SPECTACULAR JOURNALS
www.spectacularjournals.org

Journal of Research in Food Science and Nutrition Vol. 1(2) pp.013-023, September, 2020
Available online http://spectacularjournals.org/jrfsn

Original Research Article

Effect of peeling and blanching on proximate compositions, mineral profile, physico-chemical and anti-nutritional properties of plantain (*Musa AAB*) flours

Akinjayeju O.*, Badrudeen A. O. and Soretire M. Q.

Department of Food Technology, Yaba College of Technology, P. M. B. 2011, Yaba-Lagos, Nigeria.

***Corresponding Author E-mail: olujayeju2@gmail.com**

Abstract

This study aimed to evaluate the effect of peeling and blanching on proximate composition, physico-chemical and anti-nutritional properties and some mineral profile of plantain (*Musa AAB*) flours. Matured green plantain was peeled and sliced into 5mm-thick pieces(PUF), peeled, sliced and soaked in boiled water (100°C) for 10mins(PBF), sliced unpeeled(UUF), and sliced unpeeled and soaked in boiled water (100°C) for 10min (UBF). Slices were dried at 65 ±1.5°C for 8h, and milled into flour (< 212µm). Flour samples were evaluated for proximate composition, functional, pasting and anti-nutritional properties and mineral profile. There were significant ($p<0.05$) differences among the flours for most parameters evaluated. Ash and fibre were higher in unpeeled flours, while carbohydrate reduced. Unpeeled flours had significantly ($p<0.05$) higher functional, but lower pasting properties compared to peeled flours, which had significantly ($p<0.05$) lower anti-nutritional factors compared to unpeeled samples, with values of 1.25-2.69 mg/g, 3.15-4.74 mg/100g, 8.20-10.95 mg/g, 8.85-12.20 mg/g and 1.20-2.39mg/100g for phenols, phytate, tannins, oxalate and trypsin inhibitors respectively, which were within safe levels. Unpeeled flours had significantly ($p < 0.05$) higher oxalate:calcium and [Ca]:[Phy]/[Zn] molar ratios and mineral safety index values than peeled flours, which were lower than maximum safety thresholds. Peeling and blanching had significant effect on most parameters evaluated, with peeling producing greater effect than blanching.

Keywords: Anti-nutritional factors, blanching, mineral profile, peeling, physico-chemical properties, plantain flours

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INTRODUCTION

Plantain (*Musa AAB*) is grown in many tropics and subtropical countries of the world and serves as a viable source of dietary calorie staple for a large number of peoples in many parts of the world, especially Africa, including Nigeria (Falade and Oluguyi, 2010). Nigeria is by far the largest plantain in the West-African sub region, with over 65% of the total annual production for the sub-region, which comes mostly from the southern part of the country (FAO, 2006). Plantain production in Nigeria is mostly for local consumption as a result of the country's low technology to preserve this relatively highly perishable commodity. Plantain is a rich source of carbohydrates and micro-nutrients such as iron, potassium and vitamin A, but very low in macro-nutrients, fat and protein (Odenigbo et al., 2013). Plantain is consumed in different forms, including boiled, fried, grilled and roasted, depending on whether it is in ripe or unripe stage, and can also be converted into flour for the preparation of different meals, especially a local dough meal known as 'Amala' (Falade and Olugbuyi, 2010; Arisa et al., 2013). Meals prepared from matured green plantain have been observed to reduce postprandial glucose level, due to their low glycaemic index, and therefore recommended for the management of diabetes, a condition which has been linked to increased consumption of carbohydrate-rich foods with high glycaemic index values (Eleazu et al., 2013; Akinjayeju, 2019).

Post-harvest losses constituted a major limiting factor in large-scale production of many fresh plant food commodities, especially in less-technologically advanced regions of the world including Nigeria (Eleazu et al., 2013). Plantain is particularly susceptible to such post-harvest losses, due to its high moisture content of about 61% when in matured green form, high climacteric and ripening rates (Arisa et al., 2013; Zakpaal e al., 2010). As a way of reducing post-harvest losses, green matured plantain is often converted into flour of low moisture content and improved shelf stability, both by traditional, small scale, or on an industrial scale (Adeniji and Tenkouano, 22008; Uzoukwu et al., 2015). Traditional processing of plantain flour is done in different parts of African, especially in the Western part of Nigeria and involves manual peeling of green fruits, cutting the peeled flesh into small pieces, sun-drying and milling in locally-fabricated grinding mill (Arisa et al., 2013; Adeniji et al., 2006). Such flour is used mainly for the preparation of dough meal, called "Amala", a common staple in the Southwestern part of Nigeria. The appearance of dough meal prepared from such sun-dried flour is often black or dark brown due to enzyme activities on the plantain pieces during sun-drying process, which can be prevented by improved processing methods (Adeniji and Tenkouano, 2008; Oluwalana et al., 2011; Okafor and Ugwu, 2013).

