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EFFECT OF PRETREATMENTS AND DRYING METHODS ON PHYSICOCHEMICAL PROPERTIES OF UNRIPE PLANTAIN FLOUR AND SENSORY ACCEPTABILITY OF ITS COOKED DOUGH (*AMALA*)

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ABSTRACT

Effect of pretreatments (sulphiting and blanching) and drying methods (sun, oven and freeze) on physicochemical properties and acceptability of unripe plantain flour was investigated. Proximate compositions, selected mineral contents and functional properties of the flour, as well as the sensory attributes of their cooked dough (*amala*) were determined using standard methods. Pretreatments and drying methods had varying individual and interactive effects on the unripe plantain flour. Moisture contents of the flour, except the blanched sun-dried sample, were lower than the 10% recommended by Standard Organisation of Nigeria as the maximum safe-keeping limit for flour. Carbohydrate contents were generally high (80.33-83.06%) but protein (2.17-2.87%), fat (1.30-1.56%) and ash (1.75-2.10%) were most retained in freeze-dried samples and blanching caused about 40-47% reduction in crude fibre. Pretreatments reduced ($p<0.05$) calcium (32.15-30.07 mg/100g) but increased ($p<0.05$) phosphorus (21.51-23.00 mg/100g) contents of sun-dried flour while sodium generally increased with sulphiting. Freeze-dried flour had highest bulk density (0.83-0.84 g/ml), swelling index (4.12-4.17%), water absorption capacity (24.80-27.68%) and dispersibility (60.10-63.00%). Cooked dough (*amala*) prepared from the various unripe plantain flour were all accepted by the panelists but those from freeze-dried flour were the most generally acceptable with the sulphited-freeze-dried unripe plantain cooked dough being rated as the best.

1. Introduction

Plantain (*Musa paradisiaca*) is a perennial tree crop which belongs to the kingdom Plantae and the family *Musaceae*. It is attractive to farmers due to its low requirement of labour and agricultural input for production (Marriott and Lancester, 1983) and has been reported to contribute to subsistence economies in Africa. Production of plantain in Nigeria was reported to have doubled within two decades before 2010 and the fruit was ranked third among starchy staples (Akinyemi *et al.,* 2010), serving as a source of carbohydrates for millions of people in the country. Plantain is low in fat and protein but rich in essential minerals (Karim *et al*., 2015).

The African landrace, "Agbagba*",* at the green stage, has a moisture content of about 61% (on wet basis), which increases during ripening to about 68% due to carbohydrate hydrolysis (Adeniji *et al*., 2006). The high moisture content of plantain makes it a perishable fruit. In Nigeria, for instance, quite a fraction of over 80% of plantain harvested during the peak period between September and February goes into a waste (Ogazi, 1996). This limits off-season availability of the fruit and, in particular, its use by urban populations. As noted by Karim (2005) for fruits and vegetables, one of the most difficult aspects of plantain production is the maintenance of its freshness as there is a physiological deterioration during storage resulting to a significant loss of nutritional value and in many cases, loss of the whole fruits. This phenomenon is usually worse with stored ripe fruits. Unripe plantain on the other hand has a relatively longer shelf life and a more stable physical and nutritional quality. In addition, it offers some health benefits such as reduction of blood sugar level owing to its rich content of dietary fibre (8.20%) and resistant starch (16.20%) as well as essential micronutrients (Chinma *et al*., 2012).

A technique to further extend the shelf life and utilization of unripe plantain is the processing of the fruit into flour which can then be stirred in appropriate quantity of boiling water to form gel (*amala*) and eaten with vegetable soup or any other soup of one's choice. Processing into flour adds value to plantain for both local market and export purposes (Zakpaa *et al.,* 2010; Falade and Ogunwolu, 2012) while also helping to curtail glut (Ogundare-Akanmu, *et al.,* 2012). Drying prior to milling into flour significantly extends the shelf life of a food material as moisture content and water activity will have greatly reduced. Different methods of drying including cabinet, solar, sun, oven, microwave oven, foam-mat, fluidized bed, tray and freeze drying have been reported to influence the physical, chemical, functional and nutritional qualities of unripe plantain flour (Emperatríz *et al.,* 2008; Falade and Olugbuyi, 2010; Falade and Oyeyinka, 2015; Yarkwan and Uvir, 2015; Arinola *et al*., 2016; Fadimu *et al*., 2018a; Ndayambaje *et al*., 2019). This is associated with different rate and pattern of heat and mass transfer, due to different structural make-up of the material being dried (Karim, 2010). Although most of these authors employed a single or combined pretreatments among sulphiting, osmotic dehydration and blanching to control the plantain products' qualities, the influence of pretreatments, singly or in combination with different drying methods was not distinctively elucidated.

