

Effects of Drying Methods on the Nutritional Composition of Unripe Plantain Flour

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Abstract
Food processing is often thought to bring about changes in nutrients content, thus decreasing its patronage. To investigate this in a Nigerian staple, unripe plantain (*Musa paradisiaca*) flours were prepared following sun drying and oven drying methods. These were compared against fresh plantain for their nutritional composition. Unripe plantain was purchased from railway market, Makurdi metropolis, Benue State, Nigeria. Proximate composition, phytochemical screening, vitamin C content and inorganic minerals contents were determined following AOAC methods, colorimetric methods and titration methods respectively. The results showed that the unripe plantains pulp contained 59.77%, 1.42%, 1.51%, 1.40%, 7.65%, 28.23%, 40.22% and 38.80% of moisture, ash, fat/oils, crude fibre, crude protein, carbohydrates, dry matter and organic matter respectively. Calcium, sodium, potassium, iron, and nitrogen were determined to be 0.1534 ppm, 0.2613 ppm, 0.3034 ppm, 0.7808 ppm and 0.2240 ppm respectively. Saponin, tannins, and phenols were not detected in both the processed and fresh samples. Vit C was 5.00 mg/100g in the fresh sample, and 1.24 and 1.27 mg/100g in the oven dried and sun dried samples respectively. Both of the processing methods produced flour with similar nutritional composition. However, oven drying gave the lowest moisture content in the flour, suggesting a higher capacity to prevent microbial growth and decay in dried sample, hence prolonging storage life.
Keywords: phytochemicals, vitamin C, proximate composition, *Musa paradisiaca*

1. Introduction

Plantain, (*Musa paradisiaca)* is cultivated in the tropics and is an important staple food in sub-saharan Africa. About 63 million tones of the crop are produced annually, of which as much as 90 % is consumed locally in the producing countries, allowing only a meager 10% for foreign financial earnings through exportation (Awodoyin, 2003; Baiyeri *et al.*, 2011). This is largely attributed to poor storage condition of the crop, worsened by poor or lack of storage facilities and processing technology (Adeniji and Empere, 2001). Certain times, processed foods are not appreciated among the populace due to textural differences, arising from the processing (Yarkwan, 2004).

Plantain is a rich source of nutrients. It is well patronized as a staple food in many parts of the West and Central Africa (Adeniji *et al.*, 2006a). It is a rich source of nutrients such as iron, zinc, potassium and sodium (Mepba *et al.*, 2007; Zakpaa *et al.*, 2010; Baiyeri *et al.*, 2011). Adeniji *et al.* (2006a) reported between 14.275 to 36.500 µg/g of iron in plantain, depending on the cultivar.

Plantain falls under banana and it is a monocotyledonous perennial and important crop in the tropical and sub-tropical regions of the world (Baiyeri *et al.*, 2011).

In Nigeria, Cameroun, Coted' Voire, and other plantain producing countries in Africa, the entire fruit of pulp of plantain either unripe or half-ripe are roasted on hot charcoal and eaten with other delicacies such as roasted pums, avocado, roasted fish or meat, and kelat and sometimes in combination of hot stew. In Nigeria, as well as other West African countries, the unripe plantain is traditionally processed into flour (Ukhum and Ukpebor, 1991).

In other instances, unripe plantains are harvested, peeled, sliced and sundried, then pounded and ground to obtain flour. This is usually prepared by mixing the plantain flour with boiling water to an elastic pastry (amala, as fondly called among the Yorubas in Nigeria) and 'foufou' in Cameroun, and is eaten with various sauces. This tropical crop is seasonal. Its abundance is hardly contained during the harvest season, leading to spoilage, while it is insufficient during its off season periods. It is highly perishable after harvest. This makes it necessary for it to be processed within the shortest period of time following harvest to avoid postharvest losses. This compels farmers to process their harvest in order to increase the availability of the staple food produce all through the year, thereby ensuring food security and also providing for themselves a means of financial income during the off season periods.

Plantains, grouped along with tubers constitute a whopping 22.60% of the total per food commodity expenditure profile for Nigerian households (NBS, 2010). This translates to an estimated 14.62% of the total per commodity expenditure profile for Nigerian homes (NBS, 2010). The food item is of great commercial value and since tubers are not farmed in some parts of the country, such as the riverine states, where plantain is massively produced, it replaces the pounded yam produced in the yam farming communities of Nigeria. However, over 30% of produced crops in Nigeria are lost following harvest, due to poor storage facilities, poor or lack of processing technology, among others (Osagie and Eka, 1998).

