Physical and Functional Properties of Trifoliate Yam Flours as Affected by Harvesting Periods and Pre-treatment Methods

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Abstract
The physical and functional properties of trifoliate yam flours processed using different pre-treated methods at varying harvesting periods were examined. The flours were subjected to physical (bulk density) and functional (water absorption, solubility and swelling power) analyses. The bulk density values for the trifoliate flours ranged from 0.54-1.03 g/cm³. The parboiled flours had higher bulk densities in both cultivars of trifoliate yam flour. The parboiled white trifoliate yam flour harvested at 10 months had higher water absorption capacity (4.52 ml H₂O/g) and was significantly different (p<0.05) from other flours harvested at other periods. Soaked (60°C) flours harvested at 11 months had the least solubility (3.49%) while the parboiled trifoliate yam flour had higher solubility. At 60-80°C, parboiled flours had higher swelling power values than the other flours while at 90°C, the raw flours harvested at 7 and 9 months had higher values which was significantly different (p<0.05) from other flour samples. The physical and functional properties of trifoliate yam flours were more dependent on the pre-treatment methods rather than the harvesting periods.

Keywords: Functional; Harvesting periods; Physical properties; Pre-treatment methods; Trifoliate yam

Introduction
Yam is an important agricultural crop in Nigeria, though its importance in the diets of the various tribes in the country varies. They are the most preferred of all roots and tubers by millions of people in the yam zones of Africa [1]. Yams, the edible tubers of various species of the genus Dioscorea, are important staple foods and a potential source of ingredients for fabricated foods in many tropical countries because of their high starch content [2]. The flour from trifoliate yam had been reported to have high water holding capacity and swelling index when compared to other yam species [3]. Mahajan and Dua [4] explained the functionality of a food as the property of a food ingredient, apart from its nutritional value, that has great impact on its utilization. In Nigeria, the only way of consuming trifoliate yam is by boiling the tubers with peels and eaten with palm oil or sauce. Nutritionaly, the tuber is superior to the commonly consumed yams, having high protein and mineral content [3]. It has a mean protein content of 9.6% (dry weight basis) compared to 8.2% for water yam (D. alata) and 7.0% for White yam (D. rotundata) [5].

Generally, the nutritive and anti-nutritional properties of trifoliate yam are documented [6-8] but effect of harvesting periods and pre-treatment methods on the functional properties had not been widely studied. There is limited information on the use of flours from trifoliate yam in food industries and at household levels in Nigeria. This could probably be due to lack of information on the usefulness and importance of the flours for functional food products. Studying the properties of trifoliate yam flours as affected by harvesting periods and pre-treatment methods provides a wide range of flours with varying characteristics which could be useful to food processors. Being a high yielding and cheaper crop, it could serve as raw materials for food formulation. Therefore, this paper examined the physical and functional properties of trifoliate yam as affected by harvesting periods and pre-treatment methods.

Materials and Methods

Materials
Trifoliate yam (white and yellow cultivars) tubers were harvested at 7, 8, 9, 10 and 11 months of maturity on a farm at Osogbo, Osun State, Nigeria.

Methods

Preparation of raw flour: The freshly harvested yam tubers were washed, drained and peeled. The peeled tubers were sliced and dried in the hot air oven at 60°C for 48 hrs. The dried chips were milled into flour with hammer mill and sieved (600 µm). The flour samples were sealed in polythene bag [8].

Preparation of soaked (ambient) flour: The freshly harvested yam tubers were washed, drained and peeled. The peeled tubers were diced, soaked in water for 1 hr and dried in the hot air oven at 60°C for 48 hrs. The dried chips were milled into flour with hammer mill and sieved (600 µm). The flour samples were sealed in polythene bag [8].

Preparation of soaked (60°C) flour: The freshly harvested yam tubers were washed, drained and peeled. The peeled tubers were diced, blanched (60°C) and soaked for 12 hrs at ambient temperature and dried in the oven 60°C for 48 hrs. The dried chips were milled into flour with hammer mill and sieved (600 µm). The flour samples were sealed in polythene bag [8].

Preparation of parboiled flour: The freshly harvested yam tubers were washed, peeled, diced and pre-cooked for 10 min in water bath maintained at 100°C ± 2. The samples were dried in an oven set at 60°C for 48 hrs. The dried chips were milled into flour with hammer mill and sieved (600 µm). The flour samples were sealed in polythene bag [8].

