Comparative Evaluation of Nutritional and Anti-nutritional Properties of Peeled, Unpeeled and Blanched Plantain (*Musa AAB*) Flours and Consumer Acceptability of Their Dumplings

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Authors' contributions

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ABSTRACT

This investigation evaluated some nutritional and anti-nutritional properties of flours from peeled, unpeeled, and blanched plantain (*Musa AAB*). Green matured plantain was peeled and sliced (PUF), peeled, sliced and soaked in boiled water (100°C) for 10 mins (PBF), sliced unpeeled (UUF), and sliced, unpeeled and soaked in boiled water (100°C) for 10 mins (UBF). Slices were dried at 65 ±1.5°C until constant weight was obtained and milled into flour (< 212 μm) using a grinding mill. Flours were evaluated for anti-nutritional, minerals and amino acid contents and protein quality indices. Dumplings prepared from flours were evaluated for sensory parameters. There were significant (*P* = .05) differences among flours for most properties evaluated, and for most sensory parameters of dumplings. Minerals, mineral-mineral ratios and anti-nutritional

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contents were significantly (P = .05) higher in unpeeled flours than peeled flours, but anti-nutrients and phytate-mineral molar ratios 0.013-0.016(Ca), .059-0.062(Fe) and 0.098-0.121(Zn) were within acceptable thresholds. Essential amino acids were slightly lower in unpeeled flours than peeled flours, but flour from unpeeled unblanched sample (UUF) was slightly higher in leucine, valine and isoleucine compared to other samples, with values of 6.47, 4.10 and 3.25mg/100g protein respectively. Protein quality indices were 54-66%, 1.52-2.22, 47-60.7% and 4.19-6.07 for EAAI, PER, BV and NI respectively, with samples PUF and UUF having highest and sample (UUF) having 59%, 2.22, 53% and 4.19 respectively. All dumpling samples had high acceptability mean scores (6-7) for most sensory parameters, while flour sample from unpeeled, unblanched matured green plantain (UUF) produced dough meal with high consumer acceptability and nutritional quality.

1. INTRODUCTION

Plantain, a member of the genus *Musa and* family *Musaceae*, is an important plant food crop, which is cultivated in many tropical and subtropical countries of the world, and ranks third after yam and cassava, as a source of dietary calorie staple for millions of people in Nigeria [1]. Nigeria, mostly in the southern part of the country, is one of the largest producers of plantain world, and the largest in the West-African sub region [2], but does not feature among plantain-exporting countries, partly because it produces mostly for local consumption than for export, and low level technology for its preservation [3]. Plantain is a rich source of carbohydrates, which is the highest nutrient it contains, along with minerals such as iron and potassium, but low in fat and protein [4,5], and processed and consumed in different forms, including fried, grilled, boiled and dried at different stages of its maturity [1]. Meals from unripe plantain have been recommended for diabetics in order to reduce postprandial glucose level, due to its relatively low glycaemic index, since the tendency to develop diabetes has been linked to increased consumption of carbohydrate-rich foods with high glycaemic index values [6,7,8].

In Nigeria, post-harvest losses constitute a major limiting factor in the production of plantain, due partly its high moisture content of about 61% when in matured green form, high climacteric and ripening rates and absence of appropriate storage facilities, which can be used to ensure its longer shelf life [9,10] One important and effective method of reducing post-harvest losses in mature green plantain is to convert it into flour of low moisture content and high storability. Matured green plantain is traditionally processed into flour in West and other Central African countries, by manual peeling of the fruits, cutting the peeled fleshy fruit into small pieces, followed by sun-drying and milling into flour using some locally-fabricated grinding mill [4]. The flour is used mainly for the preparation of dough meal, called "Amala", a common staple in the Southwestern part of Nigeria. The colour of the prepared dough meal is often dark brown due to the action of browning enzymes during the long time sun-drying. There have been some studies at improving the traditional method of production of plantain flours to obtain better quality flours, with the addition of high protein and high-fibre food crops to enhance the protein and fibre contents of the flours [11,12].

Nigeria has the capacity to improve production of plantain for local consumption and for export of semi-finished products like dried chips and flour, as source of foreign exchange. There are therefore very good prospects of large-scale industrial processing of plantain in Nigeria, through value addition. Such large scale processing will however result in the production of large quantity of wastes from the peels. The production of good quality flour from unpeeled matured green plantain may have good prospects in industrial processing of the commodity, with reduced problem of waste management. Several studies have been done on the proximate, functional, pasting and some nutritional properties of peeled and blanched plantain flours [13,10,12,14]. However, not much studies have been done in the area of comparing the physico-chemical and nutritional properties of peeled and unpeeled plantain flours, especially mineral bio-availability and amino acid profiles. This study evaluated the nutritional and anti-nutritional properties of flours from peeled, unpeeled and unripe plantain, subjected to mild heat blanching, and evaluated the consumer acceptability of the dough meal prepared from

the flours. The study is therefore aimed at investigating the effects of peeling and blanching on mature green plantain flours and on the sensory attributes of dough meal prepared from the flours.

