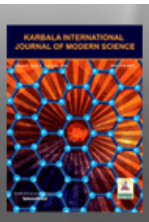

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Comparative evaluation of the antioxidant activity, trace elements, and phytochemical analysis of the extracts of unripe plantain whole fruit and pulp

Damilare Emmanuel ROTIMI
SDG 03 Group – Good Health & Well-being, Landmark University, Omu-Aran 251101, Kwara State, Nigeria

Oluyomi Stephen ADEYEMI
SDG 03 Group – Good Health & Well-being, Landmark University, Omu-Aran 251101, Kwara State, Nigeria, yomibowa@yahoo.com

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Keywords

Antioxidants; Fruits; Mineral content; Medicinal value; Nutraceutical; Unripe plantain

RESEARCH PAPER

Comparative Evaluation of the Antioxidant Activity, Trace Elements, and Phytochemical Analysis of the Extracts of Unripe Plantain Whole Fruit and Pulp

Damilare E. Rotimi [a,b], Oluyomi S. Adeyemi [a,b,c,*]

[a] SDG 03 Group – Good Health & Well-being, Landmark University, Omu-Aran 251101, Kwara State, Nigeria
[b] Department of Biochemistry, Medicinal Biochemistry, Nanomedicine & Toxicology Laboratory, Landmark University, PMB 1001, Omu-Aran, 251101, Nigeria
[c] Laboratory of Sustainable Animal Environment, Graduate School of Agricultural Science, Tohoku University, 232-3 Yomogida, Naruko-onsen, Osaki, Miyagi 989-6711, Japan

Abstract

Plantains make a substantial contribution to food security and malnutrition eradication, thus making them a staple food in several tropical and subtropical climates. This research determined the mineral contents, antioxidant capacities and phytochemical constituents of plantain whole fruit (pulp and peel) and pulp extracts. To this end, the plantain samples were evaluated for their phytochemicals, mineral element content, and in vitro antioxidant properties. The phytochemical screening showed that the plantain whole fruit and pulp extracts contained phenols, terpenoids, flavonoids, cardiac glycosides, reducing sugars, alkaloids, and steroids. Tannins, on the other hand, were detected only in the plantain whole fruit extract. The mineral elements in the whole fruit were higher than those in the pulp, especially for iron, sodium, calcium, phosphorus, zinc, and copper. Among the mineral contents, sodium was predominant. In comparison to the plantain whole fruit extract, the pulp showed better scavenging activity for nitric oxide, DPPH, and hydroxyl free radicals. In conclusion, the findings revealed that unripe plantain whole fruit and pulp extracts may be a promising source of critical nutrients and bioactive substances.

Keywords: Antioxidants, Fruits, Mineral content, Medicinal value, Nutraceutical, Unripe plantain

1. Introduction

Plantain (*Musa paradisiaca Linn*.) is a tropical fruit that is grown extensively throughout Central and West Africa as a major food crop. Plantains are ranked among the most commonly consumed staple foods in the modern world [1]. Plantain intake contributes more than 25% of the carbohydrates necessary for no less than 70 million individuals in Africa [2]. Annually, Nigeria produces around 2.11 million metric tons of plantains, which make a significant contribution to the vital nutrients of subtropical local populations. Plantain is a perennial crop with strong pseudostems and a large, broad spiral pattern of stacked leaves [2,3].

Numerous recipes utilize plantains. When ground into flour, it is usually used to make porridge. Mature fruits are cooked, roasted, mashed, baked, or fried [4]. Banana meals are often served with stews or vegetable sauces and either fish or meat, depending on the household's income [5]. As a result, the demand for plantains is strong in Nigeria. Plantain is traditionally used to treat scorpion stings, dog bites, diarrhea, tuberculosis, marasmus, migraine, abscess, burns, septicemia, dysentery, nausea, psoriasis, headaches, hemorrhage, cancer, hypertension, diabetes, ringworm infection, sores,

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* Corresponding author at: SDG 03 Group – Good Health & Well-being, Landmark University, Omu-Aran 251101, Kwara State, Nigeria.
E-mail address: yomibowa@yahoo.com (O.S. Adeyemi).

