Abstract

This research investigated the physicochemical and functional properties of flours and starches from two varieties of tiger nut (Yellow and Black). The flours and starches were produced using standard methods and subsequently analysed for proximate, functional, mineral and pasting characteristics. The proximate compositions showed that both YTF and BTF are high in crude oil (26.10 and 28.40%) and protein (7.90 and 10.25) but lower content in their starches ranged from 1.86 to 2.16% and 4.1 to 5.3 % for YSTN and BSTN respectively. The minerals examined were Ca, Na, P, K, Fe, Zn and Cu. The results showed YTF and BTF are high in Ca, Na, K and P with values ranged from (156 to 142), (245 to 235), (216 to 255) and (120 to 118)mg/100g respectively. However, Zn, Fe and Cu are very low in the entire sample. The bulk density of all the samples ranges from 0.59 to 0.63, while foam capacities also ranged from 2.29 to 10.91. YSTN and BSTN have the higher bulk density than YTF and BTF while YTF and BTF foam capacities are higher than YSTN and BSTN. The pasting characteristic of the samples showed YSTN and BSTN with high final viscosity (2768 and 2894) RVU with a peak temperature and time of 82.3°C and 6.3 min for BSTN. The characteristics of tiger nut flour and its starch showed a great nutrition and huge potential as an underutilized crop.

Keywords: Tiger-nut, flour, starch, pasting, bulk density

Introduction

Tiger nut (Cyperus esculentus) is an underutilized crop of family Cyperaceae, which produces rhizomes from the base of the tuber that is somewhat spherical. It is a tuber that grow freely and is consumed widely in Nigeria, other parts of west Africa, east Africa, parts of Europe particularly Spain as well as in the Arabian Peninsula (Aning, 2012). The crop is commonly consume as a junk food or at most as a snack. Although, it is generally enjoyed by many people because of its palatability and it is known to be rich in starch, oil, minerals and vitamins E and C (Sylvia et al., 2015). It is also a good source of phosphorus, potassium, iron, magnesium, calcium, zinc, copper, sodium and manganese (Nwobosiet al., 2013). It has been reported to be high in dietary fibre content which could be used in the treatment and prevention of many degenerative diseases such as colon cancer, coronary heart diseases, obesity, diabetes and gastrointestinal diseases (Aning, 2012).

Tiger nut is rich in sucrose (17.40–20.00%), fat (25.50%) and protein (8%) (Umerie and Enebeli 1997). It has also been reported that the quality of fat composition is similar to olives and rich in mineral content, especially phosphorus and potassium (Tunde-Akintunde and Oke, 2011). The anti-nutrient composition of tiger nut varies with variety. Adgidzid (2010) reported that the anti-nutritional factors especially polyphenols present in yellow variety tiger nut are lower than what is obtainable in the black variety tiger nut. However, the black variety tiger nut contains more quantity of oil than the yellow variety tiger nut (Bamishaiye et al., 2011). Tiger nut has potential in the production of many products such as flour and starch which can be used for different purposes such as bread and substitute in animal feed manufacture. Oil can also be obtained from tiger nut, which is highly unsaturated and good for the health of humans. Tiger nut can be used to produce drink, milk, different types of tiger nut milk are also produced, and it can also be used to produce a local snack “Dukwa”.

Starch is one of the most important products in the world; an essential component of food, providing a large proportion of daily calorie intake for both humans and livestock. Starch alone accounts for 60-70% of calorie intake of humans (Santana et al., 2014). Besides its nutritive value, starch is a very versatile raw material with a wide range of applications in food, feed, pharmaceutical, textile, paper, cosmetic and construction industries. Starch may also be used as a thickener, filler which may increase the solid content of soups, as a binder to consolidate the mass of food and prevent the food from drying out during cooking and as a stabilizer in the food industry (Lawton, 2014).
Research for lesser known crop such as tiger nut has been intensified to create a balance between population growth and agricultural productivity particularly in tropical and sub-tropical areas of the world (FAO, 1985). Therefore, this study investigated the physico-chemical properties of tiger nut flour and its starch to bridge the information gap that may exist and also to create awareness on its inherent potential to promote its utilization.