Enzymatic browning reaction, attributable to the activity of polyphenol oxidase (tyrosinase) (Carbonaro and Mattera, 2002) which often influences the appearance of food materials, is one of the challenges faced during the processing of plantain. This makes pretreatment an essential part of plantain processing operation. Based on this, Fadimu *et al*. (2018b) have researched and reported blanching temperature of 50 ^{0}C, a blanching time of 6.447 min and 1% potassium metabisulphite to be the optimum pre-treatment conditions for unripe plantain based on the functional properties and proximate composition of the unripe plantain flour. However, the effectiveness of pretreatments, singly in arresting enzymatic browning and other undesirable changes and in combination with different drying methods to produce high quality and acceptable plantain products is worth given special consideration. Therefore, this study aimed at investigating the effect of different pretreatments (sulphiting and blanching) and drying methods (sun, oven and freeze) on the physicochemical properties of unripe plantain flour and sensory acceptability of its cooked dough (*amala*).

2. Materials and methods

2.1. Materials

Mature unripe plantains (*Agbagba*) used for this study were obtained from Ganmo market, Ilorin, Kwara State. The plantains were of stage 1 maturity with acceptable quality for consumption.

2.2. Experimental Design

A two-factorial design adopted for this study was from three levels of pretreatments (control, sulphiting and blanching) and three drying methods (sun, oven and freeze-drying). There were 3 controls (no pretreatment), resulting to nine (3 x 3) treatments (Table 1).

2.3. Pretreatments

The unripe plantains were cleaned, peeled, washed and manually sliced (approximately 2 mm thickness). The sliced plantains were divided into three batches. Two batches each containing 5 kg of plantain slices were subjected to different pretreatments. One batch was dipped in 1,500 ppm sodium metabisulphite ($Na_2S_2O_5$) solution for 2 min, while the other was placed in a plastic drainer and then immersed in hot (70 ^{0}C) water for 2 min. Both were adequately drained on wire mesh. The third batch of the sliced plantain was used as the control (without pretreatment).

2.4. Drying of Pretreated Unripe Plantain Flour

2.4.1. Freeze Drying

Each of the batches of pretreated unripe plantain slices and the batch without pretreatment were spread out in layers of about 1 cm thickness in a separate tray-drying accessory at -18 ^{0}C for 24 hrs and then lyophilized using a Freezone 4.5 lyophilizer (Labconco; Missouri, USA) for 5 hrs as described by Emperatríz *et al*. (2008). The resulting dried unripe plantain slices were milled into flour, packed and sealed inside hermetic plastic containers and stored in a cool dry place for further analyses.

2.4.2. Oven Drying

Pretreated unripe plantain slices and the ones without pretreatment were dried in an air draft oven (Gallenkamp 300 plus series, England) at 70^{0}C for 10 hrs (Chinma *et al.,* 2012). These were then milled into flour and subsequently handled as described for freeze-dried samples.

2.4.3. Sun Drying

Another batch of unripe plantain slices (with and without pretreatments) were thinly spread out on trays and placed in the sun between 10:00 am and 4:30 pm (Agoreyo *et al*, 2011) for 3 days at 35$\pm$2 ^{0}C after which they were milled into flour, packaged and stored as described for freeze-dried samples.

2.5. Determination of Chemical Properties of Unripe Plantain Flour

The proximate compositions including moisture, crude protein, crude fat, crude fibre and ash were determined following the methods of AOAC (2005). Carbohydrates were determined by difference. Mineral contents such as calcium, iron and sodium, were determined using Atomic Absorption Spectroscopic method while colorimetric method involving the use of ammonium vanadate reaction was adopted for phosphorus determination (James, 1995).

2.6. Determination of Functional Properties of Unripe Plantain Flour

Bulk density, swelling index and water absorption capacity of the unripe plantain flour were determined following the methods described by Zakpaa *et al.* (2010) while the method described by Ohizua *et al.* (2017) was used to determine dispersibility of the flour in water.