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syphilis, smallpox, snakebites, and wounds [6,7]. This may be because the plantain fruits contain bioactive chemicals including antidiarrheal, antiulcerative, antibacterial, hypoglycemic, antioxidant, analgesic, antidiabetic, and anticonvulsant [8]. Plantain has antioxidant properties because of its phenolic concentration, which assists the body in scavenging free radicals by inhibiting oxidase, activating antioxidant enzymes, decreasing tocopherol radicals, and chelating metallic catalysts [9].

The analysis of plantains showed the presence of carbohydrates, lipids, dietary fiber, protein, minerals such as sodium (Na), calcium (Ca), phosphorus (P), iron (Fe), magnesium (Mg), potassium (K), and zinc (Zn), and water-soluble vitamins such as ascorbic acid, niacin, riboflavin, thiamine, and folic acid [10,11]. The bioactive metabolites found in plantain fruits are glycosides, ascorbic acid, phytates, oxalates, tannins, alkaloids, steroids, amino acids, flavonoids, benzoic acid derivatives, and vitamin A, along with flavonoids like quercetin [12].

The nutritional and therapeutic values of plantain pulp and peel are undisputedly clear, with many studies demonstrating their pharmacological properties. However, little emphasis has been placed on the plantain (pulp and peel), and their pharmacological importance. Thus, this work comparatively evaluates the phytochemical, mineral content and antioxidant potential of plantain (whole fruit and pulp).

2. Materials and methods

2.1. Extraction of plant samples

Mature but unripe plantains were purchased at the Oja Tuntun Market, Ilorin, Kwara State. The plant was authenticated in the Department of Plant Biology, University of Ilorin, Ilorin, Nigeria, and assigned voucher number UIH001/1186. The whole fruit or pulp, of the unripe plantain was used in the study. The fruits were rinsed thoroughly with clean water. Afterward, the pulp was prepared by cutting it into bits after removing the peels, while the whole fruit containing the pulp and peel were separately sliced into bits. The samples (whole fruit or pulp) were air-dried to constant weights and thereafter pulverized in an electric blender. The resultant flour samples were used for the extraction process.

The aqueous extraction of the unripe plantain samples (whole fruit or pulp) was separately obtained by soaking 10 g of the flour in 100 mL of distilled water. The solution was shaken intermittently for 24 h and filtered. The solvents were evaporated to dryness using a steam bath [13].

2.2. Qualitative and quantitative phytochemical analysis

The qualitative phytochemical assessment of the unripe plantain whole fruit or pulp extracts was as described by Harborne [14] and Evans [15].

For the quantitative evaluation of phytochemicals in the whole fruit or pulp extracts, we used the spectrophotometric methods. Phytochemicals including tannin was measured as determined by Gupta and Verma [16], while terpenoid content was determined as described by Harborne [14]. The total phenol content was measured using the procedure described by Wolfe, Wu and Liu [17]. The flavonoid and saponin contents were determined as described by Mattila and Kumpulainen [18] and Uematsu, Hirata, Saito and Kudo [19] respectively.

2.3. Mineral analysis

Elemental analysis was performed to determine the mineral distribution in the whole fruit, or pulp extracts of the unripe plantains. The elemental analysis included zinc, sodium, iron, magnesium, phosphorus, potassium, calcium, and copper. The elemental analysis was performed by using an atomic absorption spectrophotometry (AAS). Briefly, about 1.0 g of each sample was digested with 20 mL of acid mixture (650 mL Conc. HNO_3, 80 mL perchloric acid, 20 mL H_2SO_4) by weighing the sample into a digestion flask followed by addition of the 20 mL acid mixture. The digestion flask containing the sample and the digestion acid mixture was heated until a clear digest was obtained. The digest was diluted with distilled water to 500 mL mark and aliquots of the clear digest were used for atomic absorption spectrophotometry using filters that matched the different elements. The concentration of the each mineral element was extrapolated from the calibration curves prepared with their respective standard solutions.

2.3.1. In vitro antioxidant screening of the plantain whole fruit and pulp extracts

Antioxidant assays on the whole fruit or pulp extracts of the unripe plantains were carried out. The concentration of the extracts used for the assays was between 1 and 5 mg/mL. Ascorbic acid was used as a reference antioxidant molecule where applicable.