Materials and Methods

Collection of Material
Fresh Tiger nuts (yellow and black variety) were purchased from a local Market in Dutsinma, Katsina State, Nigeria. The tiger nuts were cleaned, sorted and washed in preparation for extraction. All the experiments were carried out at room temperature in the Food Processing laboratory of the Department of Food Science and Technology, Federal University Dutsinma, Katsina State.

Production of Tiger nut flour (yellow and black)
Tiger nut flour was prepared as described by Maziya-Dixon et al. (2007). The flours were packaged in Ziploc double zipper bags until required for analyses (Ziploc Brand Products, WI, USA).

Extraction of starch from Tiger nut
Tiger nut native starch was extracted using the modified method of Umerie et al, (1997). The cleaned tiger nut tuber was steeped in sodium metabisulphite solution (0.8133 g/L) at room temperature for 48 hrs. The tiger nut was thereafter cleaned with distilled water and milled to slurry. The slurry was stirred and passed through a muslin cloth to remove the chaff and the suspension obtained was allowed to stand for 8h at 4°C after which the supernatant was decanted and the starch sediment was collected and washed in distilled water. After washing, the starch was dried at room temperature (25–32°C). Products were kept in Ziploc double zipper bags until ready for analysis.

Analytical Methods

Proximate composition of flour and starch from tiger nut varieties
The samples were subjected to proximate analysis to determine the moisture, ash, crude fiber, crude protein using the standard method of the Association of Official Analytical Chemists, AOAC (2003).

Mineral composition of flour and starch from tiger nut varieties
The method described by AOAC (1990) was used for mineral analysis. 1g of the powdered sample was spread in porcelain dish and placed in muffle furnace. The ashed sample was digested using 6N HCl. Analysis was carried out using atomic absorption spectrophotometer (AAS) (APHA, 2005). Colorimetric method using phosphovanadomolybdate was used for phosphorus determination.

Functional properties of variety of tiger flour and starch

Determination of Bulk density
The bulk density was determined using the method described by Onwuka, (2005). Fifty grams (50g) of tiger nut flour and starch flour sample were poured into a 100ml measuring cylinder separately. The cylinder was tapped fifty (50) times on a laboratory bench to constant volume. The volume of sample was recorded.

\[
\text{Bulk density (g/cm}^3\text{)} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}}
\]

Foaming capacity and stability
The foaming capacity and stability were determined using the method described by Onwuka, (2005). Two grams (2g) of tiger nut flour and starch flour sample were added to 50ml of distilled water at 30 ± 2°C in a 100ml graduated cylinder separately. The suspension was mixed and shaken manually for 5min to foam. The volume of foam after whipping was expressed as foaming capacity using the formula;

\[
\text{Foam capacity (\%)} = \frac{\text{volume of foam after whipping}}{\text{volume of mixture}} \times 100
\]

The volume of foam was recorded at different time intervals (5, 10, 15 and 20 seconds) after whipping to determine the foam stability as percent of the initial foam volume.

Determination of swelling power
About 0.2 g sample in test tubes was suspended in 10 mL of distilled water and incubated in an agitated water bath at 50 °C for 30 min. The paste was allowed to cool to room temperature. The cool paste was centrifuged at 2200×g for 15 min. The supernatant was discarded and the weight of the swollen sediment was determined.