2. MATERIALS AND METHODS

2.1 Materials

The material used in this study was matured green plantain (*Musa AAB*), of which 10 kg was purchased at the Oyingbo Retail Market on Lagos Mainland, Lagos, Nigeria. Chemical used for analyses were of standard grade. Necessary laboratory equipment were sourced from Yaba College of Technology, Yaba, Lagos and the Federal Institute of Industrial Research, Lagos.

2.2 Preparation of Samples

Matured green plantain fruits were divided into 4 portions of 2.5 kg each, and each portion treated as follows. Potion1 was washed in potable 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). Portion 2 was cleaned in potable water, peeled under water using a clean, stainless kitchen knife, sliced into pieces of 5mm thickness, followed by scalding by immersing in boiled water (100°C) for 10 mins, and treated as peeled, blanched sample (PBF). Portion 3 was cleaned in potable water to remove dirt and contaminants, manually sliced into pieces of 5 mm thickness under water, using a stainless kitchen knife, and treated as unpeeled, un-blanched sample (UUF). Portion4 was also cleaned in potable water, manually-sliced into pieces of 5mm thickness under water, followed by scalding by immersing in boiled water (100°C) for 10 mins and treated as unpeeled, blanched sample (UBF). Each portion was dried at 65 ±1.5°C for 8 hrs, in a cabinet dryer (Carlisle CA2 5DU, Mitchel Dryers Ltd, England, 3695-010), followed by milling into flour (< 212 µm) 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.

2.3 Determination of Mineral Contents and Mineral-mineral Ratios

Minerals (Ca, Fe, Mg, Mn, Ph and Zn) were determined using the Atomic Absorption Spectrophotometer (AAS) Pye Unicam Model SP series, London). UNICAM Model 929, London) as described by [15]. Sodium and potassium were determined using flame emission photometric method of [16]. The mineral-mineral ratios were determined by dividing the mineral contents by each other as required.

2.4 Determination of Anti-nutritional Contents and Phytate-mineral Molar Ratios

Phytate and protease inhibitor were determined using the standard [16] methods, while total phenols, oxalate and hydrogen cyanide were determined using methods of [17]. Phytate-mineral molar ratio for calcium, iron and zinc of each flour sample was determined using the method of [18]. The amount of phytate and each mineral was divided by their respective atomic weight, (phytate: 660 g/mol, Fe: 56 g/mol, Zn: 65 g/mol, Ca: 40 g/mol) and the phytate-mineral molar ratio obtained by dividing the mole of phytate with the mole of the respective minerals.

2.5 Determination of Amino Acid Profiles

The amino acid profiles of flour samples were determined by extraction and analysis using the methods described by [16] and [19].

2.6 Determination of Amino Acid Compositions

The amino acid profiles were used to calculate the total amino acid compositions of each flour blend as reported by [20]. Parameters determined were: total amino acid (TAA), total essential amino acid (TEAA), Total non-essential amino acid (TNEAA) and ratios TEAA/TAA and TEAA/TNEAA respectively.

2.7 Predicted Protein Quality Indices

2.7.1 Essential amino acid index (EAAI)

Essential amino acid index was calculated by using the ratio of test protein to egg protein as reference, for each of eight essential amino acids, Histidine and addition of Methionine and Cysteine using equation 1, as quoted by [21].

$$EAAI = \sqrt[10]{\frac{100a \; X \; 100b \; X \; 100c \; X..X..X..100j}{ax \; X \; bx \; X \; cx \; X..X..X.. \; jx}}$$

(1)

where, (a,b,.......j)a represents Lysine, Threonine, Valine, Methionine, Isoleucine, Phenylalanine, Histidine, Tryptophan, Leucine and (Methionine + Cysteine) in test sample and av,bv,........jv, represent content of the amino acid in reference egg protein% respectively.

2.7.2 Predicted nutritional index

Nutrition index was determined using equation 2 as quoted by [20].

$$Nutrition\ Index\ (\%) = \frac{EAAI\ X\ \%Protein}{100} \tag{2}$$

where, EAAI is the Essential Amino Acid Index of each sample

2.7.3 Predicted protein efficiency ratio (P-PER)

Protein efficiency ratio was estimated using the regression equation by [22]. (Eq. 3).

$$PER = -468 + 0.454\ (LEU) - 0.105\ (TYR) \tag{3}$$

2.7.4 Biological value

Biological values were determined using the regression equation cited by [22], (Eq. 4).

$$BV = 1.09\ (EEAI) - 11.7 \tag{4}$$

2.7.5 Preparation of dumplings and sensory evaluation

Dough meal was prepared from each flour sample by gradually dissolving 1 part of flour in 4 parts (w/v) of boiling water in a medium-size aluminum cooking pot, with constant stirring, using a small flat turning stick while dissolving, to prevent lump formation. Cooking was done for 10 mins while stirring to a obtain a smooth consistent dough mass, which was dished in small portions, wrapped in polyethylene film and kept in a cooler to preserve hotness. Sensory evaluation of dough meal was done using an untrained panel of 20 members selected from amongst students and staff in the college community, of different ages and gender, who are familiar with quality indices of dough meal. A scoring test with graduating scales varying from 9 for liked extremely to 1 for disliked extremely was used to evaluate for sensory parameters of appearance, aroma, mouldability, taste, texture and overall acceptability, as described by [23]. Potable water was provided for panelists to rinse their mouths in between sample evaluation.