2.7. Preparation of Unripe Plantain Cooked Dough (*Amala*)

Cooked stiff dough (*amala*) was prepared following the procedures described by Karim *et al*. (2013). Briefly, unripe plantain flour was gently and gradually poured into boiling water with continuous stirring using a wooden stirrer until a homogenous paste was formed. The paste was covered and left on the heat source for about 5 min to cook. It was further stirred before being wrapped in polythene nylon and kept in a food warmer for subsequent sensory analysis.

2.8. Sensory Evaluation of Unripe Plantain Cooked Dough (*Amala*)

Fifty (50) panellists, comprising staff and students who are conversant with the quality attributes of *amala* made from yam flour, were drawn from the Department of Home Economics and Food Science, University of Ilorin. They were requested to assess the colour, aroma, mouldability and overall acceptability of the coded unripe plantain *amala* samples using a 9-point hedonic preference scale ranging from 1 (dislike extremely) to 9 (like extremely).

2.9. Statistical Analysis

Results of the various analyses were subjected to analysis of variance (ANOVA) using Statistical Package for Social Science (SPSS, version 16.0) and means generated were separated using Duncan multiple range test ($p < 0.05$).

3. Results and discussion

3.1. Proximate Composition of Unripe Plantain Flour

Results show that the various drying and pretreatment methods had significant ($p < 0.05$) effects on the moisture content of unripe plantain flour (Table 2). For each of the pretreated and control (without pretreatment) set of samples, freeze-dried plantain flour recorded the lowest moisture contents (7.36-9.29%). The highest rate of moisture removal by freeze-drying obtained in this study is similar to the finding of Emperatríz *et al.* (2008) and Shofian *et al.* (2011) who reported lower moisture contents with freeze-drying than any other methods of drying studied. The range of moisture contents of the various plantain flour, except for the blanched sun-dried sample, was below the level (10%) recommended by Standard Organisation of Nigeria (SON) for safe keeping quality of flour (Chinma *et al.,* 2012). Moisture content is an important indication of product quality stability. Unripe plantain flour without pretreatment were higher (4.07-4.13%) in crude fibre than the sulphited (3.20-3.85%) and blanched (2.13-2.46%) samples. Drying methods brought about no significant difference in crude fibre contents of the unripe plantain flour without pretreatment. Emperatríz *et al.* (2008) and Gwanfogbe *et al*. (1988) observed that dehydration methods had no significant effect on the dietary fibre of flour. However, the effect of drying methods appeared to be enhanced by the pretreatments with blanching exhibiting most effect and reducing the crude fibre content by about 40% in freeze-dried and 47% in oven-dried samples. In their report, Arisa *et al.* (2013) recorded 35% reduction in the crude fibre content of blanched plantain flour. This suggests that alteration of food tissues through pretreatment breaks down some of the components, such as resistant starch, that may have rather been present as fibre constituent. The range of values obtained in this study are however similar to the range of 2.28-4.44% reported by Arisa *et al.* (2013) and 2.56-3.21% reported by Fadimu *et al*. (2018a). Crude fibre, which is a type of dietary fibre remaining after food has been subjected to acid and alkali treatments, has useful biological functions such as aiding of digestion and diabetes management (Anderson *et al*., 2009).

The protein content of the unripe plantain flour without pretreatment was significantly ($p < 0.05$) higher with freeze-drying than sun and oven drying methods. Since the reverse was recorded in moisture contents, the apparent effect of drying methods on protein content may actually be an indirect effect of reduced moisture, bringing about different levels of concentrated proteins in the flour samples. Generally, sulphiting had a more significant increase on the protein proportion of unripe plantain flour than did blanching. Though the range of protein contents recorded in this study for unripe plantain flour was generally low (2.17-2.87%), it was not unexpected since unripe plantain flour is typically poor in protein supply (Zakpaa *et al.,* 2010; Karim *et al*. 2015; Fadimu *et al*. 2018a). Besides, the cooked dough (*amala*) is commonly eaten alongside soup prepared with meat or any other source of protein such as soycheese (meat analog). Another strategy to compensate for the low protein content is fortification of the flour with a protein rich material such as soyflour.

