage time on non enzymic browning of African breadfruit kernel flour

Storage time	Non enzymic browning index	
(month)	Polyethylene packed flour	Tin can packed flour
0	1.0	1.0
1	4.0	2.0
2	8.8	6.0
3	11.4	8.0
4	12.0	9.8
5	14.2	10.2

Values are means of three replications. Means within a column with the same superscript were not significantly different (p>0.05)

Conclusion

The heated and unheated dispersions of African breadfruit kernel flour exhibited pseudoplastic properties. Such characteristics lend the flour to some potential end uses as bulking and binding agents in food products. The equilibrium moisture contents of African breadfruits kernel flour did not change significantly on storage in both tin cans and polyethylene bags. However, the viscosity of the flour in the two packaging materials decreased while the browning index increased in storage. The tin can preserved the quality of ABKF with respect to colour and viscosity than the polyethylene bag.

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