

# EFFECT OF TUBER SECTIONING ON THE FUNCTIONAL PROPERTIES OF FLOUR FROM WHITE YAM (*DIOSCOREA ROTUNDATA*) AND WATER YAM (*DIOSCOREA ALATA*) IN ORU EAST, IMO STATE, NIGERIA

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## ABSTRACT

White yam (*D. rotundata*) and water yam (*D. alata*) were obtained from Mgbidi market, Oru East, Imo State, Nigeria, and the effect of sectioning on their functional properties was studied. Each of the yam tubers was sectioned as follows: head, middle, and tail of the yam tubers. They were manually peeled with a stainless-steel knife, washed, and sliced to a thickness of 2mm. The yam slices were treated for 20 min in 800 ppm sodium metabisulphate, drained of the solution, dried in a cabinet drier at 70 °C until a constant weight was obtained, and cooled to 25±2 °C. They were milled using an attrition mill, sieved through a 0.2mm aperture sieve, packaged in an airtight container, and labeled for subsequent analysis. The functional properties of the flour samples were determined according to the AOAC standard methods. Results were statistically analyzed at a 0.05 significance level using the General Linear Model to determine the mean, standard deviation, and analysis of variance. The results showed that, except for the swelling index, which decreased from 10.08 to 4.07 for heat-treated tail sections, the other functional properties examined were not significantly different ( $p > 0.05$ ). On average, the flour from water yams had higher wettability (22.69s), oil absorption capacity (3.87g/ml), and gelatinization temperature (71.73 °C). However, flour from white yams had a higher average bulk density (0.53g/ml), emulsion capacity (5.11%), water absorption capacity (4.9g/ml), and swelling index (4.09). The results showed that there were significant ( $p \leq 0.05$ ) differences in the functional properties of flour from the two varieties of yam tubers under examination. Based on the findings of this research, since no significant differences were observed among sections, flour from the whole tuber should be used instead of sectioning in food processing, such as for dough and pasta products, where swelling capacity is important. The high oil-absorption capacity of water yam flour suggests it could be used more effectively in baked products to enhance sensory attributes.

**Keywords:** White yam, Water yam, Sodium metabisulphate, Functional properties, Flour

## INTRODUCTION

Yams, the fourth-most-significant tropical tuber crop, contribute about 10% of the world's total root and tuber production. Yams are a common name for some species in the genus *Dioscorea* (family Dioscoreaceae). They are consumed in different forms in Nigeria: boiled, roasted, or fried, and most times dried and milled into flour. In western Nigeria, yam flour, known as 'Amala,' is a highly

regarded staple food. The paste prepared from yam flour is used as a folk remedy for stomach pain in South India. Also, wheat flour can be partially replaced with yam flour when preparing pasta. It also acts as a thickener in soups and gravies. Edible roots and tuber flours are gaining significant interest due to their lower prices and easy availability (Ogieriakhi *et al.*, 2020). Yams are essential for meeting the diverse needs of the population and for promoting food security and eradicating poverty (Srinivas, 2012). Starch makes up the majority of the carbohydrates in yams. Compared to other tubers, yam starches have greater amylose/amylopectin ratios (Wu *et al.*, 2016). White yam (*D. rotundata*) is known as true or African yam; it is the most common type of yam. It has tough brown skin and white starchy flesh. They are rich sources of carbohydrates, providing a significant amount of calories and energy, as well as vitamin C, Potassium, Folate, Iron, Manganese, and Dietary fiber (Huang *et al.*, 2018). Water yam (*D. alata*) is a large, starchy root tuber with a brown, rough skin and white flesh. It has a mild, sweet flavor and is sticky in texture; it is a good source of several nutrients, including carbohydrates, vitamin C, potassium, and iron. *D. alata* has been suggested to possess potential for increased consumer demand due to its low sugar content, an important factor for diabetic patients. Different varieties and sections of yam tubers behave and taste differently as a result of their chemical and physical properties. Several authors have studied the use of yam flour and its biochemical and functional properties, but very few have examined the functionality of different sections of the tubers (Adewale *et al.*, 2014; Wu *et al.*, 2016). The outcome of this research will help food processors identify the variety and section of yam tubers that are suitable for a particular food product. This work aims to determine the effect of sectioning on the functional properties of different yam varieties.