Swelling power (g/g) = \frac{\text{weight of swollen sediment}}{\text{weight of dry sample}}
Determination of oil and water absorption capacities

The water and oil absorption capacities were determined as described by Onimawo and Akubor (2012). One gram of the flour was mixed with 10ml distilled water or refined vegetable oil and allowed to stand at ambient temperature for 30min, and then was centrifuged for 30min at 2000rpm. Water or oil absorption capacity was expressed as percent water or oil bound per gram flour.

\[
\text{Water/oil absorption (g/g) = } \frac{\text{weight after centrifuge} - \text{weight of tube}}{\text{weight of sample}}
\]

Determination of pasting characteristics

Pasting properties of flour and starch were evaluated using a Rapid Visco Analyzer (Newport Scientific, RVA Super 3, Switzerland). The flour/starch suspension (6%, w/w) was held at 50°C for 1 min, and then heated to 95°C at 6°C/min. It was held at 95°C for 2.7 min before cooling from 95 to 50°C at the rate of 6°C/min and then held at 50°C for 2 min. A programmed heating and cooling cycle was used. The pasting curve obtained were analysed using a RVA Master Software setup Tool (SMST) to obtain the characteristic parameters.

Statistical analysis

Statistical difference was conducted at 5% significance level (P < 0.05) using SPSS 16 for Windows software (SPSS Inc., Chicago, Illinois, USA). Means were separated using Duncan’s test.

Results and Discussion

Proximate composition of tiger nut flour and starch flour

The proximate compositions of samples are shown in Table 1. The moisture content of the flour and starch ranged from 10.45% to 7.8% respectively. YTF moisture is higher than BTF and likewise YSTN moisture is higher than BSTN. These differences may be as a result of variety, handling also may alter the hydrophilic sorption sites for moisture during storage. Low moisture content is recommended for safe storage from microbial deterioration at precisely (≤13%). The BTF had the highest fat content of 28.40% followed by 26.10% of YTF, 2.16% of BSTN and 1.84% of YSTN.

Diet with high fat content contribute significantly to the energy requirement for humans. High fat content of BTF and YTF in this study would make them better sources of energy. The low values of starches for BSTN and YSTN indicate the purity of the starches. The crude protein of BTF 10.25% and YTF 7.90% were significantly higher than those of the BSTN 5.30% and YSTN 4.10% respectively. The protein contents of the flours are higher than that obtained from tiger nut varieties as reported by (Oladele and Aina, 2007). Protein influences the pasting properties of starches. The ash content of the flours ranged between 2.80% and 4.10%. The ash content of the YTF 2.80% lower than that of the BTF 3.40% which may be attributed probably to the variety of tiger nut used, the ash content 4.10% of BSTN and YSTN of 3.60% were higher than those reported by Igabu et al., 2014. The crude fibre of BTF was higher 5.40% than the YTF 4.66%, BSTN 3.10% and YSTN 2.41% respectively, which may be as a result of variation in variety of tiger nut used in this research. The carbohydrate content varied from 44.75% to 77.60%. YSTN 77.60% had the highest followed by 77.15% of BSTN, 50.39% of YTF and 44.75% of BTF.

The high carbohydrate content of YSTN suggests that it could be used in managing protein-energy malnutrition (Batool et al., 2014). Carbohydrates are good sources of energy and that a high concentration of it is desirable in breakfast meals and weaning formulas. In this regard therefore, the high carbohydrate content of the YSTN and BSTN would make it a good source of energy in breakfast formulation (Batool et al., 2014).

Mineral composition of flour and starch from tiger nut varieties

Table 2 showed the mineral composition of flour and starch from tiger nut variety. The YTF has a higher calcium, sodium and phosphorous content than BTF, YSTN and BSTN. However, other minerals such as iron, zinc and copper have low content value in all the entire samples. Calcium are important in bone and teeth formation in infant (Oladele and Aina, 2007). Other minerals such as iron also found importance in blood formation. National Institute of Health, (2013) reported that almost two-third of iron in the body is found in hemoglobin which helps in carrying oxygen to tissues.

Functional properties of variety of tiger nut flour and starch flour

The results of functional properties are shown in Table 3. The bulk densities varied significantly from 0.51g/ml for the BTF sample to 63.30g/ml for the YSTN sample. However, there was no significant
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difference (p>0.05) between sample YTF (0.59g/ml) and BTF (0.51g/ml). The slightly lower bulk density of the BTF and YTF could be attributed to probably higher loss of moisture from the surface of the flour due to the drying method applied.

