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THE PARTICLE SIZE AND THERMAL PROPERTIES OF FLOUR FROM THREE PLANTAIN (*MUSA PARADISIACA)* CULTIVARS GROWN IN NIGERIA

Kiin-Kabari David Barine[1]† --- Njoku Victor[2]
[1,2]*Department of Food Science and Technology Rivers State University of Science and Technology Port Harcourt Nigeria*

ABSTRACT

Flour from three plantain cultivars (Agbagba, Cadaba and French horn) commonly grown in Nigeria were investigated for their particle size, bulk density and thermal properties. The results showed that Agbagba cultivar had the least particle size (10.04%) at 125µm sieve size and significantly increased to 29.45% at 180µm sieve size. Cadaba and French horn plantain cultivars showed a particle size of 56.54% and 36.20% at 125µm sieve size, respectively and decreased significantly with increase in sieve sizes. The bulk density ranged from 28.62% to 30.50% and showed no significant differences between the cultivars. The moisture content ranged from 7.65% (French horn) to 8.7% for (Cadaba) and showed no significant difference ($p > 0.05$). Also, there were no significant differences ($p > 0.05$) observed in specific heat capacity, thermal conductivity and thermal diffusivity between the cultivars studied. The data thus obtained showed that chemical composition of the cultivars may influence thermal properties and this will serve as a useful engineering tool for the design and development of sieves and dryers for plantain flour.

Keywords: Plantain flour, Bulk density, Thermal properties, Cultivars, Particle size, Proximate composition.

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Contribution/ Originality

This study provides necessary information that can be used in the design of dryers for plantain flour. This study also showed that proximate composition rather than differences in cultivars influenced thermal properties.

1. INTRODUCTION

Plantain (*Musa paradisaca)* have three sets of chromosomes (they are triploid). Many are hybrid derived from two species of *Musa acuminita* and *Musa balbisiana* (Britanica, 2013). Plantain is an important crop in Nigeria. It is traditionally grown for cooking as part of a staple diet or for processing into more durable products such as flour that can be stored for later use (Wainwright and Burdon, 1991; Dadzie, 1995). Plantain flour apart from being used as a substitute for "gari" especially for diabetic patients, also serves as a raw material used in the production of cake, puff-puff, biscuits and pancakes and complementary food formulations (Sanni and Eniola, 2004).

Plantain flour is a cheap source of iron, protein and vitamin A. the product can be marketed through market women, food canteens, hotels and supermarkets (Wilson, 1987). Plantain flour also has a good potential for use as a functional agent in bakery products on account of its highly water absorption capacity (Akubor, 1998).

Thermal properties are important data needed for quality assessment, evaluation, design, operation and control of dryers. These properties include moisture content, bulk density, specific heat capacity; thermal conductivity, thermal diffusivity, knowledge of these properties and how they affect drying stages will enhance better understanding of heat and mass transfer models for drying any agricultural product (Nwanekezi and Ukagu, 1999). There are many varieties of plantain in Nigeria; we have the "Agbagba" (a medium false horned plantain), 'Obino

† *Corresponding author*
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L'ewai' (medium French plantain) and "Big Ebanga" (a giant false horned plantain) which are morphologically distinct (Zakpaa *et al.*, 2010). Others are Cadaba, (a cooking banana), including *Musa* hybrid cultivars developed by the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria which are distributed not only in Nigeria but to other West African Countries. Therefore, this work attempts to look at the effect of three varieties of plantain (Agbagba, Cadaba and medium French horn plantain) on thermal properties of the flour in order to provide data for the design of plantain dryers.

2. MATERIALS AND METHODS

Bunches of fresh matured unripe plantain of different cultivars (Agbagba, Cadaba and medium French horn) were obtained from the Rivers State Agricultural Development Project (ADP) Port Harcourt, and transported to the processing laboratory, Rivers State, University of Science and Technology, Port Harcourt, Rivers State, Nigeria. The chemicals used were obtained from the department and are of analytical grade.

2.1. Production of Plantain Flour

The method of Adeniji *et al.* (2007) was used in the production of the plantain flour, the samples were peeled manually with the aid of a stainless steel kitchen knife and the pulp were sliced evenly (15mm) and then soaked in 1.25% sodium metabisulphite solution for 5 min to inactivate the enzymes responsible for browning. The slices were drained and dried in a circulating oven (Gallanpkamp s/no, 90/02/190 U.K) at 65°C for 20h. The dried samples were milled into flour and stored in polyethene bags at room temperature (28 ± 1°C).