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Determination of bulk density: The method used by Udensi and Okaka [9] was adopted. Bulk density was determined by weighing 3 g of each sample into 10 ml graduated cylinders and tapping ten times against the palm of hand. The volume of the flour after tapping was recorded and bulk density was expressed as g/cm³.

Determination of water absorption capacity: Flour sample (1 g) from each treatment was weighed into dry centrifuge tube. Distilled water was mixed with the flour to make up to 10 ml dispersion. It was then centrifuged at 3500 rpm for 15 min. The supernatant was discarded while the tube with its content was reweighed. The gain in weight of flour (g/g).

Solubility determination: Flour dispersion [10% (w/v), db] was prepared for each of the flour samples by dispersing 1 g (db) of flour in a small quantity of distilled water which was made up to 10 ml. It was allowed to stand for 60 min while it was stirred every 15 min. Thereafter, 2 ml of the supernatant was pipetted into a weighed dry petri dish, evaporated to dryness and reweighed. The gain in mass is the water absorption capacity of the flour sample [10].

Solubility was calculated as shown below:

\[
\text{Solubility}(\%) = \left( \frac{V_s \times (M_e - M_d)}{M_s} \right) 
\]

Where \(V_s\) = Total supernatant/filtrate
\(M_d\) = Mass of empty, dry petri dish
\(M_e\) = Mass of petri dish plus residual solids after evaporative drying
\(M_s\) = Mass of flour sample used in the preparation of the dispersion

Determination of swelling power: Swelling power of yam flour was determined according to Peroni [12]. A flour sample of 0.2 g (dry starch basis) was mixed with 18 g of distilled water into glass tubes with coated screw caps. The weight of the mixture was completed to exactly 20g. The tubes were placed in a shaking water bath at 60, 70, 80 or 90°C for 30 min. The tubes were closed, inverted for homogenization and centrifuged at 1700 g for 5min. The supernatant was removed carefully and swelling power was determined as sediment weight divided by dry weight of flour (g/g).

Statistical analysis

All analyses were carried out in triplicates on the replicate samples. The mean and standard deviation of the data obtained were calculated. The data were evaluated for significant differences in their means with Analysis of Variance (ANOVA) (p ≤ 0.05). Differences between the means were separated using Tukey test as packaged by SPSS (17.0) software.

Results and Discussion

Effect of harvesting periods and pre-treatment methods on the bulk densities of trifoliate yam flours

The bulk densities of the trifoliate yam tuber are shown in Figure 1. The parboiled samples had higher bulk densities in both cultivar of trifoliate yam flour. The values obtained for the raw and processed yellow samples were higher than that of white cultivar. The bulk density values for the white cultivar flours ranged from 0.54-1.03 g/cm³ while the values for the yellow cultivar flours ranged from 0.68-1.07 g/cm³. The bulk densities of parboiled white trifoliate yam flours decreased from 7 to 11 months of maturity. The least bulk density was in soaked (ambient) white Yam flour at 11 months and Nelson-Quartey [13] reported that low bulk density is suitable for infant food formulation. The bulk density of cooked trifoliate yam flour observed by Ezeocha [14] was 0.86 g/cm³. Mayaki, et al. [15] reported higher bulk density (0.71 kg/m³) in parboiled pulp of breadfruit flour than that of raw pulp (0.38 kg/m³). Cooking consolidated the pulp into meal, displacing the air spaces in the material [15]. Increase in bulk density increased the sink ability of powdered particles and this aids their ability to disperse [9,16]. The density of the flour is important in determining the packaging requirement and material handling [14].

Effect of harvesting periods and pre-treatments on the water absorption capacity of trifoliate yam flour

There were variations in the water absorption capacities of trifoliate yam cultivars with harvesting periods and pre-treatment methods (Table 1). The parboiled white trifoliate yam flour harvested at 10 months had higher water absorption capacity (4.52 ml H₂O/g) and was significantly different (p<0.05) from other flours harvested at other periods. There was no significant difference (p>0.05) in the raw white yam flours harvested from 7-10 months. The least water absorption capacity was observed in the raw white trifoliate yam flour harvested at 11 months. Likewise, in the yellow cultivar, the parboiled flours had higher water absorption capacity at 8 months but no significant difference (p>0.05) existed at 7, 8 and 10 months. The least water absorption capacity in raw yellow flour was at 11 months but it was not significantly different (p>0.05) from soaked yellow flour at 11 months.

