# Evaluation of Physico-Chemical Properties of Unripe Plantain Peels as Affected by Different Drying Temperature Regimes

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***Abstract***
*This study evaluated the physico-chemical properties of unripe plantain peel, as affected by different drying temperature regimes. The plantain peels were subjected different drying temperatures of 60, 75, 90 and 105 °C for 12 hours, using a laboratory Oven to produce flour samples. Results of the physico-chemical analysis of the flour samples showed that samples dried at 60, 75, 90 and 105 °C had moisture contents of 2.67, 2.00, 1.38 and 0.66%, respectively; ash contents of 15.83, 15.35, 15.08 and 14.97%, respectively; fibre contents of 12.84, 13.34, 13.68 and 14.10%, respectively; protein contents of 9.80, 8.40, 7.35 and 7.00%, respectively; lipid contents of 77.43, 7.55, 7.80 and 7.94%, respectively; carbohydrate contents of 54.09, 55.02, 56.32 and 56.43%, respectively; caloric values of 321.47, 322.63, 324.32 and 325.74 kcal, respectively. There was a significant difference (p < 0.05) in moisture, ash, fibre, protein, lipid and carbohydrate contents, as well as the caloric value of the unripe plantain peel flour samples. The different drying temperature regimes had significant effect on the physico-chemical properties of the unripe plantain peel. Moisture, ash, fibre and protein contents decreased with corresponding increase in drying temperature, while lipid content, carbohydrate content and caloric value increased with increase in drying temperature.*

**Keywords:** *Physico-chemical properties, Unripe plantain, Temperature regimes, Evaluation, Plantain peel*

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## 1.0 INTRODUCTION

Plantain (*Musa paradisiaca*) with a world production index of 20.5 million tons per year is a very important food of the tropics and subtropics, where both ripe and unripe foods are consumed (MacDonald and Low, 1990).

Plantain is a versatile and very nutritious food staple that is widely consumed, either ripe or unripe. They are a great source of carbohydrates, having a nutritional value that is similar to that of yam or potato. In Nigeria, they are eaten as snacks in the form of chips, as plantain *amala*, or *dodo ikire* (Umoh *et al*., 2024). Unripe and mature plantain could be ground into flour.

Typically, in Nigeria, flour is turned into *amala*, a low-glycemic gruel that is frequently advised for diabetics. Plantain is rich in healthy components such as phenols, carotenoids and dietary fiber (Baskar *et al*. 2011; Davey *et al*. 2006; Fatemeh *et al*. 2012).

The peel of foods contains a higher proportion of bioactive compounds compared to the pulp (Vu *et al*. 2018). Moreover, the antioxidant activity of the peel is greater than that of the food itself (Someya *et al*. 2002).

Research on some nutritional properties of thirteen plantain cultivars after proximate analysis revealed that moisture content in cultivars (peels) ranged from 78.74% to 87.33%; Ash content varied between 0.87% and 2.38%; Protein content ranged from 1.67% to 4.2%; Lipid content varied from 0.84% to 2.24%; Fibre values oscillated between 2.38% and 3.72%; Dry matter content fluctuated between 12.67% and 21.26%; and Carbohydrate content ranged from 88.84% to 92.91% (Ogidi *et al*., 2017).

The end-use of banana and plantain peel depends on its chemical composition, which is affected by the fruit’s ripeness. Peel from unripe fruit presents (on a dry basis) 6–10% protein, 6–12% ash, 2–6% lipids, 11–39% starch, and 33–43% total dietary fiber (Agama-Acevedo *et al*., 2016)

Plantain peels are also an excellent source of dopamine, a powerful antioxidant. It is assumed that catecholamine is largely attributed to the antioxidant in plantain (Vu *et al*. 2018). In many countries, plantain peel has been used as a traditional medicine for centuries (Imam and Akter 2011; Pereira and Maraschin 2015), indicated that plantain peel extract could be used as functional ingredient in the food industry. In order to improve the function of bioactive compounds such as phenolic compounds in plantain peel, it is necessary to extract them from the peel and then encapsulate them to protect them from degradation and improve storage efficiency. Optimal extraction and efficient encapsulation are therefore extremely important for the preparation of functional plantain peel powder.