There are excellent prospects of large-scale industrial processing of plantain into flours in Nigeria, which will serve as food for her teeming population, industrial raw material and for export (Falade and Olugbuyi, 2010; Okafor and Ugwu, 2013). Such large scale processing of plantain flour will however produce large quantity of peels and subsequent waste management challenges, which however can be prevented by using unpeeled green plantain. Many studies have been carried on proximate, functional, pasting and nutritional properties of flours from peeled and blanched plantain flours (Arisa et al., 2013; Adeniji and Tenkouano, 2008; Oluwalana et al., 2011; Oluwalana and Oluwamukomi, 2011), but there are little reports on comparative evaluation of properties of peeled, unpeeled and blanched plantain flours. Flours of good nutritional profiles with respect to amino acid profiles and mineral contents from peeled and unpeeled plantain and high consumer acceptability of their dough meal have been reported (Akinjayeju et al., 2020). It is expected that the functional, pasting and anti-nutritional properties of the flours will have marked effects on the flour samples and the dough meal prepared from them. The objective of this study was to compare some physico-chemical, pasting and anti-nutritional properties and some mineral profile of flours from peeled and unpeeled matured green plantain fruit subjected to mild heat blanching.

MATERIALS AND METHODS

Materials

The material used in this study was matured green plantain (*Musa AAB*) fruits, which were purchased at the Oyingbo Retail Market on Lagos Mainland, Lagos, Nigeria. Chemical used for analyses were of standard grade. Necessary laboratory equipments were sourced from Yaba College of Technology, Yaba, Lagos and the Federal Institute of Industrial Research, Lagos. Chemicals used were of standard grade.

Preparation of samples

Matured green plantain fruits were divided into 4 portions of 2.5kg each, and each portion treated as follows: First potion was washed in portable water, manually peeled under water using a stainless kitchen knife, followed by manual slicing into pieces of 5-mm thickness, and treated as peeled, un-blanched sample (PUF). Second portion was peeled under water, sliced into pieces of 5mm thickness, followed by blanching by immersing in boiled water (100^oC) for 10 min, and treated as peeled, blanched sample (PBF). Portion 3 was manually sliced into pieces of 5mm thickness under water, without peeling and treated as unpeeled, un-blanched sample(UUF), while the fourth portion was manually-sliced into pieces of 5mm thickness, without peeling, followed by immersing in boiled water (100^oC) for 10 min and treated as unpeeled, blanched sample(UBF). Each portion was dried at 65 ± 2.5^oC for 8 h, in a cabinet dryer (Carlisle CA2 5DU, Mitchel Dryers Ltd, England, 3695-010), followed by milling into flour (< 212µm) using a grinding hammer mill (Type S/03 7.5HP, Petrel Limited, Birmingham England, 2121A). Each flour sample was then packaged in a high-density polyethylene bag and stored in a cool dry place until used.

Determination of percentage yields

Percentage yields of each flour relative to the total amount of matured green plantain used, and peeled and unpeeled dried samples were determined using equation 1.

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$$\% \, Yield = \frac{weight \; of \; flour \; sample \; obtained}{weight \; of \; green \; plantain \; used \; or \; weight \; of \; dried \; sample} \; x \; 100$$

(Eq. 1)

Proximate analysis of flour samples

This was carried out using the standard methods (AOAC, 2005), to determine the percentages of moisture, crude protein, crude fat, total ash and crude fibre. Carbohydrate was calculated by difference and values expressed on dry weight basis except moisture.

Determination of functional properties

Loose bulk density was estimated as described by (Arisa et al., 2013). Water absorption capacity, swelling power and solubility index of each flour sample were determined using the methods described by (Falade and Okafor, 2015).

Determination of pasting properties

Pasting properties of the flour samples were determined using the Rapid Visco Analyzer (RVA), (Model 3C, Newport Scientific PTY Ltd, Sydney) and the curves obtained were used to obtain the peak viscosity, trough viscosity, final viscosity, breakdown, setback viscosity, peak time and pasting temperature (Newport Scientific, 1998).

Determination of anti-nutritional factors, selected minerals and molar ratios

Total phenols and hydrogen cyanide were determined using methods of (Onwuka, 2005), oxalate was determined by the titration method described by (Agbaire, 2011), while phytate and protease inhibitor were determined using the standard method of (AOAC, 2005). Phytate and oxalate-mineral molar ratios were determined by the method described by (Norhaizan and Nor Fazaidal Ain, 2009), while mineral-mineral, [Ca][Phy]/[Zn] and [K:Ca + Mg)] milli-equivalent ratios were calculated according to (Adeyaye et al., 2012). [Phytate = 660, Oxalate = 88, Fe = 56, Zn = 65, and Ca = 40].

Calculation of Mineral Safety Index (MSI)

The minerals safety index (MSI) of each sample for Fe, Ca, P, Mg, Zn and Na were calculated using the method described by (Watts, 2010), (equation 2). The standard MSI for minerals determined are Na (4.8), Mg (15), P (10), Ca (10), Fe (6.7) and Zn (Adeyeye et al., 2012).

$$Calculated \; MSI = \frac{MSI \; x \; Research \; data \; value}{RAI} \qquad \text{Eq. 2}$$

where: MSI = standard MSI for each mineral from Table; RAI = Recommended adult intake for each mineral.