2.4. 2,2-Diphenyl-1-picrazyl hydrazyl (DPPH) assay

The DPPH free radical scavenging assay was carried out as described by Elebiyo et al. [20] with

slight changes. An aliquot (0.1 mL) of the sample (whole fruit or pulp extracts, or ascorbic acid) at various concentrations (1, 2, and 5 mg/mL) was mixed with 0.1 mM DPPH-ethanol (2.9 mL). The mixture was incubated for 30 min at 25 °C. The decrease in absorbance was measured at 517 nm (UV/VIS spectrophotometer, Jenway, Staffordshire, UK). The calculation is given below;

$$\%\text{Activity} = \left[1 - \left(\frac{Absorbance of sample - Absorbance of blank}{Absorbance of control}\right)\right] \times 100$$

2.5. Hydroxyl (OH) radical scavenging assay

The OH radical scavenging assay was carried out by the modified method of Oyedemi, Bradley and Afolayan [21]. An aliquot (2 mL) of the samples (whole fruit or pulp extracts, or ascorbic acid) at various concentrations (1, 2, and 5 mg/mL) were mixed with 0.6 mL of the H_2O_2, and incubated for 15 min at 25 °C. Absorbance was read at 230 nm (UV/VIS spectrophotometer, Jenway, Staffordshire, UK). The control contained 2.6 mL of H_2O_2-phosphate buffer and the blank contained 0.6 mL phosphate buffer (without H_2O_2) and 2 mL distilled water. The percentage inhibition of the H_2O_2 is calculated as;

$$\%\text{Activity} = \left(\frac{Absorbance of sample - Absorbance of blank}{Absorbance of control}\right) \times 100$$

2.6. Ferric reducing antioxidant power assay (FRAP)

The FRAP assay was as described by Ojo et al. [22]. An aliquot (0.25 mL) of the samples (whole fruit or pulp extracts or ascorbic acid) at various concentrations (1, 2, and 5 mg/mL) was mixed with 2.5 mL of 1% potassium ferricyanide and 2.5 mL of potassium phosphate buffer. The mixture was allowed to incubate at 50 °C for 20 min. Then 2.5 mL of 10% TCA was added and the mixture was centrifuged at 650 g for 10 min. The supernatant was then collected and mixed with an equal volume of distilled water. After centrifuging, 1 mL of 0.1% $FeCl_3$ was added. The absorbance of the mixture was read at 700 nm (UV/Vis spectrophotometer, Jenway, Staffordshire, UK). The blank used was distilled water.

2.7. Nitric oxide (NO) scavenging assay

The NO scavenging assay was analyzed according to the procedure described by Ilavarasan and Venkataraman [23]. Equal volumes of the test compounds (whole fruit or pulp extracts or ascorbic acid) at various concentrations (1, 2, and 5 mg/mL) and sodium nitroprusside were mixed and incubated at 25 °C for 5 h. After 5 h, 0.5 mL of the incubation mixture was diluted with 0.5 mL of Greiss reagent. Then the absorbance was read at 540 nm.

Calculation = 100/ blank absorbance x sample absorbance

2.8. Total antioxidant capacity (TAC)

The TAC was carried out as described by Saha, Hasan, Akter, Hossain, Alam, Alam and Mazumder [24]. About 3 mL of reagent solution and an aliquot (0.3 mL) of the sample (whole fruit or pulp extracts or ascorbic acid) at various concentrations (1, 2, and 5 mg/mL) were mixed and incubated at 95 °C for 90 min. After cooling the mixture to room temperature, the absorbance was read at 695 nm against a blank. Methanol was used as blank.

Total antioxidant capacity (%) = 100 x [(Abs. of control − Abs. of the sample)/(Abs. of control]

2.9. Statistical analysis

The results were analyzed using one-way ANOVA on a GraphPad Prism 5 (CA, USA). The data are presented as the mean values of three replicates ± standard deviation (SD). For multiple comparisons, Tukey's posthoc test was used, with a significance level of $p < 0.05$.

3. Results

3.1. Qualitative phytochemical analysis

Table 1 shows several secondary metabolites are present in the plantain extracts. The results showed that saponin was not detected in both extracts. Moreover, tannin was not detected in the pulp extract. Other phytochemicals detected included

Table 1. Qualitative phytochemicals in unripe Plantain whole fruit extract and plantain pulp extract.