Plantain peels are important raw materials for several products yet termed useless and unproductive which makes the cost of the raw material reliant on the food excluding the peels in the market because consumers do not know the usefulness of its peels and hence, they are discarded. The process of indiscriminate disposal of this peel waste constitutes an environmental problem.

Currently peels of a variety of fruits and foods get focused as natural source of antioxidants and dietary fibre. With these grounds, plantain peel has attracted attention as recent reports suggest it as a very good source of dietary fibre and antioxidant.

The aim of this study is to evaluate the physico-chemical properties of unripe plantain peels, as affected by different drying temperature regimes.

## 2.0 MATERIALS AND METHODS

### 2.1 Sample Collection and Preparation

Fresh unripe plantain was bought from the local market in Ikot Akpaden, Mkpat Enin L.G.A., Akwa Ibom State, Nigeria. The unripe plantain was cleaned, peeled and the peels made into chips, of uniform sizes. The fresh chips oven-dried for 12 hours at 60, 75, 90 and 105 ᵒC, respectively, and then milled using Food Grade model SK-30-SS disc attrition mill, manufactured by Munson Machinery Co. Inc., New York, sieved with laboratory sieve of 600 µm aperture size, and the sample stored for laboratory analyses (Umoh e*t al*., 2024).

### 2.2 Determination of Physico-Chemical Properties

### 2.2.1 Moisture Content Determination

Moisture content was determined according to the standard method of analysis of the Association of Official Analytical Chemists, AOAC, (2010), as highlighted by Umoh and Iwe (2022). A beaker that had been cleaned and dried in the oven was weighed after it had cooled in a desiccator (a). The beaker was weighed after adding two grams (2 g) of the flour mix sample, and the weight of the beaker plus sample was recorded (b). After being dried for four hours at 105 °C in the oven, the beaker and its contents were swiftly placed into a desiccator to cool before being weighed again. This process was carried out repeatedly until a consistent weight, (c) was achieved. Equation 2.1 was used to compute the moisture content.

Calculation:

$$\text{Moisture Content } (\%) = \frac{\text{loss in weight due to drying}}{\text{weight of sample taken}}$$

$$= \frac{b-c}{b-a} \times 100 \text{ .................................. Equation 2.1}$$

Where: a = weight of empty beaker (g)
b = weight of beaker + sample (g)
c = weight of beaker + sample after drying (g)

### 2.2.2 Ash Content Determination

A muffle furnace (Model SXL-1200) was used to ignite a crucible with a lid at 105 °C for one hour. After that, it was weighed and placed in a desiccator to cool (a). The pre-weighed crucible was filled with two grams (2g) of the flour sample, and the weight of the crucible and its content taken (b). In a fume cupboard, bunsen flame was used to burn the crucible and its contents until the smoking stopped. The crucible and content were moved into a muffle furnace and heated to 550 °C for two hours, or until a white ash formed. The crucible was then cooled, covered, and put in a desiccator, before it was weighed (c). Equation 2.2 was used to determine the amount of ash content in the sample (AOAC, 2010).

$$\text{Ash } (\%) = \frac{b-C}{b-a} \times 100 \text{ ...................................... Equation 2.2}$$

Where: a = weight of crucible (g)
b = weight of crucible + sample (g)
c = weight of crucible + ash (g)

### 2.2.3 Crude Fibre Determination

Two grams (2 g) of the sample was defatted with petroleum ether for 2 h. It was boiled for 30 minutes with 200 ml of $H_2SO_4$ solution, filtered through linen on a fluted funnel and washed with boiling water until the washings were no longer acidic.