Statistical analysis

Data were collected in triplicates and analyzed using the IBM SPSS version 23 (SPSS Inc., NY, USA) and results expressed as mean ± SD. Significant difference between means was determined using the one-way analysis of Variance (ANOVA), while means were separated using the New Duncan Multiple Range Test (NDMRT) at 0.05 (SPSS, 2015).

RESULTS AND DISCUSSION

% Yield of resultant flours

The percentage yields of flours per weight of green fruit and dried pieces are presented in Table 1. Flours from unpeeled fruit had higher % yields per weight of green matured fruit than for unpeeled fruit, while flours from blanched plantain had slightly lower % yield per weight of matured green fruit. % yields per weight of matured green fruit ranged from 19.25% for sample PBF to 28.05% for flour from unpeeled unblanched plantain (PUF). The higher % yield per weight of green fruit for unpeeled flour samples is due to the presence of peel in these flours which contributed to their higher quantity of flours. The peel of plantain and banana has been reported to constitute almost 25% of the whole fruit (Adeniji et al., 2006). This increase in yield will be an advantage, especially in commercial processing of plantain flour. The slightly lower % yield per weight of green plantain of flours from blanched plantain could be attributed to leaching and shrinkage caused by soaking and mild heating during blanching. The slightly higher % flour yield per weight of dried plantain for flours from blanched plantain is most probably due to their relatively higher moisture content, which increased the weights of both dried plantain slices and flours compared to flours from unblanched plantain.

Proximate composition of resultant flours

The proximate compositions of the flour samples are presented in Table 2. These results show that there are significant differences ($p < 0.05$) among the samples for all the proximate parameters. The moisture content of the

Table 1. % Yields of resultant flours from peeled, unpeeled and blanched plantain.

Parameters/Samples	PUF	PBF	UUF	UBF
Weight of green plantain (g)	2000	2000	2000	2000
Weight of dried plantain (g)	421.85	406.00	598.00	575.00
Weight of flour (g)	388.50	385.00	561.00	542.60
Flour yield /Weight of green plantain (%)	19.43	19.25	28.05	27.13
Flour yield/Weight of dried plantain (%)	92.10	94.82	93.80	94.36

PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour

Table 2. Proximate composition of peeled, unpeeled and blanched plantain flours.

Parameters/Samples	PUF	PBF	UUF	UBF
Moisture content (%)	9.81 ± 0.04^{b}	10.46 ± 0.10^{a}	9.20 ± 0.05^{c}	10.50 ± 0.12^{a}
Crude protein (%)	4.53 ± 0.20^{a}	4.04 ± 0.14^{b}	3.65 ± 0.25^{c}	3.30 ± 0.42^{d}
Total fat (%)	1.84 ± 0.02^{a}	1.31 ± 0.02^{b}	1.06 ± 0.05^{c}	1.10 ± 0.04^{c}
Total ash (%)	2.45 ± 0.07^{c}	2.24 ± 0.10^{d}	3.93 ± 0.07^{a}	3.38 ± 0.15^{b}
Crude fibre (%)	3.28 ± 0.13^{c}	2.90 ± 0.08^{d}	5.63 ± 0.12^{a}	4.85 ± 0.15^{b}
Carbohydrate (%)	87.90 ± 0.20^{c}	89.51 ± 0.15^{a}	85.73 ± 0.75^{b}	87.37 ± 0.10^{d}

Means of triplicate determinations are reported and expressed on dry weight basis
Means with similar superscripts along same rows are not statistically significant ($p > 0.05$)
PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour

plantain flour samples ranged between 8.50% for sample PBF and 10.46% for PUF. All samples are within the range of safe moisture content (< 11.1%) for plantain flour as reported by Oluwalana et al. (2011). Low moisture contents in flour samples have been associated with longer storage life, since growth of spoilage microorganisms, most especially moulds are hindered. The crude protein contents of the flour samples varied significantly ($p < 0.05$), ranging from 3.30% for unpeeled blanched flour, to 4.53% for peeled unblanched samples respectively, with peeled samples having slightly but significantly ($p < 0.05$) higher protein contents than unpeeled samples. These values are within the range obtained by Adeniji et al., 2006) for flours of some plantain hybrids, and by Oluwalana et al. (2011) for blanched plantain flours. Flour samples from peeled plantain had slightly but significant ($p < 0.05$) higher crude protein content than from unpeeled plantain, while blanched sampled had slightly but significantly ($p < 0.05$) lower crude protein contents than unblanched samples, which are similar to the observations of Arisa et al. (2013).

The crude fat contents of the flours were between 1.06% for unpeeled unblanched sample (UUF), to 1.84% for peeled unblanched flour sample (PUF). Flours from unpeeled plantain had slightly but significantly ($p < 0.05$) higher crude fat contents than flour from peeled plantain, while there is non-significant difference ($p > 0.05$) in the crude fat contents of flours from unpeeled plantain. The low fat contents of the samples are in agreement with values earlier reported for flours from different hybrids of plantain (Zakpaa et al., 2010; deniji et al., 2007), which will prevent the development of rancid flavour during storage (Badejo et al., 2017). The total ash and crude fibre contents of the flour samples showed significant difference ($p < 0.05$) among the samples, ranging from 2.24 to 3.93, and 2.90 to 5.63 for samples PBF and UUF, respectively, with flours from unpeeled plantain having higher values for both parameters compared to peeled plantain samples, while flours from blanched plantain had slightly but significantly ($p < 0.05$) lower total ash and crude fibre contents. The relatively higher total ash and crude fibre contents of flours from unpeeled plantain was due to the incorporation of the peels, which contain mostly lignin, hemicelluloses and other high-molecular weight carbohydrate responsible for ash and fibre contents of foods (Zakpaa et al., 2010). The lower total ash and fibre contents of flours from blanched plantain compared to unblanched samples is most probably due to slight break down of the high-molecular weight polymer structure brought about the by the blanching process, which agreed with previous results (Arisa et al., 2013; Oluwalana et al., 2011).