Soaking at 60°C and parboiling improved the water absorption capacity of trifoliate yam flours. Blanching of white yam varieties at 100°C for 10 min was reported to increase the water absorption capacity up to 5.4% [17]. Percentage water absorption capacity recorded for different varieties of D. rotundata ranged from 21.30-193.30 % [16]. Parboiling method weakens the associative forces in the starch components resulting in high water absorption capacity. According to Aryee [18], water absorption capacity depends on the associative forces among starch components where weak inter associative forces result in high water binding capacity.

Water absorption capacity is the ability of flour particles to entrap large amounts of water, such that exudation is prevented [19]. It also refers to the total amount of water held by a starch gel under a defined state of conditions [20]. It is highly dependent on the crystalline properties of starch being high for starches with low crystallinity and hence, is correlated to the amylose content of starch [21]. Water
absorption capacity varies with size, shape, presence of proteins, carbohydrates and lipids, pH and salts [14]. Water binding capacity is affected by the presence of minerals like phosphorus in starch where starches having high phosphorus contents have high water binding capacities [22].

### Effect of delayed harvesting and pre-treatment methods on the solubility of trifoliate yam flour

Solubility values ranged from 3.43-5.96%. Parboiled white trifoliate yam flour had higher solubility (5.96%) at 7 months (Table 1). This was not significantly different (p>0.05) from other parboiled flours, raw flours harvested at 7-10 months and soaked flour harvested at 8-9 months. Soaked (60°C) white flours harvested at 11 months had the least solubility (3.49%) while the parboiled trifoliate yam flour had higher solubility. Parboiled yellow flour harvested at 7 months had higher solubility and significantly different (p<0.05) from other flours. Soaked (60°C) yellow flour at 8 months had the least solubility value (3.43%). Solubility is a measure of the ease with which the flour particles are able to dissolve in cooking water. It permits rapid and extensive dispersion of flour particles in solution.

This leads to a finely dispersed colloidal system, with homogenous macroscopic structure and a smooth texture. Data on solubility characteristics are very useful for determining optimum conditions for the extraction of flour [23]. The result showed that the degree of swelling and amount of soluble components depend on the type and species of yam tubers. Increase in temperature allowed amylose (water soluble fraction) molecules located in the bulk amorphous regions to interact with the branched segment of amylopectin (water insoluble fraction) in the crystalline regions. This implies that high temperature weakens the starch granules of flour leading to improved solubility [24].

### Effect of delayed harvesting and pre-treatment methods on the swelling power of trifoliate yam flour

The swelling power of white soaked trifoliate yam flour harvested at 7 months had the least value (1.61) at 60°C (Tables 2 and 3). The swelling power of the raw, soaked (ambient), soaked (60°C) and parboiled flours increased with rise in temperatures. At 60-70°C, parboiled flours had higher values than the other flours while at 90°C, the white trifoliate raw flours harvested at 7 and 9 months had higher values which was significantly different (p<0.05) from other flour samples. Lower swelling power was observed in the raw flours at 60°C and these increased with rise in temperature. At low temperature, the starch contents of the raw flours were intact and would not swell until it reached the gelatinization temperature. Gelatinization is the disruption of molecular order within granules leading to leaching of amylose, irreversible granule swelling, loss of birefringence, and loss of crystallinity [25]. The raw, soaked (ambient) and soaked (60°C) flours had ability to swell at 90°C than the parboiled flours. Parboiled yellow trifoliate yam flour swelled more than the parboiled white trifoliate yam flour at 60°C while at 90°C, the swelling power of the parboiled trifoliate yam flours were reduced. This could be due to heat treatment given to the tuber as this result into reduction in the swelling ability at 90°C than the untreated flours. Higher swelling power in parboiled flour at 60°C was as a result of amylose leaching into the cooking medium during processing. High swelling power is an important criterion for good quality flour for noodle production [26].

Wiereko-Manu, et al. [27] observed that swelling power are largely controlled by the strength and character of the micellar network within starch granules and the extent of this interaction have been reported to be influenced by the amylose/amylopectin ratio [11,28]. Amylose was reported to restrict swelling and that starch granules show complete swelling after amylose has been leached out of the granules [29]. Starch swelling capacity and amylose leaching have been associated to amount of amylose complexed with lipid, chain length of amylose, inter-chain interaction of amylose and amylopectin in the starch granules, and phosphate content [29]. Swelling power is an indication of the water absorption index of the granules during heating and reflects the extent of the associative forces within the granules [30].