After being moved to a beaker, the residue was heated for a further thirty minutes with 200 milliliters of NaOH solution. It was then filtered, and boiling water was used to wash the residue multiple times until it was clear of base (NaOH). Ultimately, the residue underwent two methanol washes, was quantitatively moved into a crucible that had been weighed beforehand, and was oven dried at 105 °C (Io). It was weighed (Ia), chilled in a desiccator, and burned at 550 °C. After burning, the weight loss was also recorded. Using equation 2.3, the crude fiber content was determined (AOAC, 2010)

$$\text{Crude fibre (\%)} = \frac{\mathrm{I}_{a-}\mathrm{I}_{o}}{\text{weight of original sample taken}} \text{ X } 100 \text{ ..................... Equation 2.3}$$

### 2.2.4 Crude Protein Determination

The method of Kjeldahl, as described by Umoh and Iwe (2022), was used to determine crude protein. Precisely one gram (1g) of the flour sample was weighed and placed into a standard 250 ml Kjeldahl flask together with 1.5 g of catalyst ($CuSO_4$), 1.5g of Na2SO4, and 5 ml of concentrated $H_2SO_4$. After placing the digesting (Kjeldahl) flask on a heating mantle, it was gradually heated for several hours to produce a clear, blue solution—a measure taken to avoid foaming. After allowing the digested solution to cool, it was quantitatively transferred to a 100 ml standard flask and filled with distilled water to the appropriate level. A twenty milliliter (20 ml) portion of the digest was treated with an equivalent volume of 40% NaOH solution after being pipetted into a semi-micro Kjeldahl distillation unit.

Following a steam distillation process, the ammonia developed into a 100 ml conical flask that held a 10 ml saturated boric acid solution with two drops of Tashirus indicator (double indicator) added.

After submerging the condenser tip in the boric acid – double indicator solution, the distillation process was carried out until roughly two thirds of the initial volume was recovered. The distillate was then titrated with 0.1M HCl solution until a purple-pink end-point was noticed, and the tip of the condenser was washed with a few milliliters of distilled water. A blank determination was also performed in the same way, as previously mentioned, with the exception of the sample being excluded. The percentage of nitrogen content was multiplied by a factor (6.25) to obtain the crude protein, as shown in equation 2.4.

$$\frac{(\text{Sample titre} - \text{blank titre})0.1 \times 0.014}{\text{weight of sample}} \times \frac{100}{20} \times \frac{100}{1} \times 6.25 \text{ ………….. Equation 2.4}$$

### 2.2.5 Crude Fat Determination

The extraction thimble was filled with two grams (2 g) of the flour samples after it had been cleaned, dried in the oven, and slightly blocked with cotton wool. A round bottom flask with a capacity of 500 ml was filled with 150 ml of petroleum ether, which has a boiling point ranging from 35 to 60 ℃. The round-bottom flask was placed on a heating mantle and the soxhlet extractor was inserted. After being put together, the soxhlet device was left to reflux for almost four hours. A dried, pre-weighed beaker ($W_1$) was filled with the extract, and the thimble was then cleaned with some ether before being returned to the beaker. After being heated in a steam bath to remove extra solvent, the beaker was cooled in a desiccator and weighed ($W_2$). The crude fat content was calculated using equation 2.5 (AOAC, 2010).

$$\text{Crude fat (\%)} = \frac{\text{weight gain in flask}}{\text{weight of sample}} \times \frac{100}{1}$$

$$= \frac{W_2 - W_1}{\text{weight of sample}} \times \frac{100}{1} \text{ ………………… Equation 2.5}$$

### 2.2.6 Carbohydrate Content Determination

Determination of carbohydrate content of the sample was carried out by subtracting the total estimations (in %) made of nitrogen (protein), fat, ash and crude fibre contents from 100%. The resultant value gave the percentage carbohydrate content by difference, using equation 2.6 (AOAC, 2010).

$$\text{Carbohydrate (\%)} = 100 - (a + b + c + d) \text{ ………………………… Equation 2.6}$$

Where,

a = percentage protein content
b = percentage lipid content
c = percentage ash content
d = percentage fibre content

### 2.2.7 Caloric Value Determination

This was obtained using the Atwater factor method. The values of the crude protein, fat, and carbohydrate obtained were multiplied by 4, 9, 4 respectively, and the sum of the products was taken as the caloric or energy value, (in kcal) of the sample, using equation 2.7 (AOAC, 2010).

$$\text{Energy value (kcal)} = (x \times 4) + (y \times 9) + (z \times 4) \text{ …………………….. Equation 2.7}$$

Where, x = protein content
y = lipid content
z = carbohydrate content

### 2.3 Statistical Analysis

The triple-checked data were analyzed using the Statistical Analysis of Variance (ANOVA), with a 5% threshold of significance applied to the mean separation using the Duncan's Multiple Range Test.