The higher fibre contents of flours from unpeeled plantain is expected to produce health benefits, as it will aid in the digestion of the dough meal prepared from the flours and reduce constipation often associated with low-fibre diets (Jideani and Onwuabali, 2009; Elleuch et al., 2011). Moreover, studies have shown that dietary fibre plays an important role in the prevention of many diseases like cardiovascular diseases, irritable colon, cancer and diabetes (Slavin, 2005; Elleuch et al., 2011).. There was also significant difference ($p < 0.05$) in the carbohydrate contents of the flour samples, which ranged between 85.73% for unpeeled unblanched plantain (UUF) to 89.51% for flour from peeled blanched plantain (PBF). The significantly ($p < 0.05$) lower carbohydrate content of sample PBF compared to other samples is due to its relatively higher values for other proximate parameters especially total ash and crude fibre contents. These results are in agreement with previous studies for plantain flours (Arisa et a., 203; Adeniji and Tenkouano, 2008; Uzoukwu et al., 2015; Oluwalana et al., 2011).

Functional properties of resultant flours

The functional properties of the flour samples are presented in Table 3. These results showed significant differences among the samples for most functional properties. The bulk densities of the flours ranged from 0.51g/ml for sample PUF (flour from peeled blanched plantain) to 0.58 g/ml for sample UUF (flour from unpeeled un-blanched plantain). The bulk densities of the flours are relatively higher than 0.46 g/cm^3 obtained for 100% plantain flours by Abioye et al., 2011). The relatively higher bulk densities for unpeeled flours is most likely due to the presence of peeled which produced denser flours compared to flours from unpeeled plantain. It has been previously observed (Kiin-Kibari et al., 2015), that the denser a flour sample, the higher the bulk density. There significant difference ($p < 0.05$) in the water absorption capacities of the flour samples, which ranged between 247% for flour from peeled blanched plantain to 312.5% for unpeeled unblanched sample.

Blanching and peeling had significant ($p < 0.05$) effects on the flours, with unpeeled flour having higher water absorption than peeled flour while blanched flour had higher water absorption than unblanched flour, as well as presence of starch, fibre, protein and fat contents which also contribute to absorption capacities of flours (Fadimu et al., 2018). High water absorption capacity is very important in foods that require high viscosity such as dough and as thickening agent (Badejo et al., 2017). There is significant difference ($p < 0.05$) in the swelling capacities of the flours, which ranged from 2.15g/g for flour from peeled and blanched plantain to 3.15g/g for flour from unpeeled and unblanched plantain. The results also show that flour samples from unpeeled plantain had significantly ($p< 0.05$) higher swelling capacity than flours from peeled plantain, while flours from blanched plantain had significantly ($p < 0.05$) lower swelling capacity than four from unblanched plantain. The higher swelling capacity for flours from unblanched plantain is most probably due to the higher fibre content from plantain peel (Arisa et al., 2013; Fadimu et al., 2018). Water solubility index is used to describe the rate and the extent to which powder materials dissolve in water (Filli et al., 2010), and contributes to the yield of flours when rehydrated during food preparation (Badejo et al., 2017). The lower swelling capacity of flours from blanched plantain samples compared to flours from unblanched plantain agrees with the observation of (Arisa et al., 2013), and could be most probably due to loss of ease of rehydration as a blanching. Water absorption capacity showed very strong positive correlation with swelling ($r = 0.94$), but very weak correlation with solubility ($r = 0.03$), while there was very weak negative correlation between swelling and solubility ($r = -0.12$).

Pasting properties of resultant flours

The pasting properties of the flour samples are presented on Table 4. There are significant differences ($p < 0.05$) among the flour samples for all pasting properties. The peak, trough and final viscosities (RVU) of the flour samples followed similar trends, for which values varied between 323 to 411, 295 to 369 and 417 to 531 for unpeeled, unblanched and peeled blanched flours respectively. Flours from peeled plantain samples had significantly ($p < 0.05$) higher values than unpeeled samples for these parameters, while blanched samples had lower values compared to unblanched samples. Peak viscosity, which is the maximum viscosity, developed during or soon after the heating portion flour paste, and provides an indication of the viscous load likely to be encountered during mixing (Arisa et al., 2013). Trough or hot paste viscosity measures the ability of a paste to resist breakdown during the cooling phase (Newport Scientific, 1998; Zaidhul, 2006), while final viscosity gives an indication of the ability of flours to form stable viscous pastes after cooking and cooling (Akinjayeju et al., 2019). The higher viscosity values for peeled flours compared to unpeeled samples is most probably due partly to their relatively higher carbohydrate

Table 3. Functional properties of peeled, unpeeled and blanched plantain flours.

