



## Effect of Drying Methods on the Chemical, Pasting and Functional Properties of Unripe Plantain (*Musa paradisiaca*) Flour

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### Authors' contributions

*This work was carried out in collaboration between all authors. Author SOA designed the study, wrote the protocol and the first draft of the manuscript. Authors EMO and SFA managed the literature searches and performed the statistical analysis. All the three authors contributed towards the execution of the protocol in lab. All authors read and approved the final manuscript.*

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### ABSTRACT

**Aims:** The effect of different drying methods on the chemical, pasting and functional properties of unripe plantain flour was evaluated in this study.

**Study Design:** Research study.

**Place and Duration of Study:** This study was carried out in the Food Chemistry and Food Processing Laboratories of the Department of Food Technology, Federal Polytechnic Ado-Ekiti, Ekiti State between October 2013 and April 2014.

**Methodology:** Equal quantity of unripe plantain pieces of the same dimension was subjected to four different drying methods: hot air oven (70°C), tray dryer (70°C, 1.5 m/s), fluidized bed dryer (70°C, 2.75 m/s) and sun drying until constant weight was obtained. The resulting samples were pulverized and then subjected to chemical, pasting and functional analysis.

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**Results:** Hot air oven was the most effective in drying the unripe plantain to the lowest moisture content of 3.24%, the moisture content of unripe plantain dried with tray dryer was the highest (5.43%). The protein and ash contents of the unripe plantain dried with hot air oven; fluidized bed dryer; tray dryer and sun drying were 3.82% and 3.11%; 3.07% and 3.14%; 3.21% and 3.91%; 3.04% and 3.56% respectively. The pH and energy value of the four samples were in the range of 5.70 – 6.20 and 3.68 – 3.83 Kcal/g respectively. The peak and final viscosities of the unripe plantain dried with hot air oven; fluidized bed dryer; tray dryer and sun drying were 166.25 RVU and 293.33 RVU; 119.67 RVU and 126.50 RVU; 163.17 RVU and 243.58 RVU; 239.83 RVU and 124.33 RVU respectively. The water absorption capacity, oil absorption capacity and swelling power of samples dried with hot air oven; fluidized bed dryer; tray dryer and sun drying were 160 ml/100 g, 195 ml/100 g and 3.58; 160 ml/100 g, 200 ml/100 g and 3.65; 180 ml/100 g, 165 ml/100 g and 3.22; 130 ml/100 g, 210 ml/100 g and 3.05 respectively.

**Conclusion:** Oven and fluidized bed drying provided better alternatives to the traditional natural sun drying of unripe plantain especially in terms of final viscosity, peak viscosity, breakthrough viscosity; chemical and functional properties.

**Keywords:** Plantain; drying; chemical properties; pasting properties; functional properties.

## 1. INTRODUCTION

Plantain (*Musa paradisiaca*) is an important starchy, staple and commercial crop in the West and Central African where fifty percent of the world's plantain crop is produced [1]. It constitutes a major source of carbohydrate for millions of African people, it is low in protein and fat but rich in starch and mineral elements especially potassium. In Nigeria, plantain is widely consumed by the entire population, ripe plantain can be eaten boiled, fried or roasted, and the pulp has been used to produce wine. Unripe plantain has been processed into flour and such flour has been considered as having commercial potential on their own or as ingredient for other foods such as baby weaning food. Unripe plantain flour is gradually finding application in the production of weaning foods and composite flour which has been used to produce some bakery products [2,3]. In recent times unripe plantain flour has been recommended as a good diet for diabetic patients, this may be because of its low glycaemic response when consumed and its free radical scavenging activity in diabetics [4].

According to FAO [5] more than 2.3 million metric tons of plantain is produced in Nigeria annually, however about 35 to 60% post harvest losses had been recorded and attributed to lack of storage facilities and inappropriate technologies for food processing. One of the processing technologies that have been employed in preservation of food materials is drying. Drying is a method of food preservation that works by removing water from the food thereby reducing water activity and inhibiting the growth of microorganisms. Additionally dried foods take

much less storage space than canned or frozen foods. Traditionally unripe plantain is usually processed into flour by local producers using the natural sun drying method. The flour produced is mixed with boiling water to prepare elastic dough (*amala*) which is usually eaten with various soups.