2.8 Statistical Analysis

Data were collected in triplicates and analyzed using the IBM SPSS version 23 [24] 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 a significant level of .05.

3. RESULTS AND DISCUSSION

3.1 Mineral Contents and Mineral-mineral Ratios

The mineral contents of the flour samples are presented in Table 1. These results show significant (*P* = .05) differences in the mineral contents of the flours samples with flour from unpeeled unblanched plantain (UUF) having the highest mineral contents, while flour from peeled blanched plantain (PBF) having the lowest values. Flours from unpeeled plantain have significantly (*P* = .05) higher mineral content that peeled flours, while mineral contents of unblanched flours are higher than for blanched. Potassium has the highest content in the flours ranging from 108 mg/100 to 162 mg/100 g, while manganese is the least mineral with values from 1.01 mg/100 g to 2.74 mg/100 for peeled, blanched flour (PBF) and unpeeled, unblanched flours respectively. The high content of potassium in plant food crops, including plantain have been previously reported [4,11,12]. The high content of potassium in these samples will be beneficial to the consumer since this mineral has been credited with offering protection against arterial hypertension, maintenance of osmotic balance of body fluids and regulation of muscle irritability [25]. The mineral contents obtained for peeled unblanched flour in this study were relatively lower than results of [11], but slightly higher than results of [26] for similarly-treated plantain flour. The relatively high mineral contents of unpeeled flours compared to peeled flours, is most probably due to presence of some minerals in the peels, while the lower mineral contents in blanched flours is probably due to the effect of heat. High mineral contents in the peels of plantain fruit at different stages of ripening has been previously reported [27]. The high mineral contents of the flours will enhance the nutritional values of the dough meal prepared from the flours, which will offer some nutritional benefits to the consumers, and prevent certain nutritional deficiency disease conditions as reported by [28].

The amounts of some minerals relative to others, or mineral-mineral ratios, of the flour samples, which are considered crucial in human nutrition, are also presented in Table 1, These include sodium:potassium, Sodium:magnesium, calcium:phosphorus and calcium:magnesium. For instance, sodium-potassium ratio in the diet is often considered more crucial than the amount of individual mineral, since high consumption of sodium is believed to result in the incidence of high blood pressure, while potassium reduces its incidence. This means there will be risk of high blood pressure when sodium-potassium ratio is high, resulting in possible ill-health [29,30]. Calcium:magnesium ratio is also important since there may not be optimal usage of calcium in human cells, without proper balance of magnesium, while magnesium reserve could be adversely affected in high calcium intake without commensurate amount of magnesium [31,32]. Low dietary intakes of calcium relative to phosphorus results in lower Calcium:Phosphorus ratio, which has been observed to result in some adverse health conditions such as bone loss and arterial calcification, and even death in severe cases [33]. High sodium-magnesium ratio has been reported to correlate positively with systolic blood pressure in American adults [34]. The standard ratios of sodium to potassium and calcium to phosphorus should not be more than 1, calcium to magnesium should be between 1 and 2, but not more than 2, and sodium-magnesium ratio of 2:1 [35,29,34]. All the flour samples have mineral-mineral ratios within these standards. The relatively low sodium content of the flour samples relative to their contents of potassium and magnesium will be beneficial to the consumers as this will result in lowering of blood pressure and risk of cardio vascular disease and diabetes [36].

3.2 Anti-nutritional Contents and Phytate-mineral Ratios

The anti-nutritional compositions and phytate-mineral molar ratios of selected minerals are presented in Table 2. With respect to anti-nutritional factors, results show there are significant differences among the flour samples. The values for phenolic compounds, phytate, tannin, oxalate and trypsin inhibitors are 1.25-2.69 mg/g, 3.15-4.74 mg/100 g, 8.20-10.95 mg/g, 8.85-12.20 mg/g and 1.20-2.39 mg/100 g respectively, with flour from peeled, blanched plantain (PBF) having the least values and flour from unpeeled, unblanched plantain (UUF) highest values for all anti-nutritional factors.