Traditionally, sundrying is the common method used in processing plantains. The fruit is first peeled, sliced, sundried and ground into fine powder (called in Yoruba elubo ogede, Tiv – mwem ma ayaba). The present mode for sun drying in the open air exposes the product to dirt, damage from insects, bacteria infestation and the deposition of fungal spores, and a varying degree of other environmental toxicants, depending on the site/location of drying. Thus, the need for a hygienic, effective drying method is apparent.

Modern methods of drying include oven and solar drying. Both of these utilize heat to remove the moisture content in the food to the barest minimum, by evaporation. These modern methods of drying are used in drying plant materials at specific temperatures over a defined period of time.

While the traditional method of preservation continues, enlighted consumers tend to be skeptical over the nutritional content of the resultant flour they feed on, a factor which affects the patronage of such products. However, the local peasants enjoy the meals without bothering. There is however, scanty information available in literature over the effect of these drying methods on the nutritional composition of the resultant flour. Hence, this study is designed to bridge this knowledge gap.

2. Materials and Methods

This study was carried out between February and March. A bunch of matured, unripe plantain was purchased from Railway Market in Makurdi, Benue state Nigeria. It was then transferred to the Veterinary Biochemistry Laboratory, University of Agriculture Makurdi. Fingers were picked and washed in a bowl of portable water to remove the latex and avoid darkening of the pulp during peeling. The washed fingers were then randomly divided into three groups, namely fresh, oven drying and sun drying groups. Then each group was peeled, sliced in thin slices of about 5.0 mm thick using a stainless steel knife. The treatments were then given as follows:

Sun drying: slices in this group were dried on a non – adsorbent surface directly under the sun, in a manner similar to what the farmers do in their houses. This was removed into the lab in the evenings and resumed drying during the day. This continued till the slices were crispy dry.

Oven drying: an electrically heated oven was turned on, with a thermometer fitted to monitor the temperature at 105˚C for 24 hours. This was removed after the 24 hours, cooled and pounded in a porcelain mortar and pestle. This was sieved into fine flour using a mesh net of about 0.2 mm mesh size. Sodium metabissulphite was not used since browning was not going to be a limiting factor. The third portion of the sliced plantain was not dried. Analyses were carried out on it while still fresh, serving as the control.

The above samples were used for determination of proximate composition, phytochemicals, vitamin C, and mineral nutrients compositions. The methods of Association of Official and Analytical Chemists, (AOAC, 1990) were employed for the determination of proximate parameters, phytochemicals analysis and vitamin C content. The method of International Institute of Tropical Agriculture (IITA, 2000) was used to determine the mineral composition.

Since fresh samples and dry samples were being compared, a formular to provide a common denominator to warrant comparisons of the organic nutrients' content only was used. It was expressed in relation to the organic matter content of each sample. This is irrespective of the moisture and ash content. Thus,

$$Nutrient\ contribution\ to\ O.M.content = \%\ organic\ nutrient\ content\ /OM\ X\ 100$$

Where O.M. is Organic matter

Organic nutrients are: Proteins, carbohydrates, lipids and crude fibre

Results were analysed through the statistical package for social scientists, (SPSS) and reported as Mean±Standard deviation.

3. Results and Discussion

The results of proximate analysis of fresh, sundried and oven dried samples are given below (table 1). The result showed that plantain contained appreciable amounts of carbohydrates, whether fresh or processed.

Table1: Proximate composition of fresh plantain, sundried and oven dried unripe plantain flours

Parameter	Fresh	Oven-dried	Sun-dried
Moisture	59.77±0.03[a]	9.09±0.01[c]	15.00±0.01[b]
Ash	1.42±0.01[b]	5.44±0.01[a]	4.80±0.01[a]
Fat	1.51±0.02[a]	1.55±0.01[a]	1.37±0.01[b]
Crude fibre	1.40±0.02[b]	10.11±0.01[a]	10.43±0.01[a]
Crude protein	7.65±0.01[a]	3.60±0.01[b]	3.34±0.01[b]
Carbohydrates	28.23±0.06[c]	70.19±0.01[a]	65.04±0.03[b]
Dry matter	40.22±0.03 [c]	90.90±0.01[a]	84.99±0.01[b]
Organic matter	38.80±0.02[b]	85.46±0.01[a]	80.19±0.00[a]