## 3.0 RESULTS AND DISCUSSIONS

The results of the physico-chemical properties of unripe plantain peel flour are presented in Table 3.1.

**Table 3.1: Physico-Chemical Properties of Unripe Plantain Peels Flour**

| Sample | Temp (ºC) | Moisture Content (%) | Ash (%) | Fibre (%) | Protein (%) | Lipid (%) | CHO (%) | Caloric Value (kcal) |
|---|---|---|---|---|---|---|---|---|
| A | 60 | $2.67 \pm 0.003^{a}$ | $15.83 \pm 0.010^{a}$ | $12.84 \pm 0.022^{d}$ | $9.80 \pm 0.003^{a}$ | $7.43 \pm 0.004^{d}$ | $54.09 \pm 0.011^{d}$ | $321.47 \pm 0.002^{c}$ |
| B | 75 | $2.00 \pm 0.011^{b}$ | $15.35 \pm 0.022^{b}$ | $13.34 \pm 0.001^{b}$ | $8.40 \pm 0.022^{b}$ | $7.55 \pm 0.006^{c}$ | $55.02 \pm 0.002^{c}$ | $322.63 \pm 0.026^{d}$ |
| C | 90 | $1.38 \pm 0.001^{c}$ | $15.08 \pm 0.002^{c}$ | $13.68 \pm 0.006^{c}$ | $7.35 \pm 0.020^{c}$ | $7.80 \pm 0.032^{b}$ | $56.32 \pm 0.022^{a}$ | $324.32 \pm 0.041^{a}$ |
| D | 105 | $0.66 \pm 0.100^{d}$ | $14.97 \pm 0.004^{d}$ | $14.10 \pm 0.021^{a}$ | $7.00 \pm 0.201^{d}$ | $7.94 \pm 0.024^{a}$ | $56.43 \pm 0.006^{b}$ | $325.74 \pm 0.021^{b}$ |

Note: Values are mean ± standard deviation of triple determination. Mean values with different superscripts are significantly different ($p < 0.05$)

### 3.1 Moisture Content

Results of the physico-chemical analysis of the unripe plantain peel flour samples indicated that sample dried at 60, 75, 90 and 105 $^{o}$C had moisture contents of 2.67, 2.00, 1.38 and 0.66%, respectively. Sample dried at the lowest temperature (sample A) recorded the highest moisture content, while the highest drying temperature produced the sample with the lowest moisture content (Table 3.1). There was a significant difference ($p < 0.05$) in the moisture contents of the samples. The moisture content of the unripe plantain peel decreased with increase in the drying temperature. Therefore, drying temperature significantly affected the moisture content of the unripe plantain peel. Moisture content of samples is presumed as one of the most important determination of shelf stability. The moisture content values for the flour samples ensure adequate storage in packages (Umoh, 2020).

### 3.2 Ash Content

The unripe plantain peel recorded ash contents of 15.83, 15.35, 15.08 and 14.97% for samples dried at 60, 75, 90 and 105 $^{o}$C, respectively (Table 3.1). These recorded values are higher than 3.94 to 4.28%, earlier reported for green plantain flour (Umoh *et al.*, 2024). The high ash content is an indication that unripe plantain peel is a rich potential source of mineral elements. Similarly, there was a significant difference ($p < 0.05$) in the ash contents of the unripe plantain flour samples. Increase in drying temperature resulted in decrease in ash content of the sample. Thus, drying temperature had a significant effect on the ash contents of the unripe plantain peel.