These results show that while samples from peeled plantain have lower anti-nutritional compositions compared to unpeeled samples, blanched samples have lower values than unblanched flours. The higher anti-nutritional values for unpeeled flours is possibly due to the presence of peels in these samples which have been reported to contain high contents of anti-nutritional factors [37,27,26]. The slightly but significantly (P = .05) lower anti-nutritional contents of flours from blanched flours 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 [38,39,40]. Anti-nutritional factors adversely affect the nutritional value of plant-based foods by reducing the bioavailability of the nutrient contained in them [41]. For instance, phytate has been shown to have considerable adverse effect on the bioavailability of minerals, especially those with divalent and trivalent ions, like Zn, Fe, Ca [42] and also chelate certain minerals, starch and protein [43,44]. The acid of oxalate is capable of forming strong bonds with certain minerals, while its insoluble salts may solidify in the urinary tract and form kidney stone [45]. Tannins inhibit the digestive enzymes, thereby lowering digestibility of most nutrients, especially protein and carbohydrates [42] and also responsible for decreased amino acid availability and increased fecal nitrogen [46], while high amount of trypsin inhibitor causes hypertrophy of the pancreas [47].

These adverse effects of the common anti-nutritional factors often occur when they are ingested at levels higher than the safety threshold allowed, which are 2-5 mg/g for oxalate, 5-6 mg/100 g for phytate and 2.5 mg/g for trypsin inhibitor and 30mg/kg for tannins respectively [48,49]. The flour samples used in this study, including those milled from unpeeled plantain are within safety thresholds for most anti-nutritional factors. This means that the dough meal samples prepared from the flours will be safe for the consumers. In addition, flour samples from unpeeled plantain with relatively higher anti-nutritional factors will offer health benefit to the consumers. Some anti-nutritional factors have been credited with certain advantages and benefits to human health when consumed at acceptable safety levels. At low levels, phytate, polyphenols, and oxalate have been credited with decreasing blood glucose and lessening of growth dangers [50,51] and reduce

cancer risks. Polyphenols and tannins have also been shown to act as food bioactive compounds, which are extra-nutritional constituents that typically occur in small quantities in foods, with considerable beneficial health effects [52,53]. The phytate-mineral molar ratios of the flour samples are also presented in Table 2. These results show that while there is significant difference (P = .05) between flours from peeled and unpeeled plantain, there is no significant difference (P = .05) between blanched and unblanched samples. This means that blanching had no effects on the phytate-mineral ratios, while values for samples from peeled plantain are slightly but significantly (P = .05) lower than for flours from unpeeled plantain for both phytate-calcium and phytate-zinc, but slightly higher for phytate-iron molar ratio. This is most probably due to the relatively lower amount of iron in samples from peeled plantain compared to its amount of calcium and zinc, and low phytate contents of the flour samples.

Table 1. Mineral and heavy metals contents and mineral-mineral molar ratios of peeled, unpeeled and blanched plantain flours

Parameters/Samples	PUF	PBF	UUF	UBF
Calcium (mg/100 g)	14.45±0.12[c]	12.84±0.15[d]	18.37±0.20[a]	16.84±0.03[b]
Iron (mg/100 g)	4.29±0.04[d]	3.75±0.07[c]	6.83±0.10[a]	6.12±0.06[b]
Magnesium (mg/100 g)	55.40±1.01[b]	50.28±0.07[d]	62.12±0.25[a]	58.43±0.50[b]
Manganese (mg/100 g)	2.31±0.02[c]	1.91±0.10[d]	2.74±0.07[a]	2.46±.05[b]
Phosphorus(mg/100 g)	52.50±0.50[b]	46 72±0.20[d]	55.60±1.02[a]	51.20±0.40[c]
Potassium(mg/100 g)	132.16±1.20[c]	108.20±.05[d]	162.60±0.75[a]	138.60±0.65[b]
Sodium (mg/100 g)	48.72±0.15[c]	45.28±0.20[d]	59.70±0.75[a]	56.70±0.50[b]
Zinc (mg/100 g)	3.16±0.12[b]	2.72±0.04[c]	3.87±.05[a]	3.45±0.07[bc]
Calcium/Magnesium	0.26±0.03[b]	0.26±0.02[b]	0.30±0.01[a]	0.29±0.02[a]
Calcium/Phosphorus	0.28±0.02[b]	0.27±0.00[b]	0.33±0.01[a]	0.33±0.01[a]
Calcium/Potassium	0.11±0.01[a]	0.12±0.01[a]	0.11±0.012[a]	0.12±0.01[a]
Sodium/Magnesium	0.88±0.02[c]	0.94±0.02[ab]	0.96±0.07[a]	0.97±.05[a]
Sodium/Potassium	0.37±0.02[b]	0.42±0.01[a]	0.37±0.01[b]	0.41±0.02[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 = .05)
PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour
s.d. = standard deviation

Table 2. Anti-nutritional contents and phytate-mineral molar ratios of selected minerals of peeled, unpeeled and blanched plantain flours