Pretreatment methods did not show a particularly defined significant effect on the fat contents of the unripe plantain flour but freeze-dried samples generally had the highest range of fat contents (1.45-1.56%) while the oven-dried samples had the lowest (1.35-1.36%). A similar finding was reported by Emperatríz *et al.* (2008) that freeze-dried and oven-dried unripe plantain flour had highest and lowest fat contents, respectively. Freeze-dried unripe plantain flour recorded the highest ash contents (1.97-2.10%), significantly varied with pretreatment methods, while sun-dried samples recorded the lowest (1.75-1.79%) but did not show any significant response to pretreatment differences (Table 2). The ash contents obtained in this study were similar to those (1.98-2.30%) reported by Emperatríz *et al.* (2008). Ash content represents the amount of minerals in food stuff.

The carbohydrate content of the unripe plantain flour ranged from 80.33-83.06% with blanched samples having the highest values while the samples without pretreatment (control) had the lowest. This again is suggestive of the possibility that as pretreatment alters the tissue matrix of food materials, more carbohydrate constituents may have been made more available for chemical analysis, which by extension, could be indicative of a digestive advantage. A similar effect of pretreatment on the carbohydrate content of plantain flour was observed by Arisa *et al.* (2013). Carbohydrate rich foods supply energy to the body more readily than any other energy source, and energy supply is the main contribution of plantain to diet (Zakpaa *et al.,* 2010).

3.2. Mineral Content of Unripe Plantain Flour

Calcium and phosphorus were more predominant in the unripe plantain flour than iron and sodium (Table 3). Sulphiting had a significant ($p < 0.05$) effect, increasing the sodium content of the unripe plantain flour. This could be attributed to sodium up-take from sodium metabisulphite solution used as one of the pretreatments. Blanching and sulphiting had significant ($p < 0.05$) effect on sun-dried unripe plantain flour, both causing decreased in calcium and increased in phosphorus contents. Freeze-dried samples were generally significantly ($p < 0.05$) higher in iron content than their sun-dried counterparts. The sodium contents (2.07-2.39%), though a bit higher than the range of values (0.52-1.05%) reported by Arisa *et al.* (2013) for pretreated plantain flour, were generally low, and this could be recommended for a low-sodium diet (Ojure and Quadri, 2012). It can be used in the management of high blood pressure and heart disease (Dzomeku *et al*., 2007) The findings of Ojure and Quadri (2012) support the relatively higher amount of calcium obtained in this study for unripe plantain flour. The authors reported a value as high as 71.5 mg/100g in the variety of plantain studied.

3.3. Functional Properties of the Unripe Plantain Flour

Generally, the bulk densities of freeze-dried unripe plantain flour (0.83-0.84 g/ml) were higher than those of oven and sun-dried samples (0.76-0.81 g/ml and 0.79-0.82 g/ml, respectively), but drying methods had no individual significant effect (Table 4). Blanching was the only pretreatment that appeared to have singly reduced bulk density significantly ($p < 0.05$) and this was just in oven-dried unripe plantain flour (i.e., between oven-dried blanched and oven-dried unblanched samples). This was similar to the finding of Arisa *et al*. (2013) who reported that blanched plantain flour had significantly lower bulk density than sulphited plantain flour and control (without pretreatment). Zakpaa *et al.* (2010) reported a slightly lower value (0.755 g/ml) for ripe plantain flour. Bulk density is an important factor for bulk storage and transportation.

Similarly, freeze-dried unripe plantain flour showed the highest swelling indices (4.12-4.17%) while oven-dried samples recorded the lowest range of value of 3.11-3.25%. Drying and pretreatment methods had both individual and interactive significant ($p < 0.05$) effects on the swelling indices of unripe plantain flour, with blanching causing most increase in swelling indices. Freeze-dried plantain flour had better swelling indices probably due to the destructive effect of other drying methods on the starch components of the plantain (Olawuni *et al.,* 2013). Swelling index is an indication of the absorption index of the starch granules during heating.

Methods of drying showed a significant ($p < 0.05$) effect on the water absorption capacity of unripe plantain flour without pretreatment, with freeze-dried and oven-dried controls having 27.68% and 25.31%, respectively. Pretreatments methods had significant ($p < 0.05$) effect on water absorption capacity of the unripe plantain flour, except in oven-dried samples. The unripe plantain flour that were not pretreated showed significant ($p < 0.05$) differences in dispersibility with drying methods. The dispersibility of the flour which ranged between 60.10% and 63.00% was higher than 52.00-56.00% reported for unblanched cooking banana and sweet potato flour, respectively, by Ohizua *et al.* (2017). This means that the unripe plantain flour will be relatively easier to reconstitute in the making of consistent cooked dough (*amala*).