## MATERIALS AND METHODS

### Raw Material Collection and Sample Preparation,

Five tubers each of white yam (*D. rotundata*) and water yam (*D. alata*) were obtained from the Mgbidi market in Oru East, Imo State, Nigeria. The yam tubers were washed in potable water, manually peeled with stainless steel knives, divided into 3 equal parts (sectioning) of the head, middle, and tail, and sliced to 2mm thickness using a manual slicer. The yam slices were soaked for 20 minutes in an 800 ppm solution of Sodium Metabisulphite. The soaking solution was drained completely, and the slices were further dried in a cabinet drier at 70 °C until a constant weight was attained. The dried yam slices were cooled to 25±2°C, milled using an attrition miller, sieved through a 0.2mm aperture-sized sieve,

packaged in a high-density polyethylene bag, and labeled for subsequent analysis as described by Wu *et al.* (2016) Figure 1).

### Determination of Functional Properties of Yam Flour Bulk Density Determination

This was done in accordance with Onimawo and Akubor (2005). Ten (10 ml) capacity graduated measuring cylinder was filled with the flour sample and the initial volume was recorded. The cylinder was tapped continuously to displace air and vacuum until the volume became constant. The final volume was recorded after levelling, and the bulk density of the samples was calculated as shown in equation 1.

$$\text{Bulk density (g/ml)} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \quad 1$$

### Emulsification Capacity Determination

The Method of Onwuka (2018) was adopted. Emulsification capacity was estimated by blending 2 g of the flour sample with 25 ml of distilled water at room temperature for 30 seconds in a Waring blender at 1600 rpm. After complete dispersion, 25 ml of vegetable oil (groundnut Oil) was added, and blending was continued for another 30 seconds. It was then placed in a centrifuge tube and centrifuged at 1600 rpm for 5 minutes. The volume of oil separated from the sample after centrifuging was read directly from the tube. Emulsion capacity is expressed as the amount of oil emulsified and held per gram of sample (equation 2).

$$\text{Emulsion Capacity (\%)} = \frac{\text{Height of emulsion layer in the tube}}{\text{Height of the total fluid in the tube}} \times \frac{100}{1} \quad 2$$

### Water Absorption Capacity Determination

The method described by Onwuka (2018) was adopted. A gram (1 g) of each flour sample was weighed separately, and the weight of the samples in a clean, dry centrifuge tube was also recorded. The sample and 10 ml of distilled water were mixed thoroughly for 30 seconds, then the sample was allowed to stand for 30 minutes at room temperature, centrifuged at 5000 rpm for 30 minutes, and the volume of free water (supernatant) was read directly from the graduated centrifuge tube. The density of water was assumed to be 1.0 g/ml. The water absorption (equation 3) was expressed as the amount of water retained by 1 g of flour (g/ml).

$$\text{Water absorption capacity (g/ml)} = \frac{\text{weight of water absorbed} \times \text{density of water}}{\text{weight of sample}} \quad 3$$

### Oil Absorption Capacity Determination

The method described by Onwuka (2018) was adopted. A gram (1 g) of each flour sample was weighed separately, and the weight of the samples in a clean, dry centrifuge tube was also taken. Oil was mixed with the sample to prepare a dispersion of up to 10 ml. The sample and oil were mixed thoroughly for 30 seconds, then the sample was allowed to stand at room temperature for 30 minutes and centrifuged at 5000 rpm for 30 minutes. The volume of free oil was read directly from the graduated centrifuge tube. The density of oil was assumed to be 0.94 g/ml. The Oil Absorption was expressed as the amount of oil bound by 1 g of flour (g/ml), estimated with equation 4.

$$\text{Oil absorption capacity (g/ml)} = \frac{\text{weight of oil absorbed} \times \text{density of oil}}{\text{weight of sample}} \quad 4$$

### Wettability determination

The method of Onimawo and Akubor (2005) was adopted. One gram of the flour sample was weighed into a clean, dry test tube and covered. The tube was clamped vertically on a retort stand 15 cm above a 200 cm<sup>3</sup> distilled water container in a 250 cm<sup>3</sup> beaker at room temperature. Gently, the paper covering the tube was removed, and the sample was allowed to fall under gravity into the beaker. The wetting time was recorded as the time (seconds) required for all the powder to be wetted and penetrate the surface of the still water.