Parameters/Samples	PUF	PBF	UUF	UBF	*STD
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/100 g)	3.15±0.01[c]	2.72±0.04[d]	4.74±.05[a]	4.23±0.02[b]	5-6
Tannins (mg/g)	8.50±0.07[c]	8.20±0.04[d]	10.95±0.50[a]	10.55±0.02[b]	≤ 20
Oxalate (mg/g)	2.92±.05[c]	2.25±0.10[d]	4.23±0.03[a]	3.78±0.01[b]	2-5
Trypsin inhibitors (mg/g)	1.20±0.04[c]	1.12±0.02[d]	2.39±0.50[a]	1.54±0.07[b]	< 2.5
Phytate/Calcium	0.013±0.004[b]	0.013±0.002[b]	0.016±0.001[a]	0.015±0.002[a]	< 0.20
Phytate/Iron	0.062±0.001[a]	0.062±0.003[a]	.059±0.001[b]	.059±0.003[b]	< 1.0
Phytate/Zinc	0.098±0.004[b]	0.098±0.002[b]	0.121±0.001[a]	0.121±0.002[a]	< 18

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 = .05)
PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour
*STD = Standard value: [48,49,55]
s.d. = standard deviation

The phytate-mineral molar ratios of the flour samples are much lower than standard values of phytate:calcium (< 0.17), phytate:iron (< 1), phytate:zinc (< 18) [54,55], and the critical values of >1.56 for calcium, >14 for iron and >10 for zinc, above which the absorption of these minerals will be inhibited [44,51]. This implies that the bioavailability of these important minerals will possibly not be inhibited by the amount of phytate in the flour samples, including flours from unpeeled plantain.

3.3 Amino Acid Profiles

The amino acid profiles of the flour samples are presented on Table 3. These results showed that there are significant differences (P = .05) in the both the essential and non-essential amino acid profiles among the flour samples. Generally, flours from peeled plantain have slightly but significantly (P = .05) higher essential amino acids than flours from unpeeled plantain, while there is no obvious trend for flours from blanched and unblanched plantain, most probably because soaking and mild heating during blanched had no appreciable effect on amino acid compositions. The slightly lower essential amino acid contents of flours from unpeeled plantain compared to flours from peeled plantain is most probably due to the presence of fibre in flours from unpeeled plantain which may have resulted in relatively lower amino acid contents. Similar observation has been reported by [56] for edible seaweeds, with samples with higher fibre contents having lower amino acids compositions. Leucine is the highest essential amino acid in the flour samples, with values ranging from 4.96 g/100 g protein for sample PUF (peeled unblanched flour) to 6.47 g/100 g protein for UUF (unpeeled unblanched flour), while Methionine had the lowest value for all essential amino acids, ranging from 0.79 g/100 g protein for unpeeled blanched flour (PBF) to 1.23 g/100 g protein for peeled unblanched flour (PUF). The high value of leucine in the flour samples will be beneficial to the consumer since it is believed to be, most probably, the only dietary amino acid capable of stimulating the synthesis of muscle protein [57], and have also been credited with therapeutic effects in certain stress conditions including trauma and sepsis [58].

Lysine, an important amino acid, which plays a crucial role in body tissue growth amongst other benefits, is relatively high in the flour samples ranging from 3.77 g/100 g protein in sample UUF to 4.93 g/100 g protein for sample PUF. The lysine contents of the flour samples are slightly less than values obtained for blends of plantain, soy cake and cassava fibre for functional dough meal [49]. Methionine and Tryptophan have the lowest values for all the flour samples and therefore may be regarded as the two limiting amino acids in the flour samples, which agrees with previous studies that these essential amino acids are limiting in most plant food commodities including cereals, legumes and plantain [59,49,8]. These results indicate that the flour samples will meet the daily requirements for many of these essential amino acids, including valine, phenylalanine, threonine, isoleucine and leucine, for which the flour samples have values higher than recommended daily requirements [60]. The flour samples had the full complements of the non-essential amino acids, with glutamate being the most prevalent (12.43 g/100 g protein for sample PUF to 13.44 g/100 g protein for sample PBF), while cysteine has the lowest value (1.10 g/100 g protein for sample UBF to 1.70 g/100 g protein for sample PBF). Glutamate is considered important since it helps in the synthesis of glutathione which is believed to help in removing toxic materials, free radicals and poly glutamate folate cofactor from the body [61].

Generally, flours from peeled plantain have significantly (P = .05) higher non-essential amino acid contents than samples from unpeeled plantain, while flours from blanched plantain have slightly but significantly (P = .05) lower non-essential contents compared to unblanched samples. The lower non-essential amino acid compositions in unpeeled flours is most probably due to the presence of fibre in these samples [56], while soaking and mild heating most probably produced leaching out of some of the amino acids in flour samples from blanched plantain. Arginine, initially believe to be useful only to children, has now been observed to be useful also for adults, by acting as aid in healing of wounds, as immune booster and to fight migraines, to reduce blood pressure in hypertensive adults and congestive heart failure [62,63,64]. Arginine-lysine ratios, which, when high, affect the metabolic pathway of hypertension and may result in high incidence of hypercholesterolemia, are within the allowable standards of between 1:1 and 2:1 [65,66] in the flour samples, which means that consumers will not be exposed to risk of hypercholesterolemia.