Phytochemicals	Plantain whole fruit extract	Plantain pulp extract
Phenol	+	+
Terpenoids	+	+
Tannins	+	–
Saponin	–	–
Flavonoids	+	+
Cardiac glycosides	+	+
Reducing sugar	+	+
Alkaloids	+	+
Steroids	+	+

Key: + = Detected; - = Not detected.

cardiac glycosides, terpenoids, phenols, reducing sugars, and flavonoids, alkaloids, and steroids (Table 1).

3.2. Quantitative phytochemical analysis

From the quantitative analysis in Table 2, the whole fruit extract of the unripe plantain contained the highest tannin (5.0813 ± 0.163 mg/g), flavonoid (41.851 ± 1.011 mg/g), alkaloid (1.389 ± 0.200 mg/g) and saponin (0.344 ± 0.011 mg/g) contents. Conversely, pulp extract of the unripe plantain had higher terpenoid (43.225 ± 1.651 mg/g), and phenol (4.904 ± 0.192 mg/g) contents.

3.3. Mineral composition

Iron content was significantly higher in the whole fruit extract (5.529 ± 0.003 mg/g extract) than the pulp extract (5.261 ± 0.019 mg/g extract), while magnesium and potassium were lower in whole fruit extract (9.752 ± 0.010 mg/g extract and 4.284 ± 0.003 mg/g extract respectively) than in plantain pulp (9.943 ± 0.011 and 4.756 ± 0.003 mg/g extract respectively) (Table 3). High sodium content was observed in the whole fruit extract (148.070 ± 0.114 mg/g extract), while the plantain pulp had 147.105 ± 0.057 mg/g extract. Similarly, the whole fruit extract had a higher mineral content of calcium, phosphorus, zinc, and copper (11.478 ± 0.005 mg/L; 4.694 ± 0.003 mg/g extract; 0.739 ± 0.277 mg/g extract; 1.196 ± 0.010 mg/g extract). Generally, the mineral content of sodium was predominant.

Table 2. Quantitative phytochemicals in unripe whole fruit extracts and plantain pulp.

	Plantain whole fruit extract (mg/g)	Plantain pulp extract (mg/g)
Tannins (mg GAE/g)	5.0813 ± 0.163^{c}	3.186 ± 0.172^{a}
Flavonoids (mg QE/g)	41.851 ± 1.011^{d}	28.601 ± 0.891^{a}
Terpenoids	30.387 ± 0.797^{c}	43.225 ± 1.651^{a}
Alkaloid	1.389 ± 0.200^{a}	0.861 ± 0.073^{a}
Phenol (mg GAE/g)	3.767 ± 0.231^{b}	4.904 ± 0.192^{a}
Saponins	0.344 ± 0.011^{c}	0.216 ± 0.011^{a}

The results are mean values of three replicates ± standard deviation (SD). Across the row, values with different superscripts (a-d) are statistically significant at $p < 0.05$.

Table 3. Mineral composition of unripe plantain whole fruit extracts and plantain pulp extract.

	Plantain whole fruit extract (mg/g extract)	Plantain pulp extract (mg/g extract)
Iron (Fe)	5.529 ± 0.003^{b}	5.261 ± 0.019^{a}
Magnesium (Mg)	9.752 ± 0.010^{c}	9.943 ± 0.011^{a}
Sodium (Na)	148.070 ± 0.114^{b}	147.105 ± 0.057^{a}
Calcium (Ca)	11.478 ± 0.005^{d}	10.069 ± 0.005^{a}
Potassium (K)	4.284 ± 0.003^{d}	4.756 ± 0.003^{a}
Phosphorus (P)	4.694 ± 0.003^{d}	4.313 ± 0.006^{a}
Copper (Cu)	1.196 ± 0.010^{c}	0.967 ± 0.005^{a}
Zinc (Zn)	0.739 ± 0.277^{a}	0.653 ± 0.252^{a}

The results are mean values of three replicates ± standard deviation (SD). Across the row, values with different superscripts (a-d) are statistically significant at $p < 0.05$.

3.4. Antioxidant activities

The DPPH radical scavenging activities of the unripe plantain whole fruit and plantain pulp extracts showed no significant changes in all various concentrations compared with the control except in the lowest concentration where the plantain pulp extract had a significant increase (Fig. 1).