### 3.3 Fiber Content

Fibre contents of the unripe plantain peel were 12.84, 13.34, 13.68 and 14.10% for samples dried at 60, 75, 90 and 105 $^{o}$C, respectively (Table 3.1). These values are higher than the range of values, 1.00 to 2.76%, earlier reported for aerial yam-soybean flour (Umoh, 2020), and 1.06 to 1.51% for false yam flour (Umoh and Iwe, 2014). Though crude fibre does not contribute nutrients or energy, it is essential for food bowel movement and helps in preventing obesity, diabetes, and cancer of the colon and other ailments of the gastro-intestinal tract of man (Umoh and Iwe, 2014). Unripe plantain peel is a rich potential source of dietary fibre. There was a significant difference ($p < 0.05$) in the fibre contents of the samples. Fibre content of the sample increased with a corresponding increase in drying temperature. The drying temperature significantly affected the fibre contents of the unripe plantain peel.

### 3.4 Protein Content

The unripe plantain peel flour samples recorded protein contents of 9.80, 8.40, 7.35 and 7.00% for samples dried at 60, 75, 90 and 105 $^oC$, respectively (Table 3.1). These recorded values are higher than 3.85 to 4.68%, earlier reported for green plantain flour (Umoh *et* al., 2024).There was a significant difference ($p < 0.05$) in the protein contents of the unripe plantain peel. However, the protein content decreased with increase in drying temperature. This may be attributed to the process of protein denaturation. Therefore, the drying temperature significantly affected the protein contents of the unripe plantain peel.

### 3.5 Lipid Content

Results of the physico-chemical evaluation of the unripe plantain peel flour samples showed that lipid contents were 7.43, 7.55, 7.80 and 7.94% for samples dried at 60, 75, 90 and 105 $^oC$, respectively (Table 3.1). The low lipid content is an indication that unripe plantain peel flour can be stored for long period, at the right temperature and moisture without spoilage by rancidity (Umoh and Iwe, 2014). There was a significant difference ($p < 0.05$) in the lipid contents of the unripe plantain peel. Increase in drying temperature resulted in increased lipid content of the sample. The drying temperature had a significant effect on the lipid contents of the unripe plantain peel.

### 3.6 Carbohydrate Content

The unripe plantain peel recorded carbohydrate contents of 54.09, 55.02, 56.32 and 56.43% for samples dried at 60, 75, 90 and 105 $^oC$, respectively (Table 3.1). These recorded values are lower than 85.66 to 86.81%, earlier reported for green plantain flour (Umoh *et al*., 2024). The low carbohydrates contents imply that unripe plantain peel flour could be recommended as a diet for the diabetics. There was a significant difference ($p < 0.05$) in the carbohydrate content of the samples. The carbohydrate content increased with increase in the drying temperature. The drying temperature significantly affected the carbohydrate contents of the unripe plantain peel.

### 3.7 Caloric Value

The caloric value of the unripe plantain peel ranged from 321.47 to 325.74 kcal. This range of values is a bit lower than 421.75 to 429.34 kcal for aerial yam-soybean flour, earlier reported by Umoh (2020), and 380.29 to 385.23 kcal for green plantain flour (Umoh *et al*., 2024). Samples dried at 60, 75, 90 and 105 $^oC$ had caloric values of 321.47, 322.63, 324.32 and 325.74 kcal, respectively (Table 3.1). There was a significant difference ($p < 0.05$) in the caloric values of the unripe plantain peel flour samples. The caloric value increased with a corresponding increase in the drying temperature. Consequently, the drying temperature had a significant effect on the caloric value of the unripe plantain peel.

## 4.0 CONCLUSIONS

This study has shown that different drying temperature regimes has significant effect on the physico-chemical properties (moisture, ash, fibre, protein, lipid, carbohydrate and caloric value) of unripe plantain peel. Moisture, ash, fibre and protein contents decrease with corresponding increase in drying temperature, while lipid content, carbohydrate content and caloric value increase with increase in drying temperature.

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## Conflict of Interest

The Author hereby declares that no conflicts of interest exist.

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