Parameters/Samples	PUF	PBF	UUF	UBF
Bulk density(gm/cm^3)	0.53 ± 0.05^c	0.51 ± .15^d	0.58 ± 0.12^a	0.55 ± 0.18^b
Water absorption capacity (%)	263.60 ± 1.20^c	247.15 ± 0.75^d	312.50 ± 1.45^a	272.75 ± 1.10^b
Solubility index (%)	18.95 ± 1.10^a	13.58 ± 0.95^c	15.20 ± 0.70^b	12.40 ± 0.55^d
Swelling capacity (g/g)	2.46 ± 0.02^c	2.15 ± 0.04^d	3.15 ± 0.10^a	2.85 ± 0.01^b
Reconstitution index (ml)	11.17 ± 0.15^c	9.81 ± 0.20^d	14.22 ± 0.75^a	12.85 ± 0.52^b

Values are means triplicate determinations are reported and expressed as mean ± s.d.
Means with similar superscripts along same rows are not statistically significant ($p > 0.05$)
PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour

Table 4. Pasting properties of peeled, unpeeled and blanched plantain flours.

Parameters/Samples	PUF	PBF	UUF	UBF
Peak viscosity (RVU) (a)	411.08±1.10^a	362.25±1.25^b	347.25±1.20^c	323.46±0.75^d
Trough viscosity (RVU) (b)	369.58±2.05^a	332.58±1.15^b	322.21±0.72^c	295.29±0.54^d
Final viscosity (RVU)(c)	531.50±1.75^a	476.04±0.90^b	442.25±1.10^c	427.17±0.72^d
Breakdown viscosity (RVU) (a – b)	41.50±0.25^a	29.67±0.30^c	25.04±0.25^d	28.17±0.15^b
Setback viscosity (RVU) (c – a)	120.42±0.50^a	113.79±0.45^b	95.00±0.75^d	103.71±0.72^c
Pasting temperature (^{o}C)	81.95±0.50^d	82.45±0.75^c	83.98±0.80^b	85.58±1.05^a
Pasting time (mins)	5.10±0.15^c	6.37±0.10^b	6.40±0.25^b	6.77±0.30^a

Values are means triplicate determinations are reported and expressed as mean ± s.d.
Means with similar superscripts along same rows are not statistically significant ($p > 0.05$)
PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour
RVU = Rapid Visco Units

or starch contents, and partly due to the relatively higher fibre contents of unpeeled flours, since fibre do not take part in gelatinization during cooking of flours. The viscosity values obtained in this study are similar to the results of (Adegunwa et al., 2015).

The lower viscosity values obtained for unblanched flours compared to blanched samples also deviate from the observations of (Adeniji and Tenkouano, 2008), who obtained higher viscosity values for unblanched flours. This is most probably due partly to varietal differences for plantain used in both studies and partly to the effect of peels in some flours in this study. With respect to breakdown, setback and consistency viscosities (RVU), there are significant differences among the samples. The values for these parameters varied from 15 for PUF to 41 for PBF, 93 for UUF to 125 and 121UUF to 161 for PBF, respectively. While flours from peeled plantain samples had significantly ($p < 0.05$) higher setback and consistency values, blanched flours had higher values for these parameters than unblanched samples. However, for breakdown, while flours from peeled plantain had significantly ($p < 0.05$) higher values than unpeeled flours, there was no obvious trend for blanched and unblanched flours. Higher setback values are synonymous to reduced dough digestibility, while lower setback during the cooling of flour pastes indicates lower tendency for retrogradation (Arisa et al., 2013; Shittu et al., 2001; Sandhu et al., 2007), as well as the rate of staling of the product prepared from the flour (Oduro et al., 2006). The setback and breakdown viscosities obtained in this study are comparable to values obtained for plantain and yam flours for dough meal ("Amala") (Oluwalana et al., 2011; Okafor and Ugwu, 2013; Abioye et al., 2011). The significantly ($p < 0.05$) lower setback and breakdown viscosities of flours from unpeeled flours, especially sample UUF, will be beneficial since these will reduce the susceptibility of dough meal prepared from these flours to starch retrogradation, staling and syneresis when cooled (Akinjayeju et al., 2019; Sandhu et al., 2007).

