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Nutritional Composition of Plantain Flour of (*Musa Paradisiaca*): the Effect of Various Drying Methods in Rwanda

Jean Pierre Ndayambaje[1,*], Leonce Dusengemungu[2], Pascaline Bahati[2]

[1]School of Life Science and Engineering, Lanzhou University of Technology, Lanzhou 730050, China
[2]School of Food Science and Engineering, Northwest A&F University, Xi'An 712100, China
*Corresponding author: oreteq4@gmail.com

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Abstract This research was conducted to determine the nutritional composition of plantain flour processed using three drying methods namely sun drying, oven drying, and microwave drying. A variety of *Musa paradisiaca* grown in Rwanda and locally named "*inshakara*" was peeled, sliced, dried and ground. Vitamin C, pro-vitamin A, and proteins of both fresh and flour samples were determined to examine possible losses of nutrients due to drying. Moisture content was also analyzed for the fresh sample only. The results found were 70.59%, 72.3% and 74.05% moisture loss due to sun, oven and microwave drying respectively. 6.45mg of vitamin C was determined in the fresh sample while 4.808mg, 4.156mg and 3.875mg of ascorbic acid were found in flour processed by sun drying, oven drying, and microwave drying respectively. The results obtained for ß-carotene determination were 5.674µg for the fresh sample, 5.546µg for microwave dried plantain flour, 3.215µg for sun-dried plantain flour and 2.17µg for oven dried plantain flour. Proteins resulted in 1.8712% fresh sample, 1.1786% sun dried plantain flour, 1.3266% oven dried plantain flour and 0.9851% microwave dried plantain flour. The losses of nutrients varied due to the drying system applied.

Keywords: *drying methods, moisture content, pro-vitamin a, proteins, Vitamin C*

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1. Introduction

The processing of plantain into flour as a way of preserving them from spoilage has increased in recent years and information on the effect of drying methods on the nutritional properties of plantain flour in literature is limited especially in Rwanda [1]. Musa spp., comprising banana and plantain, are among the world's leading fruit crops. All bananas and plantains belong to the same genus, *Musa*, which contains 30-40 species [2]. The FAO and the International Institute of Tropical Agriculture (IITA), among other research centers, use the word "banana" to refer to *Musa* species that are sweeter and eaten raw and "plantain" to denote *Musa* species that are starchier and cooked before eating, while many researchers use "banana" to mean all *Musa* varieties, including plantains [3].

Our research work has followed the convention of the FAO and refer to plantains as *Musa* species that need cooking before eating [4].

Plantains (*Musa paradisiaca*) is one of the important staple food crops consumed in the tropics behind rice, wheat and maize and are obtained in about 120-130 tropical countries worldwide [5]. Bananas are grown in more than 120 countries in the 5 continents and over 10 million hectares [6]. In developing countries of Western, Eastern and Central Africa, plantains, *Musa sp*. are major food staples. About 70 million people in Africa are estimated to depend on *Musa* fruits for a large proportion of their daily carbohydrate intake [7].

The aggregated world production of bananas and plantains is over 76 million metric tons out of which over 12 million metric tons are harvested yearly in Africa [8,9,10]. This largest produce of banana and plantains only few of it undergo industrial processing mostly for improved preservation and value addition. Plantains and unripe banana are consumed cooked, whereas, mature dessert banana is eaten raw [11].

Banana plantain and cooking banana (*Musa spp*) may be processed into many products such as biscuits or as an infant formula supplement at different stages of physiological maturity, unripe, ripe, overripe or in a number of ways such as frying, grilling, boiling and drying [12].

Production of plantain is seasonal whilst consumption is all year round and therefore there is the need to process them into forms with reduced moisture content [13]. Dehydration is one of the oldest methods of food preservation and converting plantain into flour could

contribute to reduce losses and allow the food industry to store the product throughout the year [14].

Drying preservation method was also found to be one of the best methods in terms of cost efficiency to preserve plantain flour and it has been shown that plantain products produced from plantain flour receive considerable shelf-life stability [15].

However, the drying process involves heat and thus affects heat sensitive nutrients of food in various ways. It can either increase the concentration of some nutrients by making them more available or decrease the concentration of some nutrients [16]. There is often a decrease in the quality of dried products because most conventional techniques use high temperature during the drying process [17].