3.4. Sensory Quality of Pretreated Sun, Oven and Freeze-Dried Unripe Plantain Cooked Dough (Amala)

Table 1. Factorial design for the study

Pretreatment	Control (No pretreatment)	Sulphiting	Blanching
Drying method	Oven drying	Sun drying	Freeze drying

Table 2. Proximate composition of pretreated sun, oven and freeze-dried plantain flour

Sample	Moisture (%)	Crude Protein (%)	Fat (%)	Ash (%)	Crude fibre (%)	Carbohydrate (%)
NS_U	9.19 ± 0.09^{bcd}	2.30 ± 0.04^{fg}	1.30 ± 0.01^{ef}	1.75 ± 0.01^{e}	4.10 ± 0.09^{a}	81.36 ± 0.05^{ab}
BS_U	10.11 ± 0.05^{a}	2.36 ± 0.15^{ef}	1.44 ± 0.04^{bcd}	1.77 ± 0.01^{e}	2.42 ± 0.01^{e}	81.90 ± 0.03^{a}
SS_U	9.80 ± 0.02^{bc}	2.61 ± 0.01^{cd}	1.45 ± 0.03^{bc}	1.79 ± 0.01^{e}	3.64 ± 0.04^{bc}	80.71 ± 0.00^{b}
NO_V	8.15 ± 0.02^{de}	2.17 ± 0.03^{g}	1.36 ± 0.03^{de}	1.87 ± 0.02^{d}	4.07 ± 0.05^{a}	82.38 ± 0.14^{a}
BO_V	8.74 ± 0.05^{bcde}	2.65 ± 0.03^{bc}	1.38 ± 0.03^{cde}	2.04 ± 0.03^{b}	2.13 ± 0.02^{f}	83.06 ± 0.06^{a}
SO_V	9.53 ± 0.01^{bcd}	2.63 ± 0.02^{cd}	1.35 ± 0.01^{ef}	2.04 ± 0.02^{b}	3.20 ± 0.01^{d}	81.25 ± 0.08^{ab}
NF_R	7.36 ± 0.03^{e}	2.67 ± 0.04^{bc}	1.45 ± 0.04^{bcd}	1.97 ± 0.01^{c}	4.13 ± 0.08^{a}	82.42 ± 0.08^{a}
BF_R	8.46 ± 0.04^{cde}	2.84 ± 0.01^{ab}	1.53 ± 0.01^{ab}	2.04 ± 0.01^{b}	2.46 ± 0.01^{e}	82.67 ± 0.03^{a}
SF_R	9.29 ± 0.01^{bcd}	2.87 ± 0.0^{a}	1.56 ± 0.01^{a}	2.10 ± 0.01^{a}	3.85 ± 0.01^{b}	80.33 ± 0.07^{b}

Data are reported as mean ± standard deviation of triplicate determinations. Mean scores within the same column with different superscripts are significantly ($p < 0.05$) different.

NS_U = Non-pretreated sun-dried unripe plantain flour

BS_U = Blanched sun-dried unripe plantain flour

SS_U = Sulphited sun-dried unripe plantain flour

NO_V = Non-pretreated oven-dried unripe plantain flour

BO_V = Blanched oven-dried unripe plantain flour
SO_V = Sulphited sun-dried unripe plantain flour
NF_R = Non-pretreated freeze-dried unripe plantain flour
BF_R = Blanched freeze-dried unripe plantain flour
SF_R = Sulphited freeze-dried unripe plantain flour

Table 3. Mineral contents of pretreated sun, oven and freeze-dried unripe plantain flour