There are significant differences ($p < 0.05$) in the pasting temperatures and times of the flour samples. Pasting temperatures ranged from 81.95^{o}C for PUF to 85.58^{o}C for sample UBF, while pasting times ranged from

5.1 min for sample PUF to 6.77 min for sample UBF. With respect to pasting temperature, unpeeled flours have slightly but significantly ($p < 0.05$) higher pasting temperatures, while blanched samples have higher pasting temperatures that unblanched samples. The relatively lower pasting temperatures for peeled samples compared to unpeeled samples is most probably due to the higher carbohydrate content in peeled samples. Pasting temperature indicates the minimum temperature required to cook a given food sample (Adebowale et al., 2005). This means that flour samples from unpeeled plantain will require slightly more heating during preparation into dough meal, most probably as a result of higher fibre content in unpeeled samples. The peak time gives an indication of the cooking time (Arisa et al. 2013; Akinjayeju et al., 2019). Flours from unpeeled plantain have significantly ($p < 0.05$) higher pasting times, most probably as a result of higher fibre content which requires longer cooking. These results are in agreement with the observation that starches of high gelatinization temperatures require longer cooking times (Newport Scientific, 1998; Oluwalana and Oluwamukomi, 2011). Peak viscosity showed very strong positive correlation with trough and final viscosities (with $r = 0.99$ in both cases), while it correlated negatively with both pasting temperature and water absorption capacity with $r = -0.90$ and -0.34, respectively. Breakdown had an average negative correlation with swelling ($r = -0.52$), which indicated that the rate of swelling of a starch paste depends on its susceptibility to disintegration during continued stirring and heating, which will also affect it stability (Koh and Singh, 2009; Falade and Okafor, 2015).

Anti-nutritional factors, selected minerals and their molar ratios

The anti-nutritional factors in the resultant flour samples are presented in Table 5, which showed significant ($p<0.05$) differences among the samples for most parameters evaluated. The values are 1.25-2.69mg/g, 3.15-4.74mg/100g, 8.20-10.95mg/g, 8.85-12.20mg/g and 1.20-2.39mg/100g for phenolic compounds, phytate, tannins, oxalate and trypsin inhibitors respectively. Flour from peeled, blanched plantain (PBF) had the least values for almost all parameters, while flour from unpeeled, unblanched plantain (UUF) had the highest values. Flour samples from peeled plantain had significantly ($p<0.05$) lower anti-nutritional compositions compared to unpeeled samples, while unblanched samples had significantly ($p<0.05$) higher values than blanched flours. The higher anti-nutritional values obtained for unpeeled flours were due to the presence of peels in these samples which have been reported to contain high contents of anti-nutritional factors (Adeniji et al., 2007; Akinsanmi et al., 2015; Wordu and Akusu, 2018). The slightly but significantly ($p<0.05$) lower anti-nutritional contents of flours from blanched plantain compared to flours from unblanched flours is most probably as a result of combined effects of heat and soaking during blanching. Soaking and heating have been reported to reduce anti-nutritional factors in plant materials (Vadivel and Biesalski, 2012; Samtiya et al., 2020).

Flours from unpeeled plantain with relatively higher anti-nutritional factors may indeed offer health benefits to the consumers, since some anti-nutritional factors have been credited with certain advantages and benefits to human health when they are ingested at acceptable levels. Polyphenols, phytate and oxalate have been credited with ability to decrease blood glucose level, and lessening of growth dangers and reduced cancer risks (Ugwu and Oranye, 2006; Mihrete, 2019). Polyphenols and tannins have also been considered as food bioactive compounds, with considerable beneficial health effects in consumers (Emire et al., 2013; Teodoro, 2019). The polyphenolic content of the flour samples will be beneficial to the consumers since phenols have been reported to contain several acids such as gallic. Syringic, chrologenic, caffeic, etc. (Mohammed et al., 2018). These acids have been reported to have several beneficial activities including anti-oxidant, anti-microbial, anti-inflammatory, anti-cancer, and anti-steatotic, among others (Du et al., 2012; Locatelli et al., 2013; Ham, et al., 2016).

The mineral profiles and bioavailability of the flour samples, in respect of Iron:Zinc, Oxalate:Calcium ratios and [K:Ca + Mg] and [Ca]:[Phy]/[Zn] molar ratios are presented in Table 5, which showed significant differences ($p < 0.05$) among the flour samples for these parameters of nutritional importance. Iron and zinc, which are important trace nutrients, share some common features like occurring in similar foods, having their bioavailability affected by similar food components, while also affecting the absorption of each other (Lim et al., 2013; Adetoye, 2019). The Fe: Zn ratio is used to assess the relationship, especially in terms of their bioavailability. There is significant ($p < 0.05$) difference among the flour samples, with flours from unpeeled plantain having slightly higher values than for peeled flours, while blanching had no significant effect ($p > 0.05$) on this parameter. The slightly higher Fe:Zn ratios of flours from unpeeled plantain is due most probably to the slightly higher values of the individual minerals in unpeeled flours compared to peeled flours. The Fe:Zn ratios for the flour samples ranged between 1.36 for sample PUF to 1.59 for sample UBF, which are lower than the value of 2 above which zinc absorption by iron will be impaired, which will be beneficial to the potential consumers.

The Oxa:Ca ratio is also very important since oxalate complexes with calcium to form the calcium oxalate, thereby making calcium unavailable. A value of not more than 1 has been suggested for Oxa:Ca ratio by Frontela et al., 2009, while Haliu and Addis (2016) proposed a

Table 5. Anti-nutritional factors, selected minerals and molar ratios of peeled, unpeeled and blanched plantain flours.