2.2. Particle Size Distribution

The flour particle size distribution was determined using the method described by Barimalaa *et al.* (2005). Fifty (50g) of each flour sample was placed on a tier of sieves of decreasing aperture as follows: 25μm, 180μm, 150μm and 125μm, respectively, on a sieve shaker (Endecotts Ltd, U.K, Model Minor 3176-130). A pan collector was placed beneath the 125μm sieve. The shaker was operated for 10 minutes and the percentage particle size retention on each sieve was then determined.

2.3. Proximate Analysis

The crude protein, fat, ash and moisture contents of the samples were determined according to AOAC (2012) procedures 2.057, 7.062, 14.006 and 14.004, respectively. Crude fibre was calculated by difference while total available carbohydrate was determined using the Clegg Anthrone method described by Osbone and Voogt (1978).

2.4. Determinations of Thermal Properties, Bulk Density

The AOAC method AOAC (2012) was used in the determination of the bulk densities of the plantain samples. The centrifuge tube was weighed and recorded; flour sample was then poured into the centrifuge tube, and weighed (untapped). The centrifuge tube was then tapped and filled until a constant volume was achieved.

$$\%\ \text{Bulk density} = \frac{\text{weight of tapped powder} - \text{weight of untapped powder}}{\text{Volume of sample}} \times 100$$

2.5. Specific Heat Capacity

The method of Choi and Okos (1986) was used to determine the specific heat capacity of the cultivars. This is the amount of heat energy required to raise the temperature of a body per unit mass and expressed as (j/g°c). The specific heat capacities were obtained using the various mass fractions derived from the proximate composition of the samples and then applying the Choi and Okos (1986).

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$Cp = 4.180\ x_w + 1.711\ x_p + 1.929\ x_f + 1.547\ x_c + 0.908\ x_a$. Where Cp is the specific heat capacity in kj/kg and x are the respective mass fractions of water, protein, fat, carbohydrate and ash present in each flour.

2.6. Thermal Conductivity

The method of Sweat (1986) was used to determine the thermal conductivity of the plantain flour from the three cultivars. The thermal conductivities were obtained by substituting the various proximate composition of the sample in the expression developed by Sweat (1986). $K = 0.25\ x_c + 0.155\ x_p + 0.16\ x_f + 0.135\ x_a + 0.58\ x_w$. Where k is the thermal conductivity (w/m°c) of the sample.

2.7. Thermal Diffus1vity

The method of Nwanekezi and Ukagu (1999) was used to determine the thermal diffusivity of the plantain cultivars. The thermal diffusivity (α) is the thermal conductivity divided by density and specific heat capacity at constant pressure and the Si unit is m^2/s. The thermal diffusivity of the samples was calculated using the expression.

$$\alpha = \frac{k}{pcp}\left(m^2 / s\right)$$

Where K = thermal conductivity, p = density and Cp = specific heat capacity

2.8. Data Analysis

Results were expressed as mean values and standard deviation of three determinations. Data were analysed using a one way analysis of variance (ANOVA) to test the level of significance ($p > 0.05$). Statistical software for windows 97 version 5.1 (soft Inc, Tulsa, USA) was used.

3. RESULT AND DISCUSSION

3.1. Proximate Composition

The proximate composition and their corresponding mass fractions of the plantain cultivars are shown in Table1. The moisture content ranged from 7.65% to 8.70%. However, there was no significant difference in moisture content between Agbagba and French horn cultivars while these two cultivars were significantly lower compared to Cadaba cultivar. The ash content of the cultivars ranged from 1.50% to 1.65% and there was no significant difference between ($p > 0.05$) the cultivars. The proximate composition of the cultivars had a very great impact on their thermal properties. Therefore, the difference in their drying rate could be attributed to the difference in their chemical composition. Similar observations had been reported by Arisa *et al.* (2013).

The percentage fat content of the cultivars ranged from 0.25% to 0.60% with Cadaba having the highest fat content. The protein content of the cultivars ranged from 3.25% to 3.95%. However, Cadaba had the highest, while Agbagba had the lowest. The percentage crude fibre ranged from 3.10% to 5.24%. The carbohydrate content of the cultivars ranged from 80.90% to 83.80% however there was no significant difference between the cultivars.

Table-1. Proximate Composition and Mass Fractions (x) for the Plantain Cultivars

Cultivars	Moisture content x_w(%)	Ash x_a(%)	Fat x_f(%)	Crude protein x_p(%)	Crude fibre (%)	Carbohydrate x_c(%)
Agbagba	7.95 ± 0.080^b	1.50 ± 0.015^a	0.25 ± 0.003^b	3.25 ± 0.0325^b	5.24 ± 0.125^a	81.8 ± 0.818^a
Medium French horn	7.65 ± 0.077^b	1.65 ± 0.165^a	0.30 ± 0.003^b	3.50 ± 0.0350^{ba}	3.10 ± 0.321^c	83.8 ± 0.838^a
Cadaba	8.70 ± 0.087^a	1.65 ± 0.017^a	0.60 ± 0.006^a	3.95 ± 0.040^a	4.20 ± 0.216^b	80.9 ± 0.809^a

Figures bearing the same superscript within the same column are not significantly different ($p \geq 0.05$).