3.4 Predicted Protein Quality Indices

The predicted protein quality indices of the flour samples are presented in Table 4, which show

that there are significant (P = .05) differences among the flour samples for almost all parameters measured, for which sample from peeled unblanched plantain (PUF) having the highest values. Generally, flour samples from peeled plantain have slightly but significantly (P = .05) higher values compared to flours from unpeeled plantain, while flour from blanched plantain have slightly but significantly (P = .05) lower values that unblanched plantain. The lower protein quality indices of flours from unpeeled plantain compared to flours from peeled plantain is most probably due the presence of peel [56]. Flour from unpeeled, unblanched plantain (UUF) notably had relatively high values for many protein quality indices, such as the TEAA, sulphur amino acids, %TEAA/TAA and predicted PER, which are close to, or even higher than, those for flour from peeled unblanched plantain, even higher than values for flour from peeled blanched plantain. The total essential amino acids (TEAA), total non-essential amino acids (TNEAA) and total amino acids (TAA) of the flour samples ranged between 26.40 g/100 g protein for sample UBF and 29.77 g/100 g of protein for sample PUF, 38.65 g/100 g protein for sample UBF and 56.60 g/100 g protein for sample PUF and 65.05 g/100 g protein and 86.57 g/100 g protein, while flour sample from unpeeled unblanched plantain (UUF) had 28.19, 41.34 and 69.53 g/100 g protein for these parameters respectively, which are close to values for sample from peeled unblanched plantain (PUF). These values are relatively lower than results of [49] for blends of plantain, soy cake and cassava fibre, but may be high enough to contribute to the nutritional status of consumers.

Sulphur amino acids play an important role in protecting the body against free radicals and heavy metals, thereby preventing their accumulation in the body, while aromatic amino acids serve as precursors for the synthesis of many biologically active compounds essential for maintaining normal biological function in the human body [67]. The values for sulphur and aromatic amino acids of the samples are slightly lower than values obtained for functional dough meal flour blends from plantain, soy cake and cassava fibre [46], and for blends of flours from wheat, soy cake and whole millet for high quality bread by [59]. The results for predicted essential amino acid index (EAAI) and biology value (BV) show significant differences (P = 0.5) among the samples, with samples from peeled plantain having higher values than flours from unpeeled plantain, while flours from blanched plantain

have slightly but significantly (P = .05) values than unblanched samples. The nutrition index (NI) also shows similar trends, while there is no particular trend for the predicted protein efficiency ratio (PER). The values for EAAI, BV, NI and PER are 54-66%, 47-60.7%, 4.19-60.7 and 1.52-2.22, with flour from unpeeled, unblanched plantain having 59%, 53%, 4.19 and 2.22 respectively. These values are higher than values obtained for raw, blanched and fermented wonderful cola flours by [20], but slightly lower than values reported for flour blends from wheat, soy cake and whole millet [59]. The values are also lower than the standard for good quality protein of >70, >70 and 2.7 for EAAI, BV, and PER respectively [20,21], but the flours will no doubt contribute to the nutritional status of the consumers.

The percentage ratios of TEAA to TAA of the flour samples range from 34.47% for sample PUF to 42.55% for sample PBF, while sample UUF has a value of 40.54%, which is higher the standard values of 11%, 26% and 39 % for ideal protein food, recommended adults, children and infants respectively [60,58]. The low TEAA/TAA for sample PUF is possibly due to its high content of non-essential amino acids compared to other samples, resulting in higher TNEAA to TAA ratio (65.53%). Sulphur and aromatic amino acids showed significant (P = .05) differences, with sample PUF having highest values of 2.87 and 7.10, while sample UUF has 2.56 and 6.17 respectively. The values for sulphur amino acids are much lower than values for aromatic amino acids due to the relatively lower values of methionine and cysteine which make up sulphur amino acids, compared to the higher values of phenylalanine and tyrosine, which make up the aromatic amino acids.

3.5 Sensory Properties

The mean scores of each sensory parameter and the overall mean score of the cooked dough meal samples prepared from the flours are presented in Table 5. There are significant (P = .05) differences in almost all sensory parameters of the dough meal samples except for aroma and taste. This means that both peeling and blanching had no appreciable effect on these organoleptic parameters, for which all the dough samples however have high acceptability mean scores (6-7). There is significant (P = .05) difference among the dough meal samples for appearance, with sample UBF having the highest mean score (7.44), while sample UUF has the

lowest (6.65). Peeled samples have slightly but significantly ($P = .05$) higher mean scores compared to unpeeled, while blanched samples have slightly but significantly ($P = .05$) higher mean scores. The lower acceptability mean scores for unpeeled samples is most probably due to the presence of peels which altered the appearance of the dough meal samples from what panelists are familiar with. The relatively high mean scores for blanched samples could be attributed to lower enzyme activity brought about by hot water soaking, while enzyme activity was most probably higher in unblanched samples, resulting in brown colour in their dough meal samples [68,69]. Texture, mouldability and mouth feel were variously affected by peeling, while blanching had no significant effect ($P = .05$) on both mouldability and mouth feel.