Conventional sun drying is the most common method applied in processing plantains into flour but, there are a number of problems associated with it such as weather unpredictability, uneven drying, and the slowness of the process, possible damage of plantain flour by bacteria and insects [18]. In order to use plantain flours as ingredients for the food industry, it is necessary to determine the effective methods used for its processing and characterize the resulted plantain flour chemical and nutritional composition, as well as their physical, physicochemical, rheological and functional properties [19].

This study was therefore carried out to establish the effects of three drying methods, namely sun drying, oven drying and microwave drying on the nutrient content in plantain (*Musa paradisiaca*) flour mostly vitamins A and C and proteins, in order to determine the most suitable method that will not only increase their shelf life but also retain their nutrients adequately. Since the high nutritional value of any food product is very desirable for both processing industries and consumers.

2. Materials and Methods

Plantain fruits for this study were collected from the local market, Musanze District, Northern Province, Rwanda and Plantain of the same variety and maturity level were carefully selected. This experiment was repeated thrice and the results remained the same.

2.1. Plantain Flour Preparation

Finger samples were collected from the second hand from the proximal end of the bunch following the recommendation of [20], the same day the bunch was harvested. About 1kg of unripe plantain (*Musa paradisiaca*) fingers were peeled and blanched at 80°C for 5 minutes, cut into small pieces and divided into three equal portions.

The three portions were dried to constant weight using sun, oven, and microwave drying methods respectively. Dried plantain flour samples were coded SDPF, ODPF and MDPF to refer to Sun dried, oven dried and microwave dried plantain flour respectively.

2.2. Sun Drying

100g of banana slices were weighed, put on a stainless-steel plate and placed under direct sunlight from 09:00 am to 04:30 pm until constant weight. They were supposed to be placed at direct sunlight from 09:00 am to 04:30 pm every day but due to weather conditions, there were some breaks caused by rain.

2.3. Oven Drying

20 g of banana slices were weighed, put on a sheet of aluminum foil and dried in an electric oven at 105°C for about 6 hours as recommended by [21].

2.4. Microwave Drying

20 g of banana slices were weighed, put on a sheet of paper and dried in the microwave until constant weight [21]. The microwave used has the capacity of setting the drying temperature related to the type of food product you want to cook or dry. The drying time was first set to 3 minutes and then 2 minutes again and again until reaching the constant weight.

2.5. Vitamin C determination

2g of plantain flour was weighed and mixed with 100ml of distilled water in a 250ml Erlenmeyer. After filtration, 5ml of the filtrate was taken in a 250ml Erlenmeyer and brought to the volume of 100ml with distilled water. 5 drops of indicator (phenolphthalein) was added and then titration with 0.01N NaOH was carried out until the color change. The following formula was used to calculate the amount of vitamin C present within 100g of a sample [21].

$$Vit.\ C = vol.NaOH \times 0.01N \times 100ml \times \frac{100\text{g}}{2} \times 176.13 \times 10^{-3}$$

Where, vol. NaOH = Volume of NaOH used for titration.

The above formula gives the milligrams of vitamin C present in 100g of the sample.

2.6. Pro-vitamin A (ß-carotene) Determination

The extraction of pro-vitamin A was carried out according to the methods by [21]. 2g of the sample was weighed and mixed with 50ml of acetone. After filtration with a filter paper, 20ml of petroleum ether was poured in a separating funnel and the filtrate was also added.

With a spray bottle, distilled water was slowly added but letting it flow on the wall of the bulb. (The two phases reversed after this step). The ether phase was washed 4 to 5 times of any trace of acetone with the wash bottle. The valve of the bulb was then opened to let flow the lower phase (of acetone and water) and the upper ether phase was recuperated in a 25ml bottle or flask.

Filtration on a layer of anhydrous Na_2SO_4 was then carried out and the filtrate was brought to the volume of 25ml with ether. Lastly, the absorbance was read on the spectrophotometer or colorimeter having a 450nm wavelength.

