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Nutraceutical potential of ripe and unripe plantain peels: A comparative study

Ibhafidon Shadrach, Adaramola Banji* and Onigbinde Adebayo

Department of Basic Sciences, Chemistry Unit, Babcock University, Ilishan-Remo Ogun State, Nigeria
*Corresponding author's E. mail: feyimicheal37@gmail.com; milliangelo@gmail.com

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This study investigated the nutraceutical potential of ripe and unripe plantain fruit peels which are commonly discarded as food wastes. Proximate and mineral analyses of the samples were performed as per the standard methods of the Association of Official Analytical Chemists. Preliminary phytochemical screening of aqueous, acetone and methanol extracts of the peels was also carried out in accordance to standard methods. From the results of the study, acetone extract of the unripe peel showed the presence of eight phytochemicals while its ripe peel showed the presence of four. Aqueous and ethanol extracts of both peels showed the presence of same phytochemicals i.e., terpenoids, cardiac glycosides, phenols, flavonoids, alkaloids, reducing sugars and saponins. Meanwhile, tannins was absent in all three solvent extracts of both peels. Fat, ash, crude fibre and carbohydrate contents of the unripe peel were higher than those of the ripe. However, moisture and protein contents of the ripe peel were significantly higher ($P < 0.05$) than those of the unripe. Of all the nine essential minerals assayed (K, Na, Mg, Ca, P, Fe, Zn, Mn, Cu), concentrations of all except calcium were significantly higher ($P < 0.05$) in the unripe peel than those of the ripe peel. Notably, none of the heavy metals (Co, Cr, Cd, Pb, Ni) assayed was detected in both samples. This study concludes that ripe and unripe plantain fruit peels could serve as promising sources of nutrients and bioactive compounds essential for the health of both livestock and humans.

Capsule Summary: Investigation of the nutraceutical potential of ripe and unripe plantain fruit peels revealed the presence of important nutrients and bioactive compounds essential for human health.

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INTRODUCTION

Plantain fruit (*Musa parasidiasca*); grown and consumed mostly in the tropical regions of Africa, South America, Central America and Asia belongs to the family; *Musaceae* and the natural order; *Plantaginaceae* (Adamu et al., 2017). It is one of the anciently cultivated fruits in both Central and West Africa and a staple in the diet of Sub-Saharan Africa especially in Nigeria. This is evident as over 2.11 million metric tons of the fruit are produced annually in Nigeria alone (Akinsanmi et al., 2015). Plantain provides over 10 % daily calorie intake for a population of more than 70 million people across the African continent (Sanjeev et al., 2012). In Nigeria, foods made from the Plantain fruit are called different names based on their methods of preparation. For example, it is referred to as "Amala" (when its flour is prepared with hot water for consumption with different

soups), as "Dodo" (fried ripe fruit), "Kpekere" (thinly sliced fried slightly ripe/unripe plantain fruit).

However, the peels are mostly regarded as waste and often discarded indiscriminately in landfills, drainages and road sides; consequently posing a threat to the environment (Auta and Kumurya, 2015; Baiyeri et al., 2011). The Plantain peel which accounts for about 40 % of the total fruit weight (Gilver and Liliana, 2017) has reportedly been shown to have potential as a promising raw material which could find useful industrial applications especially in the agro-based industries. The peels have been considered for use as organic fertilizers in places like Somalia to enrich soils and enhance better crop production and yield (Eun-Hye et al., 2010; Okareh et al., 2015). Reports have shown the peels as being good potential substitute for corn starch in the diet of snails and also incorporated with other waste materials in the diet of pigs (Okareh et al., 2015; Omale and Okafor, 2008). Meanwhile, in the chemical industry, the peels have shown potential for the generation of important chemicals like ethanol and also alkali for the manufacturing of soap. As a way of ensuring a safer environment, attempts have been made to use polyphenolic resol resins from the ethanol extract of plantain peels for the adsorption of heavy metals since the peels show high retention affinity for lead, nickel and chromium (Andres et al., 2015).

