**Full Length Research Paper**

**Some functional properties of flours from commonly consumed selected Nigerian Food Crops**

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**ABSTRACT**

The functional properties of maize (Zea mays var. yellow), local rice (Oryza sativa var. ofada white, ofada moborobo and abakaliki), millet (Pennisetum glaucum) and sorghum (Sorghum bicolor) were obtained from the open market, sorted, washed, dried at 70°C in a cabinet dryer and milled. The functional properties (swelling power, solubility index, water absorption capacity, dispersibility and bulk density) of the flours were evaluated. The value of swelling capacity and solubility index increased in direct proportion to the increase in temperature and at the highest temperature of 95°C, for swelling power, abakaliki variant of rice (Oryza sativa) flour had the highest value (5.84) while maize had the lowest value (3.81) and for solubility index maize had the highest value of 5.50 while sorghum flour and ofada white variant of rice had the lowest values of 3.00. Results for bulk density ranged from 0.65 – 0.91 g/ml with rice flour (Ofada moborobo variant) having the highest bulk density (0.91 g/ml) and maize flour having the least (0.65 g/ml). Results for dispersibility showed that maize had the least value (45.50%) while millet had the highest value (51.0%). Water absorption capacity showed significant difference (p<0.05) and results for water absorption capacity ranged from 1.43 – 1.87 g/g with millet flour having the least water absorption capacity (1.43g/g) and the ofada white variant of rice had the highest value (1.87g/g). The functional properties of these flours showed their uniqueness to each parameter measured and can be useful for food application processes.

**Keywords:** flour, functional properties, local rice, maize, millet, sorghum, temperature.

**INTRODUCTION**

Cereal grains contain 60 to 70% starch and are excellent energy rich food for human. Doctors recommended cereals as the first food to be added to infant diets and a healthy diet for adults should have most of its calories in the form of complex carbohydrates such as cereals grain starch. Cereals and millets form the staple food of diets in about 75% of the countries of the world (Khader, 2001). Cereals are an excellent source
of vitamin and minerals including fat soluble vitamin E, which is an essential antioxidant. The cereal grains are an easy protein source as required by Recommended Daily Allowance (RDA) but unfortunately they lack the essential amino acid lysine and therefore they must not be used as the sole source of dietary protein (Khatkar, 2005). Cereal grains contain about 58 to 72% carbohydrates, 8 to 13% protein, 2 to 5% fat, and 2 to 11% indigestible fibre. They also contain 300 to 350 kcal/100 g of the grain. Carbohydrates are present in the form of digestible starches and sugars. The operations of milling generally remove much of the indigestible fibre and fat from the grains when they are to be consumed for human food (Potter and Hotchkiss, 1996). The selected Nigerian cereals investigated in this study include flours from maize (Zea mays), sorghum (Sorghum bicolor), millet (Pennisetum glaucum) and rice (Oryza sativa). These crops are often processed into different food forms traditionally with or without fermentation such as fermented maize, sorghum, rice and millet in the preparation of breakfast gruel for infants and adults or as a non-fermented flour to be consumed as a stiff dough often taken with vegetable soups by a large population of Nigerians in the six geopolitical zones of the nation. Rice is also consumed boiled with soups or stew and also as boiled spiced rice.

Maize, known in some English-speaking countries as corn, is a large grain plant with leafy stalks which produce ears and contains the grains. Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain (International Grain Council, 2013). Worldwide production of maize was 817 million tonnes in 2009; more than rice (678 million tonnes) or wheat (682 million tonnes) (FAO, 2009). In 2009, over 159 million hectares (390 million acres) of maize were planted worldwide; with a yield of over 5 tonnes per hectare (FAO, 2009). The largest producer is the United States, producing 42%. Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tons, followed by South Africa. Maize and cornmeal (ground dried maize) constitute a staple food in many regions of the world. Introduced into Africa by the Portuguese in the 16th century, maize has become Africa’s most important staple food crop (FAO, 2009). Sorghum (Sorghum bicolor) is a cultivated tropical cereal grass. It is quantitatively the world’s fifth largest most important cereal grain, after wheat, maize, rice and barley. In Africa, sorghum is still largely a subsistence food crop, but studies have shown that it is increasingly forming the foundation of successful food and beverage industries (FAO, 2003). World annual sorghum production is over 60 million tonnes, of which Africa produces about 20 million tonnes (FAOSTAT, 2014). This makes sorghum, quantitatively the second most important cereal grain in Africa after maize. Nigeria, Sudan, Ethiopia and Burkina Faso account for nearly 70% of Africa’s production (FAO, 2009).