Here is the formula used for Calculation:

$$\frac{\left(\text{Absorbance (provit. A)} \times \text{Volume(ml) of sample before reading} \times 10^4\right)}{E_{1\text{Cm}}^{1\%} \times \text{Sample weight (gr).}}$$

This formula gives µg pro-vitamin A in 1 g of sample

2.7. Crude Protein Determination

The extraction of Crude proteins was also carried out according to the methods by [21]. 0.5g of the finely ground sample was weighed and put into an Erlenmeyer flask. Then 10ml of H_2SO_4 and 3g of a mixture of catalysts (sulfate of potassium, Ferrous Sulfate, Copper sulfate, Selenium) were added and the mixture was left to react for 8hours. After eight hours, the mixture was put in the Kjeldahl digester for one hour and 30minutes at 250^{O}C. The content was cooled and transverse in a volumetric flask of 100mL. The Erlenmeyer was rinsed several times with distilled water and the content of the volumetric flask was brought to the volume of 100mL. 10mL from the volumetric flask and 10mL of NaOH 40% were mixed in a distillation tube. The distillation tube was then installed in the automatic Kjeldahl analyzer. The automatic Kjeldahl analyzer distilled, analyzed and then displayed the results on its screen.

3. Results and Discussion

3.1. Moisture Content Determination for Fresh Sample

Values obtained for moisture removal are remarkably different as it is shown in Figure 1. Microwave drying has shown high potential in removing more moisture within a short time. Even if the oven drying method removed less moisture than microwave drying, it removed also 1.17% more than sun drying which removed only 70.59% of the moisture that was present in the freshly harvested banana plantain.

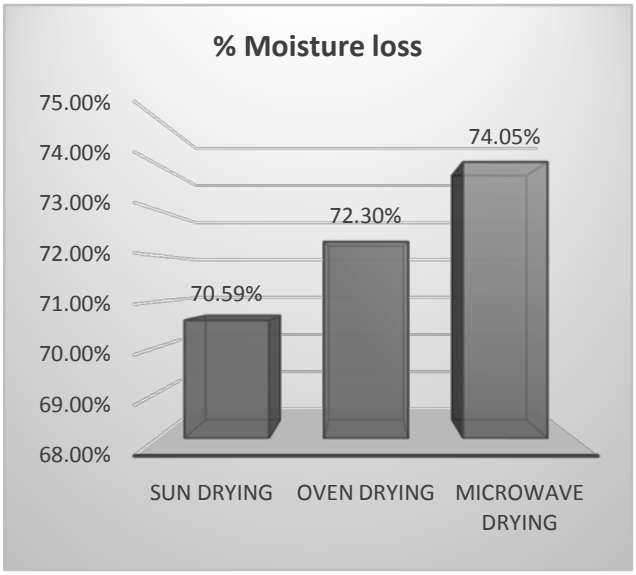

Figure 1. Moisture removal percentage using different drying methods

In general, the three drying methods were capable of removing 70-75% of the moisture in plantain, with microwave drying having the highest moisture removal capability with 74.05% of moisture removed within only 11 minutes.

Table 1. The nutritional values of bananas per 100g of the edible fresh portion. Source: [25]

Nutrients	Amount
1. Water	74%
2. Carbohydrates	23 %
3. Protein	1%
4. Fats	0.5%
5. Fiber	2.5%

The previous report [25] suggested that 74% of water is generally present in edible bananas. This agreement shows that the microwave drying used in this study is not far from the standards as shown by the table above Figure 1 making it the most efficient drying method compared to sun drying and oven drying.

3.2. Determination of Vitamin A, C, and Proteins in Fresh Plantain and in Processed Plantain Flour

3.2.1. Vitamin C Determination

Vitamin C is generally present in edible banana at an approximate amount of 11mg per 100g of the sample [22]. About 6.45mg of Vitamin C were determined from 100g of the freshly harvested plantain banana. It is remarkably low compared to 11mg found by Dickinson in 2000 [22] for the equal amount of 100g of the freshly harvested plantain banana and we have assumed that the difference was probably due to the quality and the type of banana used.