Samples	Calcium (mg/100g)	Phosphorus (mg/100g)	Iron (mg/100g)	Sodium (mg/100g)
RP	29.31 ± 0.02^{d}	21.47 ± 0.06^{e}	2.28 ± 0.04^{c}	2.07 ± 0.02^{d}
NS_U	32.15 ± 0.05^{a}	21.51 ± 0.03^{e}	2.30 ± 0.03^{c}	2.13 ± 0.02^{c}
BS_U	30.69 ± 0.03^{bc}	22.63 ± 0.01^{d}	2.33 ± 0.05^{c}	2.19 ± 0.01^{c}
SS_U	30.07 ± 0.01^{c}	23.00 ± 0.04^{c}	2.35 ± 0.01^{c}	2.27 ± 0.04^{bc}
NO_V	31.74 ± 0.05^{a}	23.14 ± 0.05^{c}	2.39 ± 0.01^{bc}	2.39 ± 0.01^{bc}
BO_V	31.39 ± 0.08^{ab}	23.63 ± 0.02^{bc}	2.42 ± 0.02^{b}	2.18 ± 0.07^{c}
SO_V	31.43 ± 0.02^{ab}	24.03 ± 0.02^{ab}	2.44 ± 0.03^{ab}	2.29 ± 0.03^{b}
NF_R	29.97 ± 0.06^{c}	23.92 ± 0.01^{ab}	2.47 ± 0.03^{a}	2.09 ± 0.01^{d}
BF_R	29.72 ± 0.02^{cd}	24.80 ± 0.01^{a}	2.48 ± 0.02^{a}	2.14 ± 0.01^{c}
SF_R	29.84 ± 0.01^{cd}	25.31 ± 0.03^{a}	2.46 ± 0.01^{a}	2.38 ± 0.05^{a}

Data are reported as mean ± standard deviation of triplicate determinations. Mean scores within the same column with different superscripts are significantly ($p < 0.05$) different.
RP = Ripe plantain flour
NS_U = Non-pretreated sun-dried unripe plantain flour
BS_U = Blanched sun-dried unripe plantain flour
SS_U = Sulphited sun-dried unripe plantain flour
NO_V = Non-pretreated oven-dried unripe plantain flour
BO_V = Blanched oven-dried unripe plantain flour
SO_V = Sulphited sun-dried unripe plantain flour
NF_R = Non-pretreated freeze-dried unripe plantain flour
BF_R = Blanched freeze-dried unripe plantain flour
SF_R = Sulphited freeze-dried unripe plantain flour

Table 4. Functional properties of pretreated sun, oven and freeze-dried unripe plantain flour

Samples	**Bulk density (g/ml)**	**Swelling power (%)**	**Water absorption capacity (%)**	**Dispersibility (%)**
NS_U	0.82 ± 0.01^{ab}	3.05 ± 0.01^{h}	26.41 ± 0.01^{b}	62.36 ± 0.04^{c}
BS_U	0.79 ± 0.01^{b}	3.29 ± 0.01^{d}	25.50 ± 0.04^{d}	61.03 ± 0.02^{f}
SS_U	0.81 ± 0.01^{ab}	3.10 ± 0.01^{g}	25.01 ± 0.01^{c}	62.63 ± 0.03^{b}
NO_V	0.79 ± 0.02^{b}	3.11 ± 0.01^{g}	25.31 ± 0.01^{cd}	61.94 ± 0.01^{d}
BO_V	0.76 ± 0.01^{c}	3.25 ± 0.01^{e}	25.00 ± 0.01^{cd}	62.02 ± 0.04^{d}
SO_V	0.81 ± 0.01^{ab}	3.13 ± 0.01^{f}	25.52 ± 0.01^{cd}	61.98 ± 0.01^{d}
NF_R	0.83 ± 0.02^{ab}	4.12 ± 0.01^{c}	27.68 ± 0.02^{a}	60.10 ± 0.14^{g}
BF_R	0.83 ± 0.01^{a}	4.31 ± 0.01^{a}	26.92 ± 0.02^{b}	61.64 ± 0.02^{e}
SF_R	0.84 ± 0.02^{a}	4.17 ± 0.01^{b}	24.80 ± 0.01^{d}	63.00 ± 0.14^{a}

Data are reported as mean ± standard deviation of triplicate determinations. Mean scores within the same column with different superscripts are significantly ($p < 0.05$) different.
NS_U = Non-pretreated sun-dried unripe plantain flour
BS_U = Blanched sun-dried unripe plantain flour

SS_U = Sulphited sun-dried unripe plantain flour
NO_V = Non-pretreated oven-dried unripe plantain flour
BO_V = Blanched oven-dried unripe plantain flour
SO_V = Sulphited sun-dried unripe plantain flour
NF_R = Non-pretreated freeze-dried unripe plantain flour
BF_R = Blanched freeze-dried unripe plantain flour
SF_R = Sulphited freeze-dried unripe plantain flour