Millet (Pennisetum glaucum) known as ‘yadi’ in Marghi language of north eastern Nigeria is the most important and probably having the greatest potential among the millet varieties. It is one of the most important dual purpose crop, and a staple food for millions of people in arid and semi-arid ecologies around the world (Chopra, 2001). Pearl millet is the sixth most important cereal annually cultivated as rain fed crop in arid and semi-arid areas of Africa and the Indian sub-continent (Khairawal et al., 1999 and FAO, 2007). It is grown in over 40 countries predominantly in Africa and Asia as a staple food grain and source of feed and fodder, fuel and construction material (FAO, 2007). Nigeria is the second top producing nation of millet producing about 5 million tonnes in 2013 which accounted for 16.7% of total world production of millet (FAOSTAT, 2014).

Rice (Oryza sativa) has become the second most important cereal in the world after wheat in terms of production, due to a recent decline in maize production (Jones, 1995). It is widely cultivated throughout the tropics; and where flood controls are effective as in South-east Asia, production is high. Much of the foreign rice imported into West Africa is from South-east Asia. In Sub-Saharan Africa, West Africa is the leading producer and consumer of rice (WARDA, 1996). West Africa accounts for 64.2% and 61.9% of total rice production and consumption in Sub-Saharan Africa.
Africa respectively. Nigeria has a leading role in rice production in West Africa. Nigeria ranks highest producer and consumer of rice in the Sub-region with figures slightly above 50% (WARDA, 1996). Rice is known to have been grown along the Niger for over 3000 years (Imolehin and Wada, 2000). Recent estimates put potential areas for rice production and actual as 4.6 - 4.9 million ha and 1.7 million ha respectively (WARDA, 1996; Singh et al., 1997; Imolehin and Wada, 2000).

Functional properties are those parameters that determine the application and end use of food materials for various food products. The application of flour or starch in food production and in the industry depend on various functional properties such as dispersibility, water absorption capacity, pasting, retrogradation, viscosity, swelling power, solubility index etc. which varies considerably based on the type of crop as well as ecological and agronomic influence (Peroni et al., 2006). These functional properties depend on the composition and molecular structures of the flour or starch which include amylose/amylopectin ratio, phosphorus content, starch molecular weight, granule size and the chain length distribution (Sasaki and Matsuki, 1998).

The commonly consumed cereal in Nigeria are rice, maize, sorghum and millet, determination of their functional properties may probably assist in determining the behavior and application of these flours for various food products. Therefore, the main aim of this research work is to determine some functional properties of maize, sorghum, rice and millet flours.

METHODOLOGY
Sample sourcing and preparation:
Maize (Zea mays var. yellow), Rice (Oryza sativa var. ofada white, ofada moborobo and abakaliki), Millet (Pennisetum glaucum) and Sorghum (Sorghum bicolor) were obtained from the market, sorted, washed, dried at 70°C in a dryer and milled. The flour samples were sieved using 250µm mesh size and were used for the following analyses.

Swelling power and solubility index determination
The method described by Hirsch (2002) was used for swelling power and solubility index determination. One gram of sample was poured into pre-weighed graduated centrifuge tube appropriately labelled. Then, 10 ml of distilled water was added to the weighed sample in the centrifuge tube and the solution was stirred and placed in a water bath heated at different temperature range (55, 65, 75, 85, 95 °C) for 1 h while shaking the sample gently to ensure that the starch granules remained in suspension until gelatinization occurred. The samples were cooled to room temperature under running water and centrifuged for 15 min at 3000 rpm. After centrifuging, the supernatant was decanted from the sediment into a pre-weighed petri-dish; the supernatant in the petri-dish was weighed and dried at 105 °C for 1 h. The sediment in the tube was weighed and the reading recorded. The starch swelling power and solubility was determined according to the equations below;

\[
\text{Swelling power} = \frac{\text{weight of swollen sediment}}{\text{weight of dry starch}}
\]

\[
\text{Solubility} = \frac{\text{weight of dry supernatant}}{\text{weight of starch sample}} \times 100
\]

Water absorption capacity determination
The method described by Adebowale et al., (2012) was used for determining the water absorption capacity (WAC). Sample of 1g was weighed into clean pre-weighed dried centrifuge tube and mixed with 10 ml distilled water with occasional stirring for 1 h. The dispersion was centrifuged at 3000 rpm for 15 min. After centrifuging, the supernatant was decanted and the tube with the sediment was weighed after removal of the adhering drops of water. The weight of water (g) retained in the sample was reported as WAC.

Dispersibility determination
Standard method was used for determining dispersibility (Kulkarni et al., 1991). Sample of 10g was dispersed in distilled water in a 100 ml measuring cylinder and distilled water was added up to 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was noted and
percentage dispersibility was calculated as follows:

\[
\text{Dispersibility (\%)} = \frac{50 - \text{volume of settled particle}}{50} \times 100
\]

**Bulk density determination**

Bulk density was determined using standard methods (Ashraf et al., 2012). Sample of 10g was measured into a 50 ml graduated measuring cylinder and gently tapped on the bench 10 times to attain a constant height. The volume of sample was recorded and expressed as grams per millilitre.

**Statistical Analysis**

All experimental data obtained were subjected to analysis of variance (ANOVA) procedure of SPSS version 15.0 (SPSS Inc., 2006) at 5% significant level.