The flour samples (YTF and BTF) probably had similar particle size distribution which explains the similarity in the bulk densities. The 0.59 g/cm³ obtained for the sample YTF is lower than the 0.62g/cm³ reported by (Oladele and Aina, 2007) for yellow tiger nut flour and 0.71g/cm³ for wheat flour reported by (Akubor and Badifu, 2004). Meanwhile, the 0.51g/cm³ for sample BTF is also lower than that reported by (Oladele and Aina, 2007) for brown tiger nut flour. However, there was significant difference (p>0.05) between YSTN and BSTN samples. Bulk density depends on the particle size and initial moisture content of flours (Suresh-Chandra and Samsher, 2013). The low bulk density of the flours would be an advantage in the formulation of complementary foods (Akpata and Akubor, 1999).

The foam capacity of samples BTF (10.91%) and YTF (10.23%) were significantly higher than those of BSTN (3.09%) and YSTN (2.29%). BTF sample obtained the highest foam capacity due to higher protein content. The values for samples BTF, BSTN, YTF and YSTN were comparatively lower than those reported by (Oladele and Aina, 2007) for both brown and yellow tiger nut flour respectively. The low foam capacity may be attributed to the low protein content of the flour since foamability is related to the amount of solubilized protein (Narayana and Narasinga Rao, 1982).

The foam stability for BTF had the highest value 57.85% compared to 50.33% of YTF. However, there was significant difference (p>0.05) between BSTN (16.75%) and 11.75% of YSTN. Foaming stability is enhanced by inherent proteins (Aşghari et al., 2016). This suggests that the BTF contained higher proportion of native proteins than the other flours. Akubor and Badifu (2004) reported 60 and 80% for wheat flour and African breadfruit kernel flour. Protein in the dispersion may cause a lowering of the surface tension at the water air interface, thus always been due to protein which forms a continuous cohesive film around the air bubbles in the foam (Kaushalet al., 2012). The YSTN sample had the highest value 1.97g/g of water absorption capacity, this was followed by the BSTN 1.82g/g, YTF 1.32g/g and then the BTF 1.17g/g respectively.

Water absorption capacity represents the ability of a product to associate with water under conditions where water is limiting. The highest water absorption capacity of the YSTN sample could be attributed to the presence of higher amounts of carbohydrates (starch) and fibre in the flour in relation to the other flours. Water absorption capacity of 1.25g/g and above for flour is an indication of good baking property (GiamiandAlu, 1993). The water absorption capacities of the samples YFR 1.32g/g, BSTN 1.82g/g and YSTN 1.97g/g were higher than 1.25g/g, suggesting that these flours would be useful in bakery products. The BTF sample had the highest oil absorption capacity of 1.13g/g. The oil absorption capacities of the BSTN, YTF and YSTN samples were 1.09g/g, 1.04g/g and 1.01g/g, respectively. The lower oil absorption capacity of sample YSTN might be due to low hydrophobic proteins which show superior binding of lipids.

**Pasting properties of flour and starches from tiger nut variety**

The results of pasting characteristics of the samples are shown in Table 4. The final viscosity of samples ranges from 2894 to 2246 RVU. YSTN has the highest value while YTF has the lowest. Final viscosity is an indication of the flour/starch to form viscous paste. It indicates the stability of the cooked paste in actual use. A high final viscosity of flour/starch indicates that the paste is more resistant to mechanical shear and may easily form a more rigid gel (Zhang et al., 2011). The peak viscosity ranges from 2769 to 1828 RVU. BSTN has the highest peak viscosity, followed by YSTN with value of 2796.5RVU.