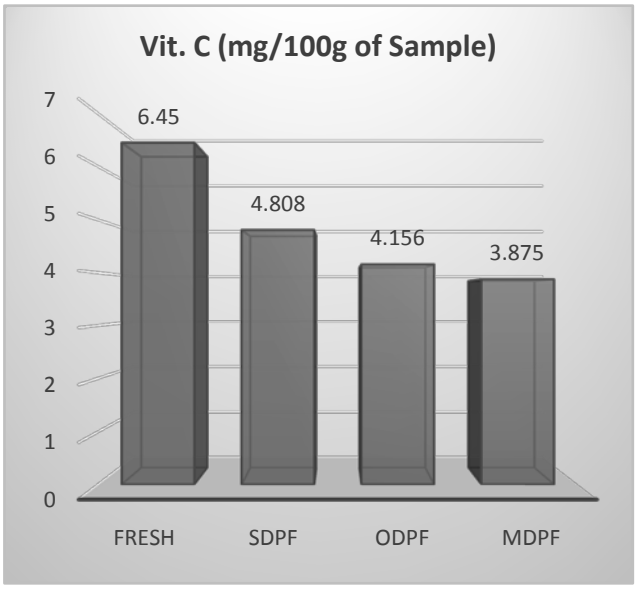

Figure 2. Vitamin C Content in fresh samples and processed plantain flour using different drying methods

Vitamin C is the most important vitamin for human nutrition that is supplied by fruits and vegetables. It is thermally sensitive and any treatment of fruits and vegetables involving heat can reduce it significantly [23,24]. It is possible that the 6.45mg of vitamin C that was present in 100g of fresh plantain used during our research was below standard.

Based on the data collected during this experiment, vitamin C was reduced by different drying methods used.

The sun-dried plantain was the most efficient as far as vitamin C deterioration is concerned due to the fact that it reduced fewer vitamins C content. With it, vitamin C was reduced from 6.45mg to 4.808mg per 100g of the plantain fresh.

Microwave drying caused the deterioration of vitamin C at the highest level; it lowered it to 3.875mg. As illustrated in Figure 2, oven drying has also decreased vitamin C content of the fresh plantain at 4.156mg. It is remarkably clear that the sun drying methods is the most effective drying method if the retention of vitamin C is desired because it reduced less vitamin C content.

3.2.2. Pro-vitamin A (ß-carotene) Determination

1g of ripe edible banana contains about 21µg of carotenes [22]. The results obtained after our analysis have shown that 5.674µg of ß-carotene was present in 1g of fresh green plantain (Figure 3). It is, of course, a low proportion compared to the amount of ß-carotene obtained by Dickinson [22] but we have to mention that the quantity of carotenes increases with the ripening of most of the fruits. Due to the fact that we dealt with only green mature plantain, we have obtained lower levels of ß-carotene.

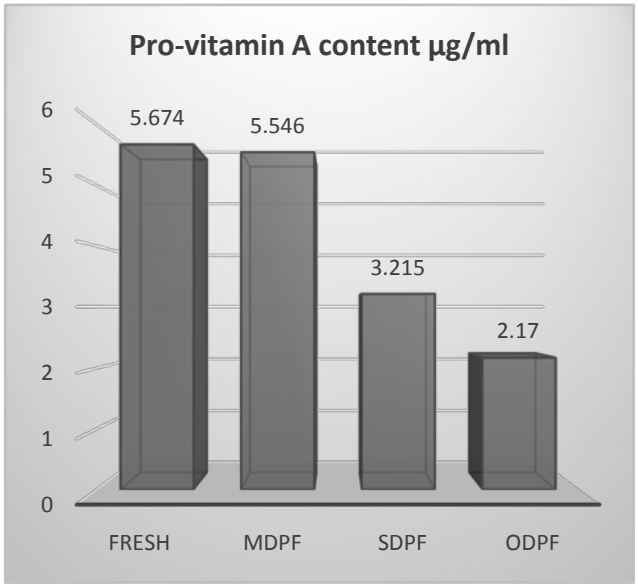

Figure 3. Pro-vitamin A content in fresh and processed plantain flour by using different drying methods

By referring to the table above (Figure 3), the reduction of ß-carotene by heat involved in drying is highly remarkable in ODPF. That heat has reduced ß-carotene down to 2.17µg. The levels of ß-carotene also have decreased considerably in SDPF. The Pro-vitamin A in MDPF was also affected but at a very low level, it was reduced from 5.674µg to 5.546µg. Considering ß-carotene retention, it is advantageous to process plantain slices by microwave drying because it showed the capability of retaining more ß-carotene than other studied drying methods.