Values are means±standard deviation. The values in a row followed by the same latter are not statistically significantly different at a significance level of 5%

Table 2. Mineral composition of fresh unripe plantain, sundried and oven dried unripe plantain flours

Parameter	Fresh plantain	Oven dried	Sundried
Calcium (ppm)	0.1534	0.4229	0.5385
Sodium (ppm)	0.2613	0.7955	0.9108
Potassium (ppm)	0.3034	1.8905	0.8170
Iron (ppm)	0.7808	0.7963	0.0239

Moisture and the protein content of plantain were lowered by the two drying methods tested in this study. Crude fibre, carbohydrates, dry matter, ash content and organic matter contents were higher in the drying methods employed here. Decrease in these macro nutrients may be attributed to the application of heat. Similar losses of these macronutrients after heat treatment have been reported (Hassan *et al*., 2007; Enomfon-Akpan and Umoh, 2004; Morris *et al*., 2004). Application of heat can be both beneficial and detrimental to nutrients. Heat improves the digestibility of food, promotes palatability and also improves the keeping quality of food, making them safe to eat. Heating process also results in nutrients' losses by inducing biochemical and nutritional variation in food composition.

The apparent increase in carbohydrate, dry matter, organic matter, ash and fibre contents observed in this study following drying treatments could be as a result of the removal of moisture which tends to increase the concentration of nutrients (Morris *et al*., 2004). Processing has been reported to increase carbohydrates availability in a more digestible form (Emperatriz *et al*., 2008). These could explain the significant difference ($P<0.05$) observed in the carbohydrates content of processed samples (oven-dried and sundried plantain flour).

The moisture content for the fresh plantain was determined to be 59.77% in agreement with 59.4% and 60.00% reported by Adepoju *et al*. (2012) and Agoyero *et al*. (2011) respectively. The moisture content of flour was determined to be 9.09% (oven-dried) 15.01% (sundried) as compared to 11.03% (oven dried) and 13.00% (sundried) reported by Agoyero *et al*. (2011). These values were all significantly different ($P<0.05$) from each other. Moisture content of food or processed products give an indication of its anticipated shelf life. Low moisture content is a requirement for long storage life. During storage, fungal growth is bound to be observed on moist food samples. Fungal food contamination could be a predisposing factor to food poisoning such as aspergillosis. Since a well dried food sample withstands fungal and other microbial infestation better during storage, oven dried flour gave lower residual moisture content, hence should be preferred.

Fat, indicating the total lipid content of the plantain was shown to be 1.51% (fresh), 1.37% (sundried) and 1.55% (oven dried) (table 1). Agoyero *et al*. (2011) reported unripe plantain fruit gives values as 2.75% (fresh), 1.38% (sundried) and 1.57% (oven dried) while Adepoju *et al*. (2012) reported 1.50% (fresh) and 3.90% (sundried). The fresh and oven dried samples are not significantly different ($P>0.05$), but these are significantly different ($P<0.05$) from the sun dried sample. These results are largely in agreement. Variations could be due to intensity of sunlight during the drying process, extent of dryness because sun drying has no objective way of assessment. The difference observed between sundried and oven dried samples could be as a result of solar radiations mediated oxidation of the composite lipids, especially the unsaturated fatty acids thereby decreasing the overall crude lipids content and quality. Nutrients have been reported to be lost as a result of chemical changes such as oxidation. Lipid oxidation is known to be increased by many factors such as heat, sun light and radiations (Savage *et al*., 2002).

Minerals, being inorganic are not destroyed by heating. They have low volatility compared to other food components. The increased ash (table 1) consequently calcium, sodium, potassium (table 2) observed in this study could be as a result of the removal of moisture which tends to increase concentration of nutrients per 100g of a food sample (Morris, *et al*., 2004). This is evident by the percentage organic matter content as it significantly differs ($P<0.05$) between the different methods of treatment studied. Since sun drying proceeds slower than oven drying, it is obvious that this prolonged drying period leaves room for several biochemical reactions to occur freely under atmospheric oxygen conditions. This holds a lot of prospects in reducing the availability of the nutrient. The decrease in the iron content of the sundried sample suggests the anti-nutritional factors, oxalate and phytate (unfortunately these were not determined in the present study) could be present in the sample, thereby making the mineral unavailable by forming complexes with them, as reported by Enonfon-Akpan and Umoh, (2004).