It measures maximum viscosity attained during or soon after cooking. It is an indication of the water binding capacity of the starch (Adebowaleet al., 2011). It indicates the strength of the pastes that are formed from gelatinization during food processing. It has been found to correlate with final product quality (Adebowaleet al., 2011), while higher peak viscosity has been found to correlate to a higher thickening power of the starch. The setback ranges from 686 to 796 RVU. The higher the setback value the lower the rate of syneresis and weeping. The breakdown
viscosity also ranges from 606 to 624 RVU. Flour/Starch with lower breakdown viscosity has higher capacity to withstand heating and shearing during cooking. There were no significant (≤0.05) differences in the pasting temperature between the starch samples and likewise the flour.

The values range from 74.6 to 82.3 °C. Pasting temperature is the temperature at which viscosity starts to rise. It ensures swelling, gelatinization and gel formation during processing (Eke-Ejiofor, 2015). Higher pasting temperature indicates lower swelling capacity. High pasting temperature could be an advantage in canned and sterilized foods which require the use of high temperatures (Otegbayo et al., 2013). Peak time is the measure of the cooking time (Adebowa et al., 2011). It is the time taken for the flour/starch to reach highest viscosity. Peak time of the starch samples ranged from 5.1 to 6.3 min. The trough is the holding strength of the flour/starch viscosity. It also measures the stability of the starch viscosity. Trough viscosity of the starch samples ranged from 1727.0-2017.5 RVU.

Table 1: The proximate composition of variety of tiger nut flour and starch flour (%)

<table>
<thead>
<tr>
<th></th>
<th>YTF</th>
<th>BTF</th>
<th>YSTN</th>
<th>BSTN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>8.15±0.2⁵</td>
<td>7.8±0.02⁴</td>
<td>10.45±0.15⁴</td>
<td>8.25±0.82⁴</td>
</tr>
<tr>
<td>Fat</td>
<td>26.10±0.42⁴</td>
<td>28.40±0.30⁴</td>
<td>1.84±0.24⁴</td>
<td>2.16±0.01⁴</td>
</tr>
<tr>
<td>Crude protein</td>
<td>7.90±0.23⁵</td>
<td>10.25±0.40⁴</td>
<td>4.10±0.02⁵</td>
<td>5.30±0.03⁵</td>
</tr>
<tr>
<td>Ash</td>
<td>2.80±0.11⁵</td>
<td>3.40±0.15⁵</td>
<td>3.60±0.05⁵</td>
<td>4.10±0.35⁵</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>4.66±0.12⁵</td>
<td>5.40±0.14⁵</td>
<td>2.41±0.25⁵</td>
<td>3.10±0.20⁵</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>50.39±0.03⁴</td>
<td>44.75±0.20⁴</td>
<td>77.60±0.14⁴</td>
<td>77.15±0.26⁴</td>
</tr>
</tbody>
</table>

Values are means ± standard deviation of duplicate determinations. Means within the row with same superscript were not significantly different (p>0.05). YTF= Yellow tiger nut flour, BTF= Brown tiger nut flour YSTN= Yellow tiger nut starch flour, BS= Brown tiger nut starch flour.

Table II. Mineral Composition of flour and starch from tiger nut varieties (mg/100g)

<table>
<thead>
<tr>
<th></th>
<th>YTF</th>
<th>BTF</th>
<th>YSTN</th>
<th>BSTN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>156.0</td>
<td>142.0</td>
<td>0.63</td>
<td>0.57</td>
</tr>
<tr>
<td>Sodium</td>
<td>245.00</td>
<td>235.00</td>
<td>12.25</td>
<td>13.10</td>
</tr>
<tr>
<td>Potassium</td>
<td>216.00</td>
<td>255.00</td>
<td>10.52</td>
<td>14.45</td>
</tr>
<tr>
<td>Iron</td>
<td>0.65</td>
<td>0.85</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Copper</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>120.00</td>
<td>118.00</td>
<td>8.24</td>
<td>7.64</td>
</tr>
</tbody>
</table>

Values are means of duplicate determinations. YTF= Yellow tiger nut flour, BTF= Brown tiger nut flour YSTN= Yellow tiger nut starch flour, BS= Brown tiger nut starch flour.
Table III: The functional properties of variety of tiger nut flour and starch flour