**RESULTS AND DISCUSSION**

The result of the swelling power of the flour samples at different temperatures is presented in Figure 1. There was significant difference (p<0.05) in the swelling power of the flour samples. From the results, it is observed that the value of swelling capacity increased in direct proportion to the increase in temperature and at the highest temperature of 95°C, rice (*Oryza sativa*) flour had the highest value with the abakaliki variant having a value of 5.84, closely followed by the ofada moborobo variant (5.83). No significant difference was observed between these two variants, however, their values were significantly different (<0.05) from the other flours; Sorghum flour (4.51), millet flour (4.47), Ofada white variant of rice (*Oryza sativa*) flour (4.45) and maize (3.81). Swelling power indicates the water holding capacity of floury samples, which has generally been used to demonstrate differences between various types of flours. The results obtained are in agreement with some previous studies (Agunbiade and Longe, 1999; Adebowale et al., 2011). This probably suggests that the internal associative forces between the flour molecules were weakened as the temperature increased. It was also observed that the lower the starch content, the lower the swelling power. This supports the findings of Jasmien (2015). This may be due to the hydrophilic nature of starch which enhanced water uptake as the starch content increases enhancing swelling occurrence.

![Figure 1: Swelling power of six flour samples at different temperature](image-url)
The result of the solubility index of the flour samples at different temperatures is presented in Figure 2. There was significant difference (p<0.05) in the solubility index of the flour samples. From the results, it is observed that the value of solubility index increased in direct proportion to the increase in temperature and at the highest temperature of 95°C, maize had the highest value (5.50), followed by the abakaliki variant of rice (Oryza sativa) flour and sorghum flour (4.00) with millet flour and the ofada white variant of rice (Oryza sativa) flour having the least values (3.00). This is in line with previous findings (Gbadamosi and Oladeji, 2013) and probably indicates that increase in temperature caused an increase in the movement of the flour molecules, thereby allowing more samples to be dispersed in the solvent.

Table 1 shows the bulk density, dispersibility and water absorption capacity of the flour samples. There was significant difference (p<0.05) in the bulk density, dispersibility and water absorption capacity of the flour samples. Bulk density is an important parameter for determining the easy ability of packaging and transportation of particulate or powdery foods. The results ranged from 0.65 – 0.91 g/ml with rice (Oryza sativa) flour (Ofada moborobo variant) having the highest bulk density (0.91 g/ml) and maize flour having the least (0.65 g/ml). This probably implies that maize flour of the same quantity as ofada moborobo will occupy less space during storage than ofada moborobo and maize flour will be more economical during transportation because more quantities can be transported. The results for bulk density of the flour blends showed that there is no significant difference (p<0.05) between rice (Oryza sativa) flours (Ofada white and abakaliki variants) samples but there is a significant difference (p<0.05) between these rice samples and other flours.

Dispersibility is a measure of reconstitution of flour or starch in water, the higher the dispersibility, the better the sample reconstitutes in water (Kulkarni et al., 1991; Adebowale et al., 2008) and gives a fine constituent during mixing (Adebowale et al., 2008; 2012). The mean value ranged from 45.50 to 51.0%. Maize had the least mean value while millet had the highest mean value. The dispersibility of these flour samples is low and this probably implies that the samples...
will have lump formation tendency during preparation.

Water absorption capacity showed significant difference (p<0.05) between rice (Oryza sativa) flour (Ofada moborobo and ofada white variants) and other samples, but samples maize, sorghum, millet and rice (abakaliki variant) showed no significant difference. The results ranged from 1.43 – 1.87 g/g with millet flour having the least water absorption capacity. The water absorption capacity was found to be similar to results obtained from previous studies (Adebowale et al., 2012). The high water absorption observed in ofada white and moborobo rice flour could be due to their high starch content since starch and proteins contains hydrophilic parts which enhance water uptake (Lawal and Adewale, 2004).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Bulk density (g/ml)</th>
<th>Dispersibility (%)</th>
<th>WAC (g)</th>
<th>Starch (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ofada Moborobo</td>
<td>0.91±0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.50±0.71&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.85±0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>70.49&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ofada White</td>
<td>0.87±0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>48.00±1.41&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1.87±0.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>68.88&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maize</td>
<td>0.65±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.50±0.71&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.49±0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.51&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Abakalili</td>
<td>0.87±0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>49.00±1.41&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>1.62±0.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>53.58&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.70±0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.00±1.41&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.46±0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>54.82&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Millet</td>
<td>0.71±0.00&lt;sup&gt;c&lt;/sup&gt;</td>
<td>51.00±1.41&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.43±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>63.08&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

± standard deviation. Mean values of duplicate. Mean value having different superscript within the same column are significantly different (p<0.05).

CONCLUSION
The functional properties of these flours revealed their uniqueness to each parameter measured and these results may probably assist in determining the behavior and application of these flours in various food formulations.

CONFLICT OF INTEREST
The authors have declared no conflict of interest.

REFERENCES