Also in the food industry, flour made from the peels has been reportedly used to enrich wheat flour at various percentages in producing snacks like cookies and sausages; serving as a good source of fibre, antioxidants and potentially benefiting humans in the management and prevention of life style related diseases (Gilver and Liliana, 2017; Arun et al., 2015). Several studies have reported the antifungal and antibacterial activities of different parts including the peel of plantain plant for the treatment of a large number of human ailments (Auta and Kumurya, 2015). The ethanol extracts of the peels were used against eight human pathogenic microbes; five bacteria and three fungi and they proved effective against these human pathogens which have been implicated in several human diseases (Ighodaro, 2012). Thus, the peel extracts have been suggested for use in pharmaceutical and medical formulations. Some of the main pharmacological effects of the plantain plant including the peels are; antiulcer, analgesic, wound-healing, hair growth promoter, haemostatic activity among others (Alexandre et al., 2019; Aruwa et al., 2019; Barroso et al., 2019; D'Eliseo et al., 2019; Elbadrawy and Sello, 2016; Mohamad Sukri et al., 2019; Sanjeev et al., 2012).

The use of plantain peel concurrently as food and medicine has not been given much attention; as focus is drawn more to its pharmacological applications. Hence, this study comparatively investigated the nutraceutical potential of ripe and unripe plantain peels. This was done by carrying out phytochemical screening on different solvent extracts of the peels as well as determining their proximate and mineral compositions.

MATERIAL AND METHODS

Sample collection and preparation

Fresh ripe and unripe plantain fruits were harvested from a farm inside the Federal Government Girls' College, Sagamu, Ogun state. The peels were separated from the plantain pulp, thoroughly washed and sliced into chip size (0.5 cm^2) with the aid of a cutting knife and then oven-dried at 50 ^oC for 10 hours. The dried peels were then pulverized with the aid of a laboratory blender (Lexus MG-2053 Optima), stored separately in airtight containers and kept in a refrigerator until further use. The pulverized samples were used for phytochemical screening, mineral and proximate composition analyses. The ripe plantain peel was coded as RPP while the unripe was coded as UPP.

Extraction of samples

Five grams each of the ripe and unripe pulverized plantain peel samples were macerated separately in 25 mL of the three different solvents viz; ethanol, acetone and water at room temperature for 48 hours. The resulting mixture was filtered through with Whatmann No. 42 filter paper and were then subjected to phytochemical screening using standard methods.

Phytochemical screening

Preliminary phytochemical screening was performed to determine the presence of secondary metabolites: alkaloids, tannins, flavonoids, phenolics, steroids, cardiac glycosides, saponins, terpenoids, reducing sugar and phytosterols in ethanol, acetone and water extracts of ripe and unripe plantain peels. These assays were carried out by standard methods (Martinez and Valencia, 2003; Pawaskar and Kale, 2007; Venkatesan et al., 2009; Sivaraj et al., 2011; Teresa and Bandiola, 2018)

Proximate analysis

Proximate analysis of both ripe and unripe pulverized samples was carried out using the standard method of the Association of Official Analytical Chemists (AOAC, 2010). The parameters analyzed were moisture, fat, ash, crude fibre, crude protein and carbohydrate. Moisture was determined by oven drying method in which samples were dried in a hot air oven at 105 °C until constant weight was obtained, cooled in a desiccator, and reweighed. Moisture content was taken as the difference in weight of sample before and after drying. Ash content of the sample was obtained by calcinating the dried sample resulting from the moisture content assay in a muffle furnace at 550 ^0C for about 6 hr. Ash content of ash was calculated by subtracting the weight of ash from the initial sample weight. Crude protein content was analyzed by the Kjeldahl method in which samples went through the three essential steps of digestion, distillation, and titration using a conversion factor of 6.25 to convert total nitrogen to crude protein.

Table 1: Phytochemicals in water, ethanol and acetone extracts of ripe and unripe Plantain peel

S/N	Phytochemical	Tests	Water		Ethanol		Acetone	
			RPP	UPP	RPP	UPP	RPP	UPP
1.	Terpenoids	Copper Acetate Test	+	+	+	+	+	+
2.	Cardiac glycosides	Legal's Test	+	+	+	+	+	+
3.	Phenols	Ferric Chloride Test	+	+	+	+	-	-
4.	Tannins	Tannins test	-	-	-	-	-	-
5.	Flavanoids	Shinoda Test	+	+	+	+	-	+
6.	Alkaloids	Wagner's Test	+	+	+	+	-	+
7.	Reducing sugar	Fehling's Test	+	+	+	+	+	+
8.	Saponins	Foam's Test	+	+	+	+	+	+
9.	Steroids	Salkowski's Test	-	-	-	-	-	+
10.	Phytosterols	Lieberman Buchard Test	-	-	-	-	-	+