<table>
<thead>
<tr>
<th></th>
<th>YTF</th>
<th>BTF</th>
<th>YSTN</th>
<th>BSTN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density (g/cm³)</td>
<td>0.59±0.01b</td>
<td>0.51±0.01c</td>
<td>0.63±0.14a</td>
<td>0.57±0.01b</td>
</tr>
<tr>
<td>Foam capacity (%)</td>
<td>10.23±0.01a</td>
<td>10.91±0.01a</td>
<td>2.29±0.02c</td>
<td>3.09±0.01b</td>
</tr>
<tr>
<td>Foam stability (%)</td>
<td>50.33±0.01b</td>
<td>57.85±0.02a</td>
<td>11.75±0.35d</td>
<td>16.75±0.35c</td>
</tr>
<tr>
<td>Swelling power (g/g)</td>
<td>2.40±0.01c</td>
<td>2.07±0.21d</td>
<td>10.39±0.01a</td>
<td>8.89±0.21b</td>
</tr>
<tr>
<td>Water absorption capacity (ml/g)</td>
<td>1.32±0.21b</td>
<td>1.17±0.21c</td>
<td>1.97±0.21a</td>
<td>1.82±0.21a</td>
</tr>
<tr>
<td>Oil absorption capacity (ml/g)</td>
<td>1.04±0.14a</td>
<td>1.13±0.14a</td>
<td>1.01±0.01a</td>
<td>1.09±0.01a</td>
</tr>
</tbody>
</table>

Values are means ± standard deviation of duplicate determinations. Means within the row with same superscript were not significantly different (p>0.05). YTF= Yellow tiger nut flour, BTF= Brown tiger nut flour YSTN= Yellow tiger nut starch flour, BSTN= Brown tiger nut starch flour.

Table IV. Pasting characteristics of flour and Starch from tiger nut variety

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>Final Viscosity</th>
<th>Peak Viscosity</th>
<th>Set-Back</th>
<th>Break-Down</th>
<th>Peak Temp</th>
<th>Peak Time</th>
<th>Trough Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>YTF</td>
<td>2246.0±155b</td>
<td>1828.5±130.81b</td>
<td>686.5±82a</td>
<td>606.0±57b</td>
<td>74.6b</td>
<td>5.30c</td>
<td>1772.5±72b</td>
</tr>
<tr>
<td>BTF</td>
<td>2389.5±40b</td>
<td>1972.5±6.36b</td>
<td>689.0±15b</td>
<td>611.0±26b</td>
<td>74.6b</td>
<td>5.13c</td>
<td>1727.5±20b</td>
</tr>
<tr>
<td>YSTN</td>
<td>2894.0±227a</td>
<td>2796.5±41.72a</td>
<td>796.0±36a</td>
<td>624.5±194a</td>
<td>81.4a</td>
<td>5.90b</td>
<td>2110.0±236a</td>
</tr>
<tr>
<td>BSTN</td>
<td>2768.5±191a</td>
<td>2812±825.90a</td>
<td>795.5±41a</td>
<td>621.0±592a</td>
<td>82.3a</td>
<td>6.30a</td>
<td>2017.5±233a</td>
</tr>
</tbody>
</table>

Values are means ± standard deviation of duplicate determinations. Means within the row with same superscript were not significantly different (p>0.05). YTF= Yellow tiger nut flour, BTF= Brown tiger nut flour YSTN= Yellow tiger nut starch flour, BSTN= Brown tiger nut starch flour.

Conclusion
The result of the study showed a great potential for tiger nut varieties. The proximate composition showed appreciable level of protein, carbohydrate, ash and fat content in the flours and starches. Essential minerals such as calcium, sodium, potassium and phosphorous were present at an appreciable level in the flours than the starches. The lower bulk densities for all the samples indicated better packaging. Moreover, oil and water absorption capacity for all the samples and not significantly different. The pasting characteristics exhibited by all the samples showed a low breakdown, setback and peak temperature which is an index of quality flours and starches.
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