<table>
<thead>
<tr>
<th>Pre-treatment Method</th>
<th>Harvesting periods (months)</th>
<th>White cultivar Water absorption capacity (ml H₂O/g)</th>
<th>Solubility (%)</th>
<th>Yellow cultivar Water absorption capacity (ml H₂O/g)</th>
<th>Solubility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Untreated</strong></td>
<td>7</td>
<td>2.53 ± 0.04⁷</td>
<td>4.95 ± 0.01**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>2.21 ± 0.01*</td>
<td>4.75 ± 0.04*</td>
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<td></td>
<td>8</td>
<td>2.51 ± 0.01*</td>
<td>4.83 ± 0.03**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>2.21 ± 0.01*</td>
<td>4.66 ± 0.01*</td>
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<td></td>
<td>9</td>
<td>2.42 ± 0.02*</td>
<td>4.69 ± 0.01**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>2.11 ± 0.18*</td>
<td>4.51 ± 0.08*</td>
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<tr>
<td></td>
<td>10</td>
<td>2.39 ± 0.02*</td>
<td>4.76 ± 0.06**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>1.89 ± 0.02*</td>
<td>4.53 ± 0.01*</td>
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<td></td>
<td>11</td>
<td>1.87 ± 0.04&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.43 ± 0.03**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>1.47 ± 0.05</td>
<td>3.52 ± 0.08</td>
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<tr>
<td><strong>Soaking (ambient temperature)</strong></td>
<td>7</td>
<td>2.25 ± 0.07&lt;sup&gt;g&lt;/sup&gt;</td>
<td>4.34 ± 0.06**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>2.20 ± 0.01&lt;sup&gt;*&lt;/sup&gt;</td>
<td>5.52 ± 0.04&lt;sup&gt;g&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>8</td>
<td>2.1 ± 0.01&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.79 ± 0.04**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>2.19 ± 0.01&lt;sup&gt;*&lt;/sup&gt;</td>
<td>4.27 ± 0.06&lt;sup&gt;h&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>9</td>
<td>2.22 ± 0.02&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.62 ± 0.01**&lt;sup&gt;abcd&lt;/sup&gt;</td>
<td>2.10 ± 0.01&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.35 ± 0.06&lt;sup&gt;h&lt;/sup&gt;</td>
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<td>2.74 ± 0.05&lt;sup&gt;h&lt;/sup&gt;</td>
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<td>2.16 ± 0.06&lt;sup&gt;h&lt;/sup&gt;</td>
<td>5.07 ± 0.09&lt;sup&gt;h&lt;/sup&gt;</td>
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<td>2.01 ± 0.01&lt;sup&gt;h&lt;/sup&gt;</td>
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<td>1.66 ± 0.04&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.08 ± 0.03&lt;sup&gt;h&lt;/sup&gt;</td>
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<tr>
<td><strong>Soaking (60°C)</strong></td>
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<td>2.12 ± 0.02&lt;sup&gt;h&lt;/sup&gt;</td>
<td>3.96 ± 0.06*</td>
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<td>3.49 ± 0.06*</td>
<td>3.13 ± 0.04&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.04 ± 0.06&lt;sup&gt;h&lt;/sup&gt;</td>
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<td><strong>Parboiled</strong></td>
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<td>5.96 ± 0.06&lt;sup&gt;h&lt;/sup&gt;</td>
<td>4.12 ± 0.03&lt;sup&gt;h&lt;/sup&gt;</td>
<td>5.74 ± 0.05&lt;sup&gt;h&lt;/sup&gt;</td>
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<tr>
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<td>5.81 ± 0.28&lt;sup&gt;abcd&lt;/sup&gt;</td>
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<td>3.72 ± 0.05&lt;sup&gt;h&lt;/sup&gt;</td>
<td>5.01 ± 0.01&lt;sup&gt;h&lt;/sup&gt;</td>
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Values with the same superscript down the column were not significant different (p < 0.05).

Table 1: Effect of harvesting periods and pre-treatment methods on the functional properties of trifoliate yam flours.
Conclusions

The properties of trifoliate yam flours showed variability in the values of the flours from the two trifoliate yam cultivars. The physical and functional properties of trifoliate yam flours depend more on the pre-treatment methods than the harvesting periods. Harvesting of trifoliate yam from 7 to 9 months showed flours with high functional qualities. Soaking at 60°C and parboiling methods improved the functional properties of trifoliate yam flours.

References