Key: **+ =** Presence; **- =** Absence; RPP = ripe plantain peel; UPP = unripe plantain peel

Fat content was determined by the semi- continuous Soxhlet extraction method with n-hexane as the extraction solvent. Difference in weight of the sample after the hexane extraction was taken as the fat content of the sample. For crude fibre determination, the moisture free and ether extracted sample was first digested with dilute H_2SO_4 followed by dilute KOH solution. The undigested residue collected after digestion was ignited and loss in weight after ignition was registered as crude fiber. Carbohydrate content was obtained based on the net difference between the total percentage composition and the sum of the percentage compositions of the other parameters. Each analysis was carried out in triplicates.

Mineral analysis

Mineral analysis was carried out using the AOAC method (AOAC, 2010). Two grams of the sample were measured into a pre-weighed crucible and incinerated in a muffle furnace at 550 ^oC for 6 hours. The resulting ash was dissolved in 50 mL of 10 % nitric acid (HNO_3) solution. The solution was heated with on a hot plate for 15 minutes and immediately filtered while hot with a Whatmann No. 42 filter paper into a 100 mL volumetric flask. The filtrate was made up to the 100 mL mark with hot distilled water and analyzed using Atomic Absorption Spectrophotometer (Buck scientific model, 2010 VGP). The concentration of thirteen minerals including five trace metals were determined using the Atomic Absorption Spectrophotometer while Phosphorus was determined using a UV-spectrophotometer (Labo med SPECTROSC.). A reagent blank was concomitantly prepared by boiling 50 mL of 10 % HNO_3 solution for 15 minutes, filtered and made up to the 100 mL mark of the volumetric flask. Each analysis was carried out in triplicate.

Statistical analysis

Data are expressed as means ± standard deviation of three replicate measurements. Data were analyzed by one-way analysis of variance and differences between means were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Results of the phytochemical screening showing the presence of different bioactive compounds in the ethanol, acetone and water extracts of both ripe and unripe plantain peel are presented in Table 1. The results showed that tannins were absent in all three extracts of both RPP and UPP. The acetone extract of the UPP revealed the presence of eight phytochemicals while the RPP acetone extract revealed only four out of the ten phytochemicals assayed. Only acetone extract of UPP showed the presence of steroids and phytosterols. This suggests that acetone was the most suitable solvent for the extraction of steroids and phytosterols from the unripe plantain peel (UPP) sample. However, literature suggest that in the process of ripening, various chemical processes and changes occur which could lead to the conversion of certain compounds into another or even the disappearance of certain compounds observed before ripening (Ogbonna et al., 2016). This could be applicable in this present study as steroid and phytosterol compounds observed in the acetone extract of the UPP sample were absent in the RPP sample. Meanwhile, water and ethanol extracts of both peels revealed the presence of the same phytochemicals such as terpenoids, cardiac glycosides, phenols, flavonoids, alkaloids, reducing sugars and saponins. In a similar work by Yen and Anh (2014), qualitative phytochemical screening of six extracts of *Scopariadulcis L.* was carried out and it was found that the aqueous and ethanol extracts also revealed the presence of about same phytochemicals. The similarity in the phytochemicals presents in the water and ethanol extracts could be due to the relatively close polarity of these solvents and so on (Tapas et al., 2008; Ehiowemwenguan et al., 2014).

Phytochemicals are bioactive compounds naturally present in plants and have protective and disease preventive properties hence their medicinal and pharmacological application (Pawaskar and Sasangan, 2017). Terpenoids have been shown to decrease blood sugar level in animal studies (Manda et al., 2009).