However there are some problems associated with sun drying such as the slowness of the process, the uncertainty of the weather, the manual labour required and uneven drying, likewise the plantain dried through this traditional sun drying method has been noted to contain extraneous materials due to environmental contamination; all these impart negatively on the quality of plantain flour that is produced. As a result of these problems, more rapid, safe and controllable methods are needed to produce unripe plantain flour of good quality. Several methods of drying such as oven drying, tray drying, cabinet drying to mention a few have been developed for use in food processing and preservation; such methods usually affect the quality of the resultant end products. Double drum dryer, freeze dryer, microwave oven and tray chamber were found to have significant effect on the physical characteristics, proximate, rheological and functional properties of unripe plantain flour [6]. This work was carried out to evaluate the effect of some drying methods (hot air oven, tray dryer, fluidized bed dryer and sun drying) on the chemical, pasting and functional properties of unripe plantain flour.

## 2. MATERIALS AND METHODS

Freshly harvested matured unripe plantains used for this study were obtained from a local farm very close to Federal Polytechnic in Ado-Ekiti.

## 2.1 Sample Preparation and Drying

The plantains were washed with clean water, peeled using stainless kitchen knife and sliced to a round shape of about 3 mm thickness into sodium metabisulphite solution (70 ppm) for 15 min. to control browning, the slices were then drained using plastic sieve. The slices were divided into four equal batches of the same quantity. One batch of the samples was dried in the tray dryer (Armfield Tray Dryer UOP8) at 70°C and at a blower speed of 1.5 m/s until a constant weight was obtained; the tray drying process lasted for 8 hrs. The second batch of the samples was sun dried between 10.00 hrs and 15.30 hrs until a constant weight was observed, the average daily temperature during this period was 33°C and relative humidity was 67%, the sun drying process lasted for 2 days (11 hrs). The third batch of the samples was dried in fluidized bed dryer (Armfield Fluid Bed Dryer MARK II) at 70°C and air velocity 2.75 m/s until a constant weight was obtained, the fluidized bed drying process lasted for 3 hrs. The last batch of the samples was dried in the hot air oven (Model DHG 9030A) at 70°C; the oven drying process lasted for 5 hrs. After drying, the four samples were pulverized and packaged in polythene bag, sealed and then stored in air tight containers with appropriate labeling. The samples of unripe plantain flour produced were subjected to chemical, pasting and functional analysis.

## 2.2 Determination of Chemical Properties

Moisture, protein, crude fat, crude fibre and ash contents of the four unripe plantain flour samples were determined according to standard methods described by AOAC [7], carbohydrate was determined by difference. For pH determination, 10 g of the sample was dispersed in 100 ml distilled water, it was mixed thoroughly and filtered; the pH of the filtrate was measured using pH meter (Starter 2100 Bench pH Meter) which had been previously standardized with buffer solution of pH 4 and 9. The energy value was calculated using Atwater factor.

## 2.3 Determination of Pasting Properties

The pasting properties were determined using Rapid Visco Analyser (RVA) (model Rva-3D). 3 g of the sample was turned to slurry by mixing with 25 ml of water; this was then transferred into RVA canister and placed inside the RVA machine. The 12 min. profile was used with sample heated from 50°C to 95°C and then cooled back to 50°C.

## 2.4 Determination of Functional Properties

The water absorption capacity and oil absorption capacity was determined by the method of Sathe et al. [8] with some modifications. 1 g of each sample was weighed into a beaker, 10 ml of water was added and the suspension was stirred with magnetic stirrer for 1 min. The suspension was then allowed to stand for 30 min. at room temperature after which it was centrifuged (New Life Centrifuge NL-90-2) at 5,000 rpm for 30 min. after centrifugation the volume of the supernatant was measured and the result was expressed as volume (ml) of water absorbed per 100 g of the sample. The same procedure was used for oil absorption capacity except that water was replaced with vegetable oil of specific gravity of 0.98 g/ml.