Table 5. Sensory attributes of pretreated sun, oven and freeze-dried unripe plantain cooked dough (*amala*)

Samples	**Colour**	**Aroma**	**Texture**	**General Acceptability**
NS_U	$4.80±0.44^{bc}$	$5.20±0.33^{b}$	$5.20±0.18^{b}$	$5.10±0.34^{b}$
BS_U	$5.80±0.39^{bc}$	$5.80±0.33^{b}$	$5.70±0.31^{b}$	$5.90±0.53^{bc}$
SS_U	$5.90±0.56^{b}$	$5.50±0.30^{b}$	$5.90±0.47^{b}$	$6.20±0.56^{b}$
NO_V	$5.60±0.26^{b}$	$4.90±0.31^{b}$	$4.60±0.40^{bc}$	$5.70±0.45^{bc}$
BO_V	$6.30±0.36^{b}$	$5.50±0.37^{b}$	$4.80±0.30^{bc}$	$6.70±0.51^{bc}$
SO_V	$6.50±0.58^{d}$	$5.10±0.55^{b}$	$6.40±0.53^{c}$	$6.80±0.58^{c}$
NF_R	$5.20±0.64^{bc}$	$6.00±0.49^{b}$	$7.20±0.41^{b}$	$6.10±0.68^{bc}$
BF_R	$7.90±0.31^{a}$	$7.30±0.30^{a}$	$7.80±0.32^{a}$	$7.80±0.32^{a}$
SF_R	$8.10±0.23^{a}$	$7.70±0.34^{a}$	$8.10±0.30^{a}$	$8.30±0.27^{a}$

Mean scores within the same column with different superscripts are significantly ($p < 0.05$) different.
NS_U = Non-pretreated sun-dried unripe plantain flour *amala*
BS_U = Blanched sun-dried unripe plantain flour *amala*
SS_U = Sulphited sun-dried unripe plantain flour *amala*
NO_V = Non-pretreated oven-dried unripe plantain flour *amala*
BO_V = Blanched oven-dried unripe plantain flour *amala*
SO_V = Sulphited sun-dried unripe plantain flour *amala*
NF_R = Non-pretreated freeze-dried unripe plantain flour *amala*
BF_R = Blanched freeze-dried unripe plantain flour *amala*
SF_R = Sulphited freeze-dried unripe plantain flour *amala*

The cooked dough (*amala*) prepared from the various unripe plantain flour (with and without pretreatment) generally had good sensory attributes as indicated by panellists' ratings (Table 5). Similarly, highest rating for colour, aroma, mouldability, consistency, mouthfeel and overall acceptability had been reported for unripe plantain *amala* compared to its moringa leaf powder fortified counterparts (Karim *et al*., 2015). Though both pretreatments (sulphiting and blanching) improved the sensory qualities, including colour, aroma and mouldability of the *amala*, only their interactive effect with freeze-drying was found to be significant ($p < 0.05$). The cooked dough (*amala*) from freeze-dried unripe plantain flour samples had higher general acceptability ratings than those from sun and oven-dried samples. The highest dispersibility of sulphited freeze-dried unripe plantain flour may have contributed to the corresponding highest value of the general acceptability of the *amala* prepared from it.

4. Conclusions

Pretreatments and drying methods had varying individual and interactive effects on the proximate, mineral and functional properties of unripe plantain flour. Sulphiting and blanching enhanced the protein, fat, ash and moisture but reduced the crude fibre of the unripe plantain flour irrespective of drying methods. Moisture contents, except of sun-dried blanched plantain flour, were generally below the maximum level

(10%) recommended for safe keeping quality of flour. Though carbohydrates predominate the proximate compositions of the unripe plantain flour, protein, fat and ash contents were most retained in freeze-dried samples. The unripe plantain flour samples were all rich in calcium and phosphorus but low in sodium, which however, significantly increased with sulphiting. Blanching and sulphiting increased the phosphorus, iron and sodium but reduced the calcium content of the unripe plantain flour. Freeze-drying improved most of the functional properties of the flour and, blanching and sulphiting significantly increased the swelling power and dispersibility of freeze-dried unripe plantain flour. The stiff cooked dough (*amala*) prepared from all the plantain flour samples were favourably rated by the panellists, with sulphiting and blanching improving all sensory attributes. However, the cooked dough (*amala*) prepared from sulphited freeze-dried unripe plantain flour was the most generally accepted.

5. References

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