### Swelling index determination

The procedure described in Ikegwu *et al.* (2010) was used to determine the swelling indexes of the flour samples. One gram of the flour sample was mixed with 10 mL of distilled water in a centrifuge tube and heated at 80 °C for 30 min with continuous agitation. After heating, the suspension was centrifuged at 1500 rpm for 15 min. The supernatant was decanted, and the weight of the paste was taken. The swelling index was calculated as shown in equation 5.

$$\text{Swelling Index} = \frac{H_2}{H_1} \quad 5$$

Where: H<sub>2</sub> = final height  
 H<sub>1</sub> = initial height

### Gelatinization Temperature Determination

The method described by Onwuka (2018) was used. Ten percent (10%) suspension of the flour sample was prepared in a test tube. The formed aqueous suspension was heated in a boiling water bath with continuous stirring. The temperature measured 30 seconds after gelatinization was visually observed and recorded as the gelatinization temperature.

### Statistical Analysis

The data obtained from the different analyses were subjected to statistical analyses such as simple descriptive mean and standard deviation, Analysis of variance (ANOVA), using version 23 of computer software (SPSS). A comparison test (LSD) was used to separate means when significant differences (p ≥ 0.05) existed.

## RESULTS AND DISCUSSION

Bulk density is an important functional property for predicting packaging requirements, handling, and wet processing in the food industry (Aluge *et al.*, 2016). Table 1 showed that, except for the flour from the tail section of the tubers, which had the highest mean bulk density of 0.55 g/ml, the mean bulk density of the whole tuber (0.54 g/ml) was not significantly (p>0.05) different from the different sections of the tubers. Bulk density, according to Bello *et al.* (2017), increases with particle size; however, the starch polymer texture and density, and the loose structure of the starch polymers, could result in low bulk density. Comparing the flour from tuber varieties (Table 2), water yam flour had the lowest bulk density (0.52 g/ml), while white yam had the highest (0.53 g/ml), though the difference was not significant (p>0.05). Researchers have shown that low bulk density is desirable in granular material because it results in lower dietary bulk and reduces paste thickness during reconstitution (Peace & Adekunle, 2017). Table 1 showed that the