Dough meal samples prepared from peeled plantain flours had significantly ($P = .05$) higher

acceptability mean scores for mouldability and mouth feel (7.00 and 6.96), compared to dough meals prepared from unpeeled plantain flour (6.60, and 6.28) for unblanched and blanched flours respectively. The relatively lower mean scores obtained for mouldability and mouth feel for dough meal samples from unpeeled plantain flours is most probably due to high fibre contents in unpeeled flours (Table 4) compared to peeled flours, which however contributed to higher mean scores for texture for dough meal samples prepared from unpeeled flours. Blanching also had no significant ($P = .05$) effect on both mouldability and mouth feel but on texture, most probably due to mild heating and tissue softening during soaking and blanching. Higher mean score for texture of dough meal prepared from a blend of quality protein maize, soy cake, whole millet and cassava starch, with higher fibre contents than other blends has been reported [70].

T able 3. Amino acid profiles (g/100 protein) of peeled, unpeeled and blanched plantain flours

Parameters/Samples	PUF	PBF	UUF	UBF	*RDA
Essential Amino Acids					
Histidine	4.71±0.02[a]	1.89±0.04[c]	1.70±0.02[c]	2.44±0.03[b]	1.9
Isoleucine	2.68±0.01[cd]	3.03±0.01[bc]	3.25±0.02[ab]	2.93±0.01[c]	2.8
Leucine	4.96±0.15[d]	5.84±0.12[b]	6.47±0.20[a]	5.40±0.10[c]	6.6
Lysine	4.93±.04[a]	4.75±0.10[a]	3.77±.05[b]	3.92±0.01[b]	5.8
Methionine	1.23±0.01[a]	1.05±0.03[b]	0.87±0.00[c]	0.79±0.01[c]	2.2
Phenylalanine	4.61±.05[a]	3.22±0.02[b]	3.75±0.04[b]	3.62±0.01[bc]	2.8
Threonine	2.41±0.01[d]	4.46±0.00[a]	3.37±0.02[b]	2.92±.05[c]	3.4
Tryptophan	1.31±0.02[a]	1.32±0.01[a]	0.91±0.03[b]	0.68±0.01[c]	1.1
Valine	2.93±0.03[d]	3.98±.05[ab]	4.10±0.04[a]	3.70±0.01[bc]	3.5
TEAAs	29.77±0.70[a]	29.54±0.10[a]	28.19±.05[b]	26.40±0.15[c]	
Total Non-essential Amino Acids					
Arginine	8.78±0.25[a]	4.43±0.07[d]	5.58±0.15[b]	4.76±.05[c]	2.0
Alanine	3.42±0.12[a]	2.35±0.20[b]	2.40±0.15[b]	2.16±.05[c]	
Aspartate	9.73±.05[a]	7.10±0.04[b]	6.96±.05[b]	6.31±0.00[c]	
Cysteine	1.64±0.01[ab]	1.70±0.00[a]	1.69±0.02[a]	1.10±0.01[c]	
Glutamate	12.43±0.12[c]	13.44±0.15[a]	13.33±0.08[a]	13.09±0.11[b]	
Glycine	4.76±0.06[b]	3.57±0.03[d]	4.91±0.01[a]	4.51±0.04[c]	
Proline	7.67±0.12[a]	2.69±0.08[b]	1.48±.05[c]	1.36±0.01[d]	
Serine	5.68±0.14[a]	3.09±0.07[c]	2.57±.05[d]	2.39±0.02[b]	
Tyrosine	2.49±0.03[a]	1.51±0.00[c]	2.42±0.01[a]	1.97±0.02[b]	
TNEAAs	56.60±0.15[a]	39.88±.05[c]	41.34±0.12[b]	38.65±0.08[d]	
TAAs	86.37±0.21[a]	69.42±0.06[b]	69.53±0.15[b]	65.05±0.08[c]	
Arginine/Lysine	1.78±0.01[a]	0.93±0.01[d]	1.48±0.00[b]	1.21±0.02[c]	
Glycine/Methionine	3.87±0.06[b]	3.40±0.07[c]	5.64±0.03[a]	5.71±.05[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 = .05)
*PUF: Peeled unblanched flour; * Recommended daily allowance (WHO/FAO, 1991)*
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour
s.d. = standard deviation

Table 4. Predicted protein quality indices of peeled, unpeeled and blanched plantain flours