Table 2: Mineral composition of ripe and unripe Plantain peels (mg/100 g)

S/N	Minerals	RPP	UPP
1	Phosphorus	85.03 ± 0.06[a]	103.94 ± 0.16[b]
2	Calcium	174.05 ± 0.13[a]	56.00 ± 0.13[b]
3	Magnesium	324.50 ± 0.15[a]	394.93 ± 0.11[b]
4	Potassium	6561.00 ± 1.63[a]	8784.70 ± 0.07[b]
5	Sodium	882.80 ± 0.21[a]	946.20 ± 0.07[b]
6	Manganese	7.11 ± 0.06[a]	13.80 ± 0.04[b]
7	Iron	19.28 ± 0.06[a]	39.14 ± 0.01[b]
8	Copper	3.29 ± 0.00[a]	3.42 ± 0.01[b]
9	Zinc	26.96 ± 0.02[a]	39.02 ± 0.01[b]
10	Cobalt	ND	ND
11	Chromium	ND	ND
12	Cadmium	ND	ND
13	Lead	ND	ND
14	Nickel	ND	ND

Key: All values are mean ± standard deviation of triplicate determination. Values across each row with different subscripts ([a-b]) differ significantly ($P < 0.05$). ND = Not Detected

Flavonoids and phenols in plants have been reported to show antioxidant, free radical scavenging abilities, anti-inflammatory and anticarcinogenic properties (Tapas et al., 2008). Phenol compounds present in plants have proven to contribute to colour, sensory and antioxidant properties of food (Eleazu et al., 2011). Alkaloids play some key metabolic role in living systems (Pawaskar and Sasangan, 2017) such as being antimicrobial (Kasolo et al., 2010). Saponins protect against hypercholesterolemia and also show antibiotic properties (Amin et al., 2013). Steroids and phytosterols have been reported to promote nitrogen retention in osteoporosis and in animals with wasting illness (Kayode et al., 2013). Cardiac glycosides have been reported to show medicinal value in the prevention of cardiac arrest. Plants containing cardiac glycoside when consumed elevates the intracellular calcium concentration, thereby increasing cardiac output through an increase in the contraction of the heart (Shamaki et al., 2012). Therefore, the presence of these important phytochemicals in ripe and unripe plantain peels underscores the potential medicinal relevance of these peels.

From the results of the mineral analysis, nine essential minerals (K, Na, Mg, Ca, P, Fe, Zn, Mn, Cu) were present at various concentrations, while the five heavy metals assayed (Co, Cr, Cd, Pb, Ni) were not detected. The concentration of these essential minerals in both RPP and UPP samples follow a similar trend with the highest mineral element being potassium followed by sodium and magnesium while the least was copper. The occurrence of the metals in each of the samples is in the order;

RPP: K > Na > Mg > Ca > P > Fe > Zn > Mn > Cu
UPP: K > Na > Mg > P > Ca > Fe > Zn > Mn > Cu

The only variation in the trend was between calcium and phosphorus as calcium was higher in the RPP samples while phosphorus was higher in the UPP samples. Across Table 2, the concentration of the minerals in the UPP samples were significantly higher ($p < 0.05$) than the RPP samples with calcium as the only exception. The result is in agreement with that of Okorie et al. (2015) where most of the minerals analyzed were in higher concentration in the UPP samples than the RPP samples except for K, Na and Cu. These variations in concentration could imply that some of the minerals are used up or even aid the chemical process of ripening. Several studies have reported these variations in different unripe and ripe crops (Egbebi and Bademosi, 2011; Chukwuka et al., 2013). Both ripe plantain and unripe plantain peels are good sources of essential minerals. These minerals have been reported to show therapeutic importance required for normal growth, development and proper functioning of the body (Ehinge et al., 2012; Mohammed et al., 2013).

The higher concentration of K to Na in both peel samples have been considered a great advantage towards good health. As diets with higher K to Na have been shown to reduce blood pressure and prevent health-threatening ailments such as hypertension, arteriosclerosis. While diets with higher Na to K ratio have been linked to incidences of hypertension (Saupi et al., 2009; Chen et al., 2010). Additionally, peels of plantain fruit have been reported as good adsorbents of heavy metals. They have been proven to have a high tendency to adsorb heavy metals even when present in the smallest concentrations and therefore have been used as indicators of heavy metals in certain environments (Andres et al., 2015; Gomes-Rebello et al., 2014). Meanwhile, the absence of heavy metals in the peels as reported in this present study is in sharp contrast with reports from several studies where at least one of the heavy metals especially lead was detected in the peels (Okorie et al., 2015; Abubakar et al., 2016). This could be attributed to the difference in our sampling method in comparison with previous studies. From the works of other researchers as cited, the plantain fruits were bought in busy market areas