The swelling power of the samples was determined according to the method described by Leach et al. [9] with some modifications. The weight of centrifuge tube containing 1.25 g of the sample was taken; the sample was turned to slurry by adding 10ml distilled water. The slurry was heated at a temperature of 70°C for 30 min. in a water bath, cooled to room temperature and centrifuged at 2300 rpm for 30 min. The supernatant was decanted and the centrifuged tube was placed in a hot air oven to dry for 30 min. at 45°C, the residue was then weighed. The swelling power was expressed as the ratio of the weight of flour paste to the weight of dry flour. The bulk density was determined by the method described by Onwuka [10].

## 2.5 Statistical Analysis

The difference in the experimental data was tested for statistical significance  $P < .05$  by Statistical Analysis of Variance (ANOVA) using SPSS 17.0 software package (Statistical Package for Social Scientist, Michigan, USA)

## 3. RESULTS AND DISCUSSION

### 3.1 Chemical Properties

The chemical properties of unripe plantain flour dried with the four different drying methods are presented in Table 1. The results indicated that drying methods had significant effect ( $P < .05$ ) on the proximate principles of unripe plantain flour. The moisture content of the sample dried with oven was the lowest and the moisture content of

sample dried with tray dryer was the highest. The moisture contents of the four samples were lower than 9.65% reported for unripe plantain dried with cabinet dryer at 60°C for 24 hrs [11]. Moisture content has implication on the shelf stability of food products; unripe plantain flour sample with the highest moisture content will therefore be more susceptible to deteriorative changes during storage. Oven dried sample had the highest protein content of 3.82% which was significantly different ( $P < .05$ ) from the protein contents of other samples, the protein contents of all the samples were comparable to 3.15% of the freeze dried unripe plantain flour as reported by Eleazu et al. [4]. The ash contents of samples dried with oven and fluidized bed dryer were not significantly different ( $P < .05$ ) however, sun dried sample had the highest ash content of 3.91% which was significantly different ( $P < .05$ ) from that of other samples. Ash content is a reflection of the mineral composition of food samples.

Unripe plantain samples dried with tray dryer had the lowest fat content while sample dried with fluidized bed dryer had the highest fat content. Generally the fat and fibre contents of unripe plantain flour were very low, and methods of drying did not have significant effect ( $P < .05$ ) on the fibre content of unripe plantain. The carbohydrates contents of samples dried with oven and fluidized bed dryer were significantly the same ( $P < .05$ ) and were higher than that of the other two samples. The pH values reported for all the samples in this work were comparable to the pH range (4.6 – 6.1) reported by Pacheco-Delahaye et al. [6] for plantain flour produced from different drying methods. Sun dried sample recorded the lowest pH because of the long period of drying during which there might have been substantial production of organic acid as a result of fermentation. Acids make an important contribution to the post harvest quality of fruits, and evaluation of pH is usually used to estimate consumption quality especially the taste of flour. Taste is majorly a balance between sugar and acid contents, it was observed that sample with higher drying time had lower pH value. There was no significant difference ( $P < .05$ ) in the energy value of sample dried with fluidized bed dryer and that dried with oven however the energy values of the two samples were significantly different ( $P < .05$ ) from that of tray dried and sun dried samples. Sample dried with fluidized bed dryer recorded the highest energy value while sample dried with tray dryer recorded the lowest energy value.

### 3.2 Pasting Properties

The effect of drying method on the pasting properties of unripe plantain flour is presented in Table 2. Unripe plantain flour being a starchy food material is usually thermally processed in a variety of ways before consumption; as a result of this the evaluation of its pasting or cooking properties becomes important. There was significant difference ( $P < .05$ ) in the pasting properties of the unripe plantain flour samples. The pasting temperature is a measure of the minimum temperature required to cook a given food sample and this also has implication on the energy cost of preparing food sample. The pasting temperatures of all the plantain samples which fell below the boiling point of water, were higher than 73.44°C and 64.65°C reported for *tapioca* and *gari* respectively [12,13], this may be due to the fact that unlike unripe plantain flour these cassava products have been partially gelatinized during processing. The pasting temperature of the four samples were significantly different ( $P < .05$ ) with unripe plantain dried in the oven having the highest (83.35°C) while unripe plantain dried in fluidized bed dryer had the lowest (80.45°C). The implication of this observation is that unripe plantain flour can generally form paste in hot water below its boiling point and that fluidized bed dried sample would gelatinize at a relatively lower temperature than oven dried sample.