Parameters/Samples	PUF	PBF	UUF	UBF
Polyphenols (mg/g)	1.48±0.01^{c}	1.25±0.10^{d}	2.69±0.06^{a}	2.45±0.04^{b}
Phytate (mg/100g)	3.15±0.01^{c}	2.72±0.04^{d}	4.74±0.05^{a}	4.23±0.02^{b}
Tannins (mg/g)	8.50±0.07^{c}	8.20±0.04^{d}	10.95±0.50^{a}	10.55±0.02^{b}
Oxalate (mg/g)	2.92±0.05^{c}	2.25±0.10^{d}	4.23±0.03^{a}	3.78±0.01^{b}
Trypsin inhibitors (mg/g)	1.20±0.04^{c}	1.12±0.02^{d}	2.39±0.50^{a}	1.54±0.07^{b}
Calcium (mg/100g)	14.45±0.12^{c}	12.84±0.15^{d}	18.37±0.20^{a}	16.84±0.03^{b}
Iron (mg/100g)	4.29±0.04^{d}	3.75±0.07^{c}	6.83±0.10^{a}	6.12±0.06^{b}
Phosphorus(mg/100g)	52.50±0.50^{b}	46.72±0.20^{d}	55.60±1.02^{a}	51.20±0.40^{c}
Magnesium (mg/100g)	55.40±1.01^{b}	50.28±0.07^{d}	62.12±0.25^{a}	58.43±0.50^{b}
Potassium (mg/100g)	132.16±1.20^{c}	108.20±0.05^{d}	162.60±0.75^{a}	138.60±0.65^{b}
Sodium (mg/100g)	48.72±0.15^{c}	45.28±0.20^{d}	59.70±0.75^{a}	56.70±0.50^{b}
Zinc (mg/100g)	3.16±0.12^{b}	2.72±0.04^{c}	4.57±0.05^{a}	3.85±0.07^{bc}
Iron:Zinc	1.36 ± 0.03^{b}	1.38 ± 0.01^{b}	1.50 ± 0.02^{a}	1.59 ± 0.00^{a}
Oxalate:Calcium	0.012 ± 0.000^{b}	0.011 ± 0.001^{b}	0.016 ± 0.00^{a}	0.015 ± 0.002^{a}
[K:Ca + Mg)] (meq.)	0.64^{ab} ± 0.01	0.57 ± 0.03^{c}	0.68 ± 0.02^{a}	0.62 ± 0.01^{b}
[Ca]:[Phy]/[Zn]	0.035 ± 0.001^{b}	0.032 ± 0.002^{b}	0.047 ± 0.002^{a}	0.046 ± 0.001^{a}

Values are means triplicate determinations are reported and expressed as mean ± S.D.
Means with similar superscripts along same rows are not statistically significant (p > 0.05)
PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour

critical value of < 2.5 at which oxalate will produce deleterious effect on dietary Ca. The Oxa:Ca ratios for all flour samples are much less than these critical values, due most probably to low oxalate contents of the flour sample. This suggests that calcium bioavailability will not be impaired in all the flour samples including those milled from unpeeled plantain. The milli-equivalent ratio [K:(Ca + Mg)], like other mineral-mineral ratios is considered more important than levels of individual minerals, since ratios often represent homeostatic balances (Ademola and Abioye, 2017). The milli-equivalent ratio determines the level of magnesium absorption even better than Ca:Mg ratio, due to the influence of potassium in the absorption of both calcium and magnesium and regulation of their balances in the body. For instance, Henkin (2018) reported that increased potassium intakes often results in increased urinary magnesium excretion, while potassium decreases urinary calcium excretion and increases body calcium balance (Sacks et al., 1995).

Magnesium is required for proper calcium absorption, since low magnesium intake may result in collection of calcium in body soft tissues and cause arthritis (Fucks 2002). The recommended [K:(Ca + Mg)] ratio that will promote adequate magnesium is < 2.2 to prevent hypomagnesaemia, a condition of abnormally low serum magnesium. The values for the milli-equivalent ratio for the flour samples were between 0.57 to 0.68 which are much lower than the recommended value of 2.2, which meant that consumers of the flours used in this study will not be exposed to risk of hypomagnesaemia (Ademola and Abioye, 2017; Niyi et al., 2017). The molar ratio [Ca]:[Phy]/[Zn] is considered a more appropriate measure of predicting bioavailability of zinc than Phy:Zn molar ratio, since dietary calcium levels may have considerable influence on the critical Phy:Zn molar ratio (Haliu and Addis, 2016). The values for this parameter are 0.032, 0.035, 0.046 and 0.047 for sample PBF, PUF, UBF and UUF respectively, with peeled samples having slightly but significantly (p < 0.05) lower values than unpeeled samples, while blanching had no significant (p > 0.05) effect. The critical value for this parameter is 0.50mol/kg (Haliu and Addis, 2016; Adetuyi, 2019), which is much higher that the values obtained in this study, which indicates that calcium will produce no interference with zinc bioavailability and absorption in our flour samples.

Mineral Safety Index

The mineral safety index (MSI) of the flour samples for Ca, Fe, Mg, Na, P, and Zn are presented in Table 6. MSI gives a measure of the ability a mineral to cause its

Table 6. Mineral safety index of selected minerals for peeled, unpeeled and blanched plantain flours.