Key: X_w = mass fraction for water, X_a = mass fraction for ash, X_f = mass fraction for protein and X_c = mass fraction for carbohydrate

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3.2. Thermal Properties

The thermal properties of the plantain cultivars are shown in Table 2. The bulk density of the different cultivars ranged from 28.62(g/ml) to 30.50 (g/ml). The specific heat capacity (kj/kgk), thermal conductivity (w/m°c) and thermal diffusivity $\alpha = \frac{k}{pcp}\left(m^2/s\right)$ of the cultivars are also presented on Table 2. The specific heat capacity (cp) of the plantain cultivars ranged from 1.67 to 1.7kg/kg.k, and there was no significant difference ($p \geq 0.05$) in heat capacity among the cultivars examined. Thermal conductivity and diffusivity of the plantain cultivars showed no significant difference ($p \geq 0.05$). These properties are affected by the proximate compositions of the plantain cultivar. These observations are in agreement with the report of Ademiluyi *et al.* (2005) who studied the thermal properties of cassava mash.

Table-2. Mean Thermal properties of the plantain cultivars

Cultivars	Bulk density (g/ml)	Specific heat capacity (kj/kgk)	Thermal conductivity (w/m°c)	Thermal diffusivity $\alpha = \frac{k}{pcp}\left(m^2/s\right)$
Agbagba	30.50±1.27[a]	1.67±0.014[a]	0.25±0.007[a]	0.00495±0.003[a]
French Horn	28.90±0.71[a]	1.69±0.007[a]	0.25±0.007[a]	0.0052±0.0002[a]
Cadaba	28.62±2.08[a]	1.70±0.035[a]	0.26±0.007[a]	0.0057±0.0057[a]

Figures with the same superscript on the same column are not significantly different ($p \geq 0.05$).

3.3. Particle Size

The effect of variety on the particle size of the plantain cultivars is shown in Figure 1. Agbagba had a particle size range of 10.04% to 29.45% and highest at 180µm sieve size. French horn and Cadaba had their particle size distribution of 36.20% and 56.54%, respectively at 125µm sieve size. Apart from Agbagba, the particle sizes of the cultivars were observed to decrease with increase in sieve sizes as shown in Figure 1. This observation compared favourably with the report of Oduro-Yeboah *et al.* (2010) on the particles size of cassava flour. Therefore, the difference in particle size distribution and thermal properties could be useful in selecting a cultivar of the appropriate maturity and a proper drying method for a particular industrial application.

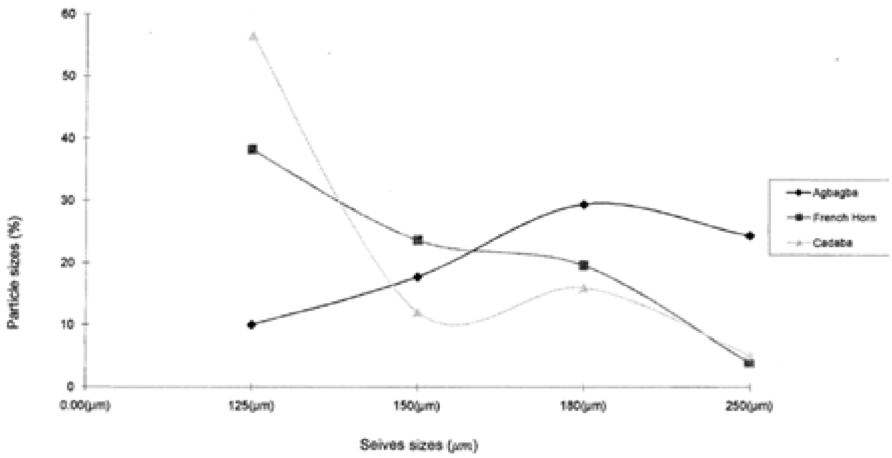

Figure-1. Effect of varietyon the particle size of the plantain cultivars

4. CONCLUSION

The different plantain cultivars studied does not influence its thermal properties rather; the proximate compositions of the cultivars may affect their thermal properties. A greater proportion of the flour was retained in

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the 125 um screen during particle size analysis and the particle sizes were observed to decrease with an increase in the sieve size.

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