The peak viscosity of the samples was in the range of 119.67 RVU to 239.83 RVU with fluidized bed dried sample and sundried sample having the lowest and highest peak viscosity respectively. The variation in peak viscosity has a correlation with the drying time i.e. duration of exposure to heat during drying; fluidized dried sample had the lowest drying time while sundried sample had the highest drying time. Peak viscosity reflects the maximum viscosity developed during cooking and gives an indication of the viscous load to be encountered during mixing. The final viscosity which indicates the ability of starchy foods to form viscous paste after cooking and cooling is an important parameter in predicting and defining the final textural quality of starch food. There was significant difference ( $P < .05$ ) in the final viscosity of the samples with unripe plantain dried in the oven having the highest and thus has ability to form elastic dough (*amala*) which may be preferable by some consumer. The hold period of the pasting test during which sample is held at high temperature (95°C) with mechanical

shear stress (rapid constant and continuous mixing) is usually accompanied by breakdown in viscosity [14]. The ability of a sample to withstand this breakdown in viscosity i.e. withstand heating and mechanical shear stress that is usually encountered during processing is measured by breakdown viscosity. The higher the breakdown viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking [15]. Breakdown viscosity, which is an important factor in determining paste stability, is the peak viscosity minus trough viscosity. There was significant difference ( $P < .05$ ) in the breakdown viscosity of the four samples, sample dried with tray dryer had the lowest breakdown viscosity of 28.17 RVU, this implies that this sample was more resistant to shear thinning or breakdown in viscosity during heating and therefore would have highest paste stability.

The phase of the pasting curve after cooling of the sample to 50°C is known as setback region, it show the tendency of the starch to associate and retrograde. There was significant difference ( $P < .05$ ) in the setback viscosity of the entire four samples, sundried sample had the lowest setback viscosity while oven dried sample had the highest setback value. The low setback value for sundried sample may be attributed to partial dextrinization of the starch molecule during the long period of drying thereby reducing the amount of starch to be gelatinized and thus lowering the setback viscosity. It was observed during drying that sundried sample had exceptionally and expectedly high drying time. Dough prepared from sundried unripe plantain flour is most likely to exhibit lower retrogradation tendency than that of others due to the low setback viscosity. Sanni et al. [16] had reported that low setback value during the cooling of the paste indicates greater resistance to retrogradation. The peak time is a measure of the cooking time [15], the shorter the peak time

the higher the ease of cooking, sundried unripe plantain sample had exceptionally low peak time when compared with other samples.

### 3.3 Functional Properties

The functional properties of the various samples are presented in Table 3. Bulk densities of flour samples dried in the oven and fluidized bed were the same (0.82 g/ml) and this value was lower than the bulk densities of flour samples dried in the tray dryer and under sun. This implies that the particle size of tray dried and sun dried flour samples are smaller compare to that of oven dried and fluidized bed dried flour samples with sun dried flour having the smallest particle size as indicated by its highest bulk density (0.88 g/ml). Bulk density has implication in the packaging and transportation of food materials; higher bulk density products are known to exhibit better packaging properties than those with low bulk density. Fagbemi [17] reported that high bulk density is desirable in that it offers greater packaging advantage as greater quantity may be packaged within a constant volume.

Water absorption capacity is the ability of flour to absorb water and swell for improved yield and consistency during food preparation. High water absorption capacity had been reported to improve yield and consistency, and give body to food [18]. Apart from starch, non starchy component (fibre, protein and fat) of flour also contribute to water absorption capacity. There was significant difference ( $P < .05$ ) in the water absorption capacity of the samples with sundried sample having the lowest and tray dried sample having the highest. The water absorption capacity reported in this work were lower than 196 ml/100 g reported for unripe plantain flour dried in the oven at 70°C for 14 hrs by Osundahunsi [19]. Water absorption capacity is an indication that a flour sample would be useful in food system such as bakery products which