Minerals/Samples	Ca		Fe		Mg		Na		P		Zn	
	SV	CV	SV	CV	SV	CV	SV	CV	SV	CV	SV	CV
PUF	10	1.20	6.7	19.16	15	20.78	4.8	4.68	10	4.38	33	69.52
PBF	10	1.07	6.7	16.75	15	18.86	4.8	4.35	10	3.89	33	59.84
UUF	10	1.53	6.7	30.51	15	23.30	4.8	5.73	10	4.63	33	100.54
UBF	10	1.40	6.7	27.34	15	21.91	4.8	5.44	10	4.27	33	84.70
Sample mean	10	1.30	6.7	23.44	15	21.21		5.05	10	4.29	33	78.65
Sample STD		0.21		6.54		1.88		0.64		0.31		17.82
***t-test $t_{\text{-calculated}}$**		|-82.86|		5.12		6.61		0.78		|-36.84|		5.12
***RAI**	1200		15		400		500		1200		15	

Table value for t-test ($t_{\text{tabulated}}$) at p = 0.05 = 3.182
PUF: Peeled unblanched flour; PBF: Peeled blanched flour; UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour; SV = Standard (Table) value; CV = Calculated value
Ca = Calcium, Fe = Iron, Mg = Magnesium, Na = Sodium, P = Phosphorus, Zn = Zinc
STD = Sample standard deviation
*RAI = Recommended Adult Intake (mg) (Adeyeye et al., 2016)

overload in the human body. These results show that the calculated MSI values for Fe, Mg and Zn are higher than the standard values for these minerals (6.7, 15 and 33), with sample UUF having the highest (30.51, 23.30 and 100.54), and sample PBF having the least (16.75, 18.86 and 59.84) for Fe, Mg and Zn respectively. This indicates that the flour samples, including those milled from peeled plantain have Fe, Mg and Zn values far above the recommended adult intakes, which may be detrimental to the potential consumers since excess Zn has been observed to interact with Cu and Fe, thereby decreasing their absorption and also results in decrease in the body immune system. Abnormally high MSI values for Mg and Zn have been previously reported in some fast foods consumed in Nigeria (Adeyeye et al., 2012), while low MSI values for Fe and Zn for cucumbers parts, peel, pulp and seed have been reported (Niyi et al., 2019). The relatively higher MSI for Mg obtained in this study (18.83 – 23.3) compared to the standard value (15), may not likely pose too much problem however, since increased intakes of Mg, along with K and Ca had been observed to result in excretion of excess Na and lowering of blood pressure and improvement in glucose tolerance (Karppanen et al., 2005). Conversely, results showed that lower MSI values for Ca, Na and P, compared to their respective standard values for all the flour samples, including flours from unpeeled plantain, which means that these minerals will not produce any risk of overload or toxic conditions to the consumers. Similarly low MSI values for these minerals have previously reported for many plant products and fast foods consumed in Nigeria (Adeyeye et al., 2012; Ademola and Abioye, 2017; Adeyeye and Adubiaro, 2018). Results of t-test showed significant ($p < 0.05$) differences in the average MSI values compared to the standard for all the minerals, except for Na for which calculated t-value (0.78) is less that tabulated t-value (3.182), unlike for other minerals for which their calculated t-values are higher than the tabulated t-value.

CONCLUSION

The results of this study showed that peeling and blanching produced significant effect on the proximate compositions, physico-chemical, anti-nutritional properties and mineral profiles of plantain flours. Peeling resulted in reduced ash and fibre contents of the flour samples, while carbohydrate content increased. The functional and pasting properties of the flour samples were similarly affected by peeling, with flours from unpeeled plantain having higher functional properties, except for swelling index, but lower pasting properties compared to flours from peeled plantain. Peeling and blanching also resulted in significant ($p < 0.05$) changes in the anti-nutritional properties of the plantain flours, with flours from unpeeled plantain having higher anti-nutritional factors than flours from peeled plantain, while flours from blanched plantain has relatively lower values for most anti-nutritional factors. However the values obtained for most anti-nutritional factors were within safe threshold levels. This means that the dough meal that will be prepared from the flour samples will be safe for consumption with respect to anti-nutritional factors. Some of the anti-nutritional factors could also act bioactive materials, which will be beneficial to the consumers. Flours from unpeeled plantain had slightly higher Fe:Zn, Oxalate:Ca and [Ca] [Phy]/[Zn] molar ratios compared to flours from peeled plantain, which were however lower than maximum values capable of impairing bioavailability, while blanching had no effect on these ratios. MSI for Fe and Zn, and to a lesser extent Mg, were higher than

Standard values which may cause overload of these minerals in consumers, especially Zn. Peeling produced more significant effects on most parameters evaluated than did blanching. The prospect of preparing dough meal from unpeeled plantain flour will enhance local production of the commodity, promote industrial processing and reduce problem of waste management from the peels. Future studies will focus on the effect of peeling and blanching on the nutritional properties of the flours including amino acid profiles and protein quality indices, as well as the consumer acceptability of the dough meal samples prepared from the flours. The safety of the meal prepared from the flours will also be evaluated through animal studies.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or non-profit sectors.

CONFLICTING INTERESTS

The Authors hereby declare that there is no conflict of interest whatsoever, before, during and after the collection of data and writing up of this paper.

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