where a lot of commercial activities and vehicular movements/emissions occur on a daily basis. However, the plantain peels used for this research were harvested in a farm located in a small town far away from commercial and industrial activities with little or no vehicular movements/emissions. This is justifiable as literature has proven that vehicular emissions are associated with and even described as 'first line sources' of heavy metal pollutants (Poszyler-Adamska and Czerniak, 2007). Also, lead, cadmium and nickel have been reported as the most prevalent heavy metals pollutant in vehicular emission due to their presence in fuel as anti-knocking agents (Suzuki et al., 2009; Atayese et al., 2010).

Table 3: Proximate composition of ripe and unripe Plantain peels

Parameters (g/100 g)	RPP	UPP
Moisture	24.75 ± 0.35[a]	13.75 ± 0.35[b]
Fat	6.00 ± 1.41[a]	10.25 ± 1.06[a]
Ash	10.35 ± 1.06[a]	13.88 ± 0.18[b]
Fibre	9.00 ± 2.12[a]	11.25 ± 1.77[a]
Protein	6.96 ± 0.08[a]	5.44 ± 0.18[b]
Carbohydrate	42.94 ± 4.16[a]	45.43 ± 2.48[a]

Key: All values are mean ± standard deviation of triplicate determination. Values across each row with different subscripts ([a-b]) differ significantly ($p < 0.05$). While values with same subscript ([a-a]) do not differ significantly ($p < 0.05$).

The proximate composition of both RPP and UPP are shown in Table 3. From the results, the moisture, ash and protein contents of RPP and UPP differ significantly ($P < 0.05$), while the fat, crude fibre and carbohydrate contents do not differ significantly ($P < 0.05$). The moisture and protein contents of RPP with values; 24.75 ± 0.35% and 6.96±0.08 % respectively are significantly higher ($P < 0.05$) than those of UPP with moisture and protein values; 13.75±0.35% and 5.44±0.18%, respectively. The fat, ash, crude fibre and carbohydrate composition values of the UPP samples are found higher than the RPP samples. The difference however is not significant ($P <$ 0.05), except the ash content. The ash contents which are an index of the amount of minerals present (Akinsanmi et al., 2015; Abubakar et al., 2016), which corresponds with the higher concentration of the essential minerals in the UPP samples to the RPP samples in Table 2.

Moisture content is a very important parameter in food analysis as it determines the means of processing as well as the shelf-life and storage of the food (Akinsanmi et al., 2015). The significant high level of moisture content in the RPP samples could be due to moisture gained from the atmosphere during the process of ripening or as a result of the overall chemical and microbial processes/activities as the fruit ripens (Adamu et al., 2017). The protein contents of both RPP and UPP can contribute significantly to the daily human protein requirement. The moisture and protein contents of the RPP sample being higher than the UPP sample agrees with the results of Adamu et al. (2017), while the fat, ash, crude fibre and carbohydrate contents of the UPP sample being higher than the RPP samples agrees with the results of Akinsanmi et al. (2015). Fat and carbohydrate are good sources of energy for livestock and humans. Crude fibre content in diets have been reported to aid digestive processes; promoting health in livestock and humans (Abubakar et al., 2016) and these findings are in line with previous reports indicating the bioactivity and application of peels of various plants (Abbas et al., 2018; Abdel Aziz et al., 2018; Ahad et al., 2018; Derakhshan et al., 2018; Garrafa-Galvez et al., 2019; Gurumallesh et al., 2019; Hu et al., 2019; Jridi et al., 2019; Kharchoufi et al., 2018; Kokila et al., 2016; Lakkab et al., 2019; Liu et al., 2017; Rodsamran and Sothornvit, 2019; Xu et al., 2019).

CONCLUSIONS

Results of this study underscore the nutritional and potential medicinal importance of both ripe and unripe plantain fruit peels. Although, the unripe peel contained more fat, ash, fibre, carbohydrate, essential minerals and phytochemicals, both peels showed promising potential for use in feed and drug formulations for livestock and even humans.

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