The highest calcium value of 0.5385 ppm was observed from the sundried sample while the fresh sample had the least value, 0.1534 ppm (table 2). This is less than the 7566.53±0.93 mg/100kg reported by Salawu et al. 2015. While the 0.44±0.00 ppm reposted by Onuoha et al. (2014) is more than the fresh sample but less than the sundried sample. Sodium followed a similar trend, being highest in sundried sample (0.9108) and least (0.2613 ppm) in the fresh sample. Potassium was highest in the oven dried sample (1.8905 ppm), and lowest in the fresh sample (0.3034 ppm). These values are all less than those reported by Onuoha *et al*. (2014) and Salawu *et al*. (2015) for both sodium and potassium. Iron had a similar pattern as potassium. It was highest in the oven dried sample (0.7963 ppm) and lowest in the sundried sample (0.0239 ppm). The rich content of calcium, sodium, iron and potassium in the unripe plantain pulp could be attributed to factors such as soil mineralization and fertilization. Variations in mineral content in crops tend to be high, owing to varying degree of ripeness, geographic and soil factors (Gibbon and Pain, 1985; Morel *et al.*,1985; Zakpaa *et al.*, 2010). These are thought to play a role here as well. These show unripe plantain to be a rich source of these minerals, especially potassium, sodium and iron. Processing does not eliminate the mineral contents.

There was a significant (P<0.05) decrease in crude protein content between the fresh sample and the dried ones. This implies drying does not conserve proteins in plantain. The crude protein content of fresh sample was determined to be 7.65% while 3.35% and 3.61% for the sundried and oven dried samples respectively. These agree with the 3.6% and 3.86 protein in unripe plantain powder reported by Salawu *et al.* (2015). In the presence of atmospheric oxygen, proteins contained in exposed tissues tend to react, forming several intermediates which make the amino group of the amino acids non bio-available. Decrease in protein content probably occurred as a result of Millard reaction; which results between carbohydrates and protein (Wiriya *et al.*, 2009). It could also be due to drying under elevated temperatures. Similar losses of crude protein by the application of heat have been reported (Hassan *et al.*, 2007; Enonfon-Akpan and Umoh, 2004; Morris *et al.*, 2004). Application of heat can be both beneficial and detrimental to nutrients. Heating improves the digestibility of food, promotes palatability and also improves the keeping quality of food, making them safe to eat. Conversely, heating process also result in nutritional losses by inducing biochemical and nutritional variations in food composition, especially sun heating. Since plantain are consumed majorly for its energy content, this significant decrease in crude protein due to processing does not invalidate the need for food security by processing nor the acceptance of this food sample in its processed form. Moreover, the gain from energy seems to appreciate significantly (P<0.05) (table 1).

Crude fibre was significantly different (P<0.05) between the fresh sample and the processed samples (table 1). It was determined to be 1.41% in agreement with the 1.40% reported by Adepoju *et al.* (2012). Values for sundried and oven dried were 10.43% and 10.12% respectively. These are in agreement with the 10.43% and 10.11% reported for sundried and oven dried respectively by Agoyero *et al.* (2011). Crude fibre represents the content of the non-digestible components of food, such as lignin, cellulose and hemicelluloses. These are essential in animal nutrition, since they enhance the transit time through the bowels, facilitates bowels movement thus reducing the risk of colon cancer.

Ash is the inorganic residue after the water and organic matter have been removed by burning a food sample. Ash was significantly different (P<0.05) between the fresh sample and the processed samples (table 1). It was determined to be 1.43% from the fresh sample, which is in agreement with the 1.40% reported by Adepoju *et al.* (2012). The dry matter content was 40.23%, 90.91% and 84.99% for fresh, oven dried and sundried samples respectively. Organic matter content was 38.80%, 85.47%, and 80.19% for fresh, sundried and oven dried samples respectively.