**Table 1. Chemical properties of unripe plantain flour**

Parameters/samples	Oven dryer	Fluidized bed dryer	Tray dryer	Sun-drying
Moisture (%)	3.24±0.04d	3.48±0.03c	5.43±0.05a	4.93±0.03b
Protein (%)	3.82±0.03a	3.07±0.06c	3.21±0.03b	3.04±0.04c
Crude fat (%)	1.15±0.04c	1.53±0.07a	0.68±0.03d	1.39±0.03b
Ash (%)	3.11±0.06c	3.14±0.04c	3.91±0.05a	3.56±0.05b
Crude fibre (%)	1.04±0.02a	1.04±0.03a	1.05±0.04a	1.04±0.05a
Carbohydrate (%)	87.64±0.40a	87.74±0.70a	85.72±0.50b	86.04±0.45b
pH	6.10±0.00a	6.20±0.10a	5.90±0.10b	5.70±0.00c
Energy Value (Kcal/g)	3.82±0.02a	3.83±0.02a	3.68±0.01c	3.75±0.03b

Data represent means of three determinations ± standard deviation  
Values with different alphabets in the same row are significantly different ( $P < .05$ )

**Table 2. Pasting properties of unripe plantain flour**

Parameters/samples	Oven dryer	Fluidized bed dryer	Tray dryer	Sun-drying
Peak viscosity (RVU)	166.25±0.02b	119.67±0.03d	163.17±0.10c	239.83±0.01a
Trough viscosity (RVU)	115.67±0.04b	70.92±0.02d	135.00±0.04a	84.25±0.02c
Breakdown viscosity(RVU)	50.58±0.05b	48.75±0.02c	28.17±0.02d	155.58±0.01a
Final viscosity (RVU)	293.33±0.03a	126.50±0.02c	243.58±0.04b	124.33±0.03d
Setback viscosity (RVU)	177.67±0.04a	55.58±0.01c	108.58±0.03b	40.08±0.02d
Peak time (Min.)	6.07±0.05b	5.73±0.03c	6.80±0.02a	3.93±0.01d
Pasting temperature (°C)	83.35±0.05a	80.45±0.07d	80.95±0.05c	82.35±0.10b

*Data represent means of three determinations ± standard deviation  
Values with different alphabets in the same row are significantly different (P < .05)*

**Table 3. Functional properties of unripe plantain flour**

Parameters/samples	Oven dryer	Fluidized bed dryer	Tray dryer	Sun-drying
Bulk density (g/ml)	0.82±0.01b	0.82±0.00b	0.84±0.02b	0.88±0.02a
Water absorption capacity (ml/100 g)	160.00±2.00b	160.00±1.00b	180.00±3.00a	130.00±1.00c
Oil absorption capacity (ml/100 g)	195.00±3.00c	200.00±2.00b	165.00±1.00d	210.00±3.00a
Swelling power	3.58±0.02b	3.65±0.03a	3.22±0.01c	3.05±0.02d

*Data represent means of three determinations ± standard deviation  
Values with different alphabets in the same row are significantly different (P < .05)*

require hydration to improve handling characteristics. Water absorption capacity of 1.25 g/g (125 ml/100 g) and above is an indication of good bakery property [20], all the four samples of unripe plantain flour in this work with water absorption capacity above 125 ml/100 g would therefore be a good starting material for bakery products.

There was significant difference (P < .05) in the oil absorption capacity of the plantain flour samples, sundried sample had the highest oil absorption capacity while tray dried sample had the lowest. The oil absorption capacities of oven dried, fluidized bed dried and sun dried samples were comparable to 210 ml/100 g reported for unripe plantain flour by Osundahunsi [19]. Oil absorption capacity of flour sample is important because oil helps to retain flavor and improve mouth feel. The swelling power of flour sample dried in fluidized bed dryer was the highest while the sundried flour sample was the lowest. A simple correlation was observed between swelling power and drying time, the lower the drying time the higher the swelling power. Swelling power indicate the degree of exposure of the internal structure of starch granules to action of water i.e. a measure of hydration capacity [21]; this may indicate that the different drying methods tend to cause slight aggregation of starch granules to different degrees and subsequently affect the level of its exposure to water and its swelling power. The significance

difference (P < .05) in the functional properties of the samples indicates that drying methods will affect the functionality and application of unripe plantain flour in food systems.

#### 4. CONCLUSION

Oven drying provided a better alternative to the traditional natural sun drying of unripe plantain especially in terms of final viscosity, peak viscosity, breakthrough viscosity and chemical properties. However the choice of fluidized bed dryer with lowest drying time, can also be acceptable depending on the type of food products the unripe plantain flour will be used to produce.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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