emulsion capacity of the flour from the whole yam tuber was 5.28% and was not significantly ( $p > 0.05$ ) different from other sections, except the flour from the tail section (2.68 %). Except for the emulsion capacity (5.73 %) of flour from whole white yam tuber, the emulsion capacity of the flour from the tuber varieties was not significantly ( $p > 0.05$ ) different from each other (Table 2). On average, the emulsion capacity of flour from white and water yam were 5.11% and 4.78%, respectively. Flours with high emulsion capacity are suitable for thickening food emulsions such as ice cream and yogurt, where they serve as emulsifying agents. Water absorption capacity of flour is an important property in determining its utilization in aqueous food formulations such as dough and related products, because flour with high water absorption capacity reduces bread firmness by providing initial softness and smoothness of the dough before and after baking (Aprianita *et al.*, 2014). Table 1 showed that no significant ( $p > 0.05$ ) difference existed among the water absorption capacities of different sections of the yam tubers under examination. They were in the range of 4.80g/ml to 4.88g/ml for the tail and middle sections, respectively. Among the varieties of yams (Table 2), flour from white yams had slightly higher water absorption capacity (4.9 g/ml) than that from water yams (4.8g/ml). Moreover, no significant difference existed in the water absorption capacities of different sections of the white yam variety. However, the water absorption capacity of flour from sections of water yam was significantly ( $p \leq 0.05$ ) different from each other, with the middle section having the highest (4.99g/ml) and the tail having the lowest (4.77g/ml) values. According to Amandikwa *et al.* (2017) and Chinma *et al.* (2018), flour with high water absorption capacity could be better applied in soup and sauce thickening, where high water absorption is of high importance. According to Alimi *et al.* (2016), the oil absorption capacity of flour is of great importance in applications requiring emulsification. It is usually affected by particle size, shape, pH, and ionic strength (Tharise *et al.*, 2014). Table 1 showed that though the tail section had the highest (4.34 g/ml) and the middle section had the lowest (3.61g/ml), there was no significant ( $p > 0.05$ ) difference among the oil absorption capacities of different sections of the yam tubers. Table 2 showed that the average oil absorption capacity of flour from water yam was 3.87g/ml and that from white yam was 3.68 g/ml. According to Appiah *et al.* (2011), oil absorption capacity is a property that aids flavour retention and enhances sensory attributes such as mouthfeel. According to Oluwole and Aderigbige (2010), wettability is strongly positively correlated with water absorption capacity and swelling power. Table 1 showed that among the yam tuber sections, flour from the tail section had 12s while that from the head had 21.79s for wettability. Considering the varieties shown in Table 2, the wettability of the flour from white yams was significantly lower (20.36s) than that of flour from water yams (22.69s). The swelling power of most starch granules is very poor at cold temperatures and increases with heating. This is because, as temperature increases, intermolecular hydrogen bonds are broken, and the networks are loosened, thereby allowing the entrance of additional moisture and granule enlargement (Odimegwu *et al.*, 2016). Table 1 shows the head section of the yam tubers generated the flour with the highest swelling index (10.08), and the tail section had the lowest (4.07). Among the varieties of yam tubers under study, the swelling index of flour from white yam (4.09) was significantly ( $p \leq 0.05$ ) different from that from water yam (4.02). This could be attributed to starch interactions with other chemical components across different tuber varieties. According to Chinma *et al.* (2018), amylose in starch tends to retard

and resist the swelling power of starch, and the level of binding forces holding the granules is shown on the swelling power of such starch. Moreover, since this property is peculiar to starch, it is also affected by interactions between starch and other components, such as protein and fat (Agume *et al.*, 2017). The formation of a protein-amylose complex, according to Shimelis *et al.* (2006), lowers the swelling index of starch. Table 1 showed no significant difference ( $p > 0.05$ ) in the gelatinization temperature of flour from different sections of the yam tubers. They were in the range of 68.53 °C to 71.32 °C. Comparing the yam varieties under study, the gelatinization temperatures of flour from water yam were significantly ( $p \leq 0.05$ ) higher than those of flour from white yam. On average, the gelatinization temperature of flour from water yam was 71.73 °C, while for white yam it was 68.64 °C. This implies that starch from white yams will form a gel faster than starch from white yams.

### Conclusion

From the findings of this research, it can be concluded that in food processing, such as dough and pasta products, where swelling capacity is important, flour from the whole tuber should be used instead of sectioning, since no significant differences were observed among the sections. The high oil-absorption capacity of water yam flour suggests it could be used more effectively in baked products to enhance sensory attributes.

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**Table 1:** Mean Effect of Sectioning on Functional Properties of Yam Flour