3.2.3. Proteins Determination

2% of the total content of fresh unripe banana is proteins [25]. Regarding the fresh sample, the values obtained in this study are not far from the values recorded in USDA reports of the year 2007. 1.8712% of proteins was the result got during this study for fresh plantain.

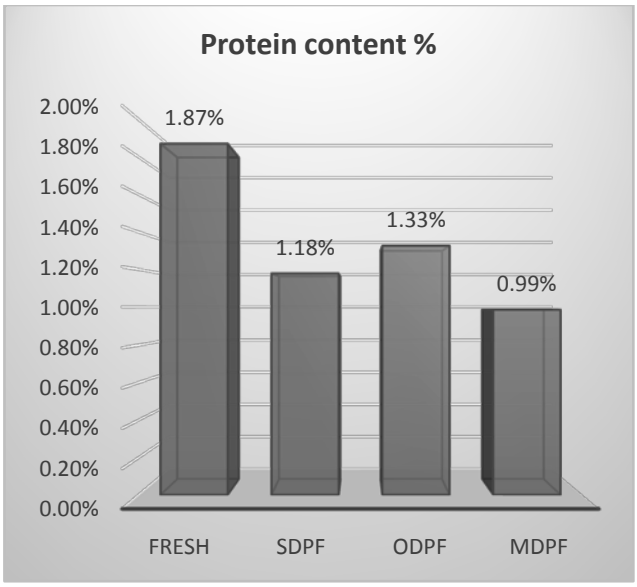

Figure 4. Protein Content Percentage before and after processing plantain into flour by different drying methods

It has been reported by [23,24] that the nutritional content of any food product depends on various factors such as the genetic make-up of the plant or animal, the soil in which it was grown, the type of fertilizers used during cultivation, prevailing weather, and maturity at harvest, packaging, storage conditions and method of preparation for processing. All those factors can be the cause of the variation seen within protein determination [23,24].

The MDPF has lost almost a half of proteins that were present in the freshly harvested plantain banana. The results of protein analysis showed that 0.9851% was remaining in it. This reduction was due to the higher temperature and speed of drying involved in the process of microwave drying. We have to mention once again that microwave drying process was the quickest and most efficient in water removal, meaning that it uses higher temperatures compared to other drying methods.

Both the sun drying and the oven drying have also reduced the protein content to 1.1786% and 1.3266% respectively. For proteins retention, the oven drying is preferred compared to three other drying methods because it showed the capability of retaining more proteins (1.3266%) than the sun and the microwave drying. More researches are required to determine the most effective method to preserve plantain with minimum loss of nutrients.

4. Conclusion

The results of this study have shown that the nutrient losses of banana plantain observed during flour processing were mainly caused by heat involved in different drying methods that have been used. This explains why the moisture content determined in the freshly harvested plantain was remarkably minimized. Every drying method has shown its capability of removing a certain amount of moisture with microwave drying rating the best with 74.05% of the total moisture removed within only 11 minutes.

Concerning Vitamin C retention, the sun drying method has shown the capacity of retaining more vitamin C ,0.652 mg and 0.933mg higher compared to oven drying and microwave drying methods respectively. However, every drying method used in this study has negatively affected the vitamin C content. Vitamin A is normally heat sensitive. It was also reduced considerably with the microwave drying retaining more Pro-vitamin A (5.546µg). Both the sun drying and the oven drying have also reduced pro-vitamin A. Proteins also are naturally denatured by heat. Microwave drying has reduced more proteins than the two remaining drying methods. The oven drying has shown the capability of retaining more proteins than other drying methods with 1.33% retained after drying.

It is recommended to plantain processors to understand both the negative and the positive effects of any drying method they want to use. The microwave drying, for example, has been efficient and quick as far as moisture removal is concerned, but has shown weakness in retaining vitamin C and proteins. Further researches can deeply focus on plantain processing as plantain-based foods can help in eradicating hunger and malnutrition mostly in developing countries where they are highly produced.

Conflict of Interest

The authors have declared no conflict of interest.

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