Table 3. Vitamin C composition of fresh unripe plantain, sundried and oven dried unripe plantain flours

Treatment	Vit C (mg/100g)
Fresh	5.00
Oven dried	1.24
Sundried	1.27

Table 4: Results for anti-nutritional factors in fresh unripe plantain, sundried and oven dried unripe plantain flours

Anti-nutritional factor	Observation
Saponin	-ve
Tannin	-ve
Phenol	-ve

The antinutritional factors (Phytochemicals) investigated were saponins, tannins and phenols. They were not detected as all the samples tested negative (table 4) for the screening of the above mentioned. Salawu *et al.* (2015) reported 0.0029 mg/g of total phenol from plantain flour, while Onuoha *et al.* 2014 reported 2.54±0.00 mg/100g and 0.08±0.00 mg/100g for tannins and saponins respectively. These variations could be due to cultivar differences.

Table 5: Percentage organic nutrient composition in respect to organic matter content

Proximate Parameter	Fresh sample	Oven dried	Sun dried
Carbohydrates	72.94^{a}	82.13^{b}	81.12^{b}
Crude protein	19.72^{a}	4.21^{b}	4.16^{b}
Crude fibre	3.61^{a}	11.83^{b}	13.00^{b}
Crude fats	3.89^{a}	1.81^{b}	1.71^{b}

The values in a row followed by different letters are significantly different at P = 5%

The vitamin C content was determined to be 5.00 mg/100g, 1.24 mg/100g and 1.27 mg/100g for the fresh, oven dried and sun dried samples respectively (table 3). This decrease in Vit C content of the processed samples could be due to the highly oxidative nature of the vitamin. In the presence of atmospheric oxygen, ascorbic acid is oxidized to glucoronate, which might have occurred under these treatment conditions. Even the 5.0 mg/100g reported for the fresh samples might not be exact reflection of the vitamin content, since it was not immediately immersed in a reducing agent (such as sodium metabissulphite) as earlier mentioned in the methodology section. It could also be attributed to the application of heat as Vitamin is heat labile (Kreutler *et al*., 1987). Vitamin C is a very good antioxidant, and highly cherished in mopping up reactive oxygen species in the body. Since the meals from this food sample are usually eaten with vegetables, it means this difference can always be made up from other ingredients used in cooking plantain meals.

The fresh plantain and the dry samples did not present a common basis of holistic comparison, as enshrined in the traditional proximate composition, always carried out. This is because the moisture content which is obviously higher in the fresh sample takes a significant part of the percentage composition of the nutrients. To correct for this observation, it is hereby suggested that a percentage composition based on the organic matter content of the different food samples would make a more realistic basis of comparison. Protein, fats, carbohydrates and crude fibre are all organic in nature. Therefore, comparing these parameters from the different food samples, especially when fresh ones and dried samples are involved does not produce a common denominator for the comparison. The organic matter seems to be so highly "diluted" in the fresh samples, while it is highly "concentrated" in the dry samples. Thus, we may be forced to say, on the proximate composition front, that the protein content of a fresh food sample is small, when taken in relation to other proximate parameters. However, its actual contribution will appear better when considered in terms of its contribution to the organic matter content.

Therefore, the actual contribution of protein to the OM content in the fresh samples is 19.72%. This is significantly higher ($P<0.05$) than that from the oven dried and sun dried samples, 4.21% and 4.16% respectively. Carbohydrates were significantly different among the three samples studied (table 1), under proximate conditions. However, on this basis of comparison, the carbohydrates content between the dried samples is not significantly different ($P>0.05$). This is similar to the situation observed for crude fats, which was shown as not been significantly different ($P>0.05$) between the fresh sample and the oven dried sample, but its shown to have differed significantly ($P<0.05$) under this basis (table 5) of comparison.

4. Conclusion and Recommendations

Based on the results obtained from the study, the two drying methods were all good as they all yielded nutritional constituents with minimal differences from the fresh sample. However, to obtain fast drying, conserve protein and iron content, the oven drying method though likely to be more expensive is recommended, while the sun-drying method is cheaply executed, takes a longer time and may be prone to contaminations from microorganisms due to unhygienic exposures.

Further studies could focus on the microbial contamination of the flours from respective processing methods, fatty acids profile and amino acid profile analysis. Moreover, the reducing sugars content and the glycemic index of the flours need to be examined. This will provide the necessary information to adopt this food sample as a dietary source for special nutritional cases, such as diabetics, depending on the results obtained.

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