Parameters/Samples	PUF	PBF	UUF	UBF
TEAA (g/100 g Protein)	29.77±0.50[a]	29.54±0.45[a]	28.19±0.25[b]	26.40±0.40[c]
TNEAA (g/100 g Protein)	56.60±0.70[a]	39.88±0.52[c]	41.34±0.60[b]	38.65±0.20[d]
TAA (g/100 g Protein)	86.37±0.70[a]	69.42±0.45[b]	69.53±0.50[b]	65.05±0.15[c]
∑(Sulf AA(Meth + Cys) (g/100 g Protein)	2.87±0.12[a]	2.75±.05[b]	2.56±0.02[b]	1.89±0.01[c]
∑ArAA(Phen+Tyr) (g/100 g Protein)	7.10±0.60[a]	4.73±0.24[d]	6.17±0.35[b]	5.59±0.15[c]
TEAA+Hist+Arg/TAA (%)	50.09±.05[b]	51.66±0.20[a]	51.01±0.15[b]	51.65±0.12[a]
TEAA/TNEAA	0.53±0.03[c]	0.74±0.02[a]	0.68±0.02[b]	0.68±0.01[b]
TEAA/TAA (%)	34.47±0.10[c]	42.55±0.12[a]	40.54±0.10[b]	40.58±.05[b]
TNEAA/TAA (%)	65.53±0.15[a]	57.45±.05[c]	59.46±0.12[b]	59.42±0.15[b]
EAAI (%)	66.43±0.45[a]	64.50±0.20[b]	58.98±0.25[c]	54.06±0.10[d]
Predicted PER	1.52±0.03[c]	2.06±0.01[a]	2.22±0.02[a]	1.78±0.01[b]
Predicted BV (%)	60.71±0.25[a]	58.61±0.30[b]	52.59±0.50[c]	47.23±0.20[d]
Nutrition Index	6.07±0.02[a]	5.19±0.01[b]	4.19±0.02[c]	4.14±0.03[c]

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 = .05)
PUF: Peeled unblanched flour,PBF: Peeled blanched flour,UUF: Unpeeled unblanched flour,UBF: Unpeeled blanched flour,s.d. = standard deviation, TEAA – Total essential amino acids; TNEAA = Total non-essential amino acids,TAA = Total amino acids; SulfAA = Sulphur amino acids; ArAA = Aromatic amino acids; EAAI = Essential amino acid index; PER = Protein efficiency ratio; BV = Biological value Phen. = Phenylalanine; Tyr. = Tyrosine; Hist. = Histidine; Arg. - Arginine

Table 5. Mean scores of sensory parameters of dough meal sample from peeled, unpeeled and blanched plantain flours

Parameters/Samples	PUF	PBF	UUF	UBF
Appearance	7.18±1.15[b]	7.44±1.25[a]	6.65±1.60[d]	6.92±1.20[c]
Aroma	7.15±1.25[a]	7.18±1.13[a]	7.14±1.10[a]	7.16±1.25[a]
Mouldability	7.00± 1.17[a]	6.96±0.98[a]	6.60±1.15[b]	6.28±1.24[c]
Mouth feel	7.05±1.39[a]	6.98±1.25[a]	6.71±0.95[b]	6.37±1.20[b]
Taste	6.80±1.74[a]	6.81±1.40[a]	6.75±1.52[a]	6.78±1.36[a]
Texture	6.68±0.94[c]	6.24±1.15[d]	7.25±1.24[a]	6.80±1.17[b]
Overall mean score	6.98±1.10[a]	6.89±1.15[ab]	6.85±1.16[b]	6.72±1.20[c]

Means with similar superscripts along same rows are not statistically significant (P = .05)
PUF: Peeled unblanched flour
PBF: Peeled blanched flour
UUF: Unpeeled unblanched flour
UBF: Unpeeled blanched flour

Functional and pasting properties of flours have been reported to contribute to sensory attributes of dough meal like texture and mouldability [8], while [71] and [72] have also reported that water absorption and pasting properties of flours are dependent on components of flours and their interactions, which in turn affect sensory parameters like texture and mouldability. The overall acceptability mean scores of the dough meals from the flour samples were in ascending order of UBF < UUF < PBF < PUF with values of 6.72, 6.85, 6.89 and 6.98 respectively out of a maximum score of 9.0, which indicates close to moderately liked on the graduating scale used (7.0), including dough sample from unpeeled unblanched flour (UUF).

4. CONCLUSION

This study showed that peeling and blanching had significant effects on nutritional and anti-nutritional properties of plantain flours. Peeling and blanching resulted in reduced fibre, but increased carbohydrate contents of the flour samples, and also produced significant alterations in the anti-nutritional and mineral contents, amino acids profiles and protein quality indices of the flours. Peeling resulted in lowering of anti-nutritional factors, but these were within safe threshold levels. Peeling also resulted in slight reduction in amino acid profiles of the flour samples. The flour samples produced dough meal of high-consumer acceptability in almost all

sensory attributes. Unpeeled, unblanched plantain (UUF), which received almost similar consumer acceptability overall mean score as other samples (6.89 out of maximum of 9.0), will provide high prospects for the commercial production of flours for preparation of consumer acceptable dough meal with high nutritional value. Such flour will contain the full complements of nutrients especially minerals and fibres contained in the peels. It will also provide some useful phytochemicals from some anti-nutritional factors like polyphenols and tannins which will be beneficial to the consumers, as well as increase in flour yield. This study showed that flour from unpeeled matured green plantain can be used to prepare dough meal with good sensory attributes, high consumer acceptability, and good nutritional properties, especially with respect to minerals fibre and phytochemicals.

DECLARATIONS

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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