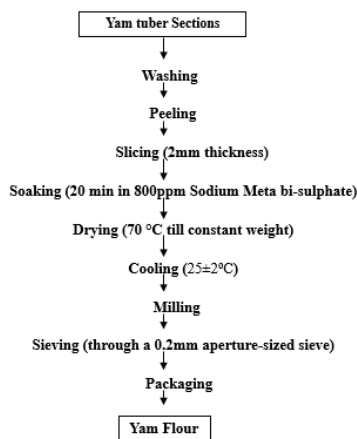
Sections	Bulk Density (g/ml)	Emulsion Capacity (%)	Water Absorption	Oil Absorption	Wettability (s)	Swelling Index	Gelation Temperature (°C)
Whole	0.54 <sup>a</sup>	5.28 <sup>b</sup>	4.86 <sup>a</sup>	3.93 <sup>ab</sup>	22.39 <sup>b</sup>	7.13 <sup>b</sup>	68.63 <sup>a</sup>
Head	0.52 <sup>a</sup>	4.83 <sup>b</sup>	4.86 <sup>a</sup>	3.68 <sup>a</sup>	21.79 <sup>b</sup>	10.08 <sup>c</sup>	69.25 <sup>a</sup>
Middle	0.47 <sup>a</sup>	4.87 <sup>b</sup>	4.88 <sup>a</sup>	3.61 <sup>a</sup>	21.22 <sup>b</sup>	4.09 <sup>a</sup>	68.53 <sup>a</sup>
Tail	0.55 <sup>b</sup>	2.68 <sup>a</sup>	4.80 <sup>a</sup>	4.34 <sup>b</sup>	12.00 <sup>a</sup>	4.07 <sup>a</sup>	71.32 <sup>a</sup>
LS	<b>0.16</b>	<b>0.89</b>	<b>0.06</b>	<b>0.21</b>	<b>3.48</b>	<b>3.55</b>	<b>14.17</b>

Means on the same column with different superscripts are significantly ( $p \leq 0.05$ ) different from each other.

**Table 2:** Functional Properties of Varieties of Yam Flours

Yam Sections	Bulk Density (g/ml)	Emulsion Capacity (%)	Water Absorption Capacity	Oil Absorption Capacity (g/ml)	Wettability (s)	Swelling Index	Gelation Temperature (°C)
<b>White Yam</b>							
Whole	0.56 <sup>b</sup>	5.73 <sup>b</sup>	4.90 <sup>b</sup>	3.99 <sup>a</sup>	21.35 <sup>a</sup>	4.12 <sup>d</sup>	68.46 <sup>ab</sup>
Head	0.53 <sup>ab</sup>	4.93 <sup>a</sup>	4.94 <sup>bc</sup>	3.41 <sup>a</sup>	20.05 <sup>b</sup>	4.02 <sup>c</sup>	67.51 <sup>a</sup>
Middle	0.46 <sup>a</sup>	4.97 <sup>a</sup>	4.99 <sup>c</sup>	3.47 <sup>b</sup>	19.89 <sup>a</sup>	4.17 <sup>e</sup>	68.52 <sup>ab</sup>
Tail	0.52 <sup>ab</sup>	4.79 <sup>a</sup>	4.77 <sup>a</sup>	3.83 <sup>d</sup>	20.17 <sup>c</sup>	4.05 <sup>c</sup>	70.05 <sup>c</sup>
<b>Mean</b>	<b>0.53</b>	<b>5.11</b>	<b>4.9</b>	<b>3.68</b>	<b>20.36</b>	<b>4.09</b>	<b>68.64</b>
<b>Water Yam</b>							
Whole	0.52 <sup>ab</sup>	4.82 <sup>a</sup>	4.82 <sup>a</sup>	3.87 <sup>de</sup>	23.44 <sup>a</sup>	4.15 <sup>d</sup>	70.05 <sup>c</sup>
Head	0.52 <sup>ab</sup>	4.74 <sup>a</sup>	4.77 <sup>a</sup>	3.95 <sup>g</sup>	23.54 <sup>h</sup>	4.15 <sup>d</sup>	69.55 <sup>bc</sup>
Middle	0.53 <sup>ab</sup>	4.77 <sup>a</sup>	4.78 <sup>a</sup>	3.74 <sup>c</sup>	22.55 <sup>f</sup>	3.97 <sup>b</sup>	74.13 <sup>d</sup>
Tail	0.51 <sup>ab</sup>	4.81 <sup>a</sup>	4.82 <sup>a</sup>	3.90 <sup>ef</sup>	21.25 <sup>d</sup>	3.86 <sup>a</sup>	73.22 <sup>d</sup>
<b>Mean</b>	<b>0.52</b>	<b>4.79</b>	<b>4.8</b>	<b>3.87</b>	<b>22.69</b>	<b>4.02</b>	<b>71.73</b>

Means on the same column with different superscripts are significantly ( $p \leq 0.05$ ) different from each other.



**Figure 1:** Flow diagram of yam flour production (Source: Wu et al., 2016)