The radical scavenging activities of the unripe plantain whole fruit and pulp extracts are shown in Figs. 2–4. Relative to ascorbic acid, the plantain whole fruit and pulp extracts showed no significant difference at all concentrations.

Fig. 5 shows the total antioxidant activity of the unripe plantain whole fruit and pulp extracts. There were significant increases in the unripe plantain pulp extract across all concentrations compared with ascorbic acid. However, the whole fruit extract showed no appreciable difference relative to ascorbic acid.

3.5. The correlation analysis between antioxidant activities and mineral contents

Tables 4 and 5 show the correlation between the antioxidant activities and mineral contents of the whole fruit or pulp extracts of the plantain. Our results showed differential correlations (positive and negative) between antioxidant activities and the mineral elements.

For the plantain pulp, our results (Table 4) showed scavenging activities for NO had moderate

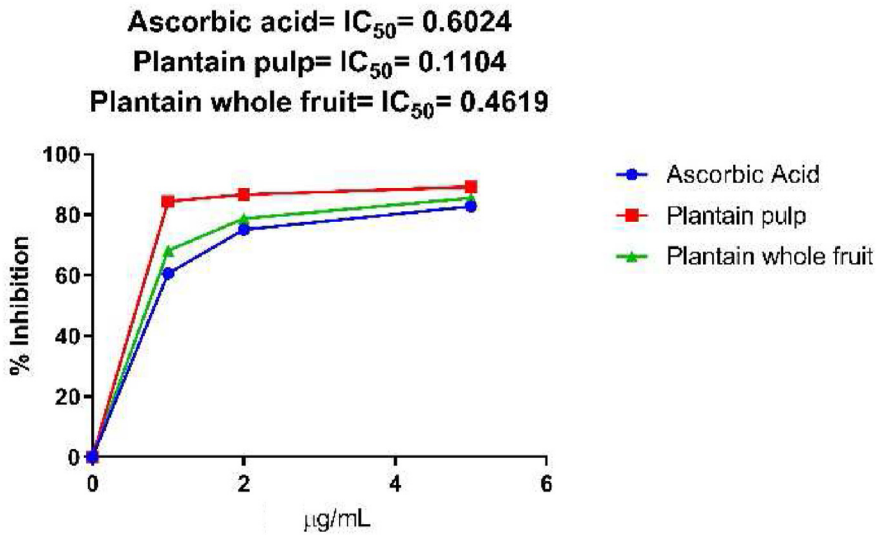

Fig. 1. DPPH radical scavenging activity of the whole fruit or pulp extracts of unripe plantain or ascorbic acid. Data are mean values of three replicates ± SD.

correlation with Fe (r = 0.504) and Na (r = 0.472); weak correlation with Ca (r = 0.397) and P (r = 0.224) and negative correlation with Mg (r = −0.786), K (r = −0.887), Cu (r = −0.376) and Zn (r = −0.719). Scavenging activity for DPPH in plantain pulp showed strong positive correlation with Ca (r = 0.999), P (r = 0.99), and Cu (r = 0.731); weak correlation with Zn (r = 0.392), K (r = 0.115) and Mg (r = 0.297) and negative correlation with Fe (r = −0.626) and Na (r = −0.655). Hydroxyl radical ($OH^{\cdot}$) scavenging activity had strong positive correlation with Ca (r = 0.923), P (r = 0.977), and Cu (r = 0.922); moderate correlation with K (r = 0.45) and Zn (r = 0.686); and negative correlation with Fe (r = −0.857) and Na (r = −0.875). TAC had weak correlation with the mineral contents of the plantain pulp; Fe (r = 0.359), Mg (r = 0.009), Na (0.393) and K (0.194), while there was negative correlation for Ca (r = −0.964), P (r = −0.301), Cu (r = −0.488) and Zn (r = −0.093). FRAP correlated negatively with all minerals except for Fe (r = 0.99) and Na (r = 0.994) which had positive correlation.

For the plantain whole fruit (Table 5), the results showed a strong correlation between the NO scavenging activity and Fe (r = 0.994) and Zn (r = 0.992); while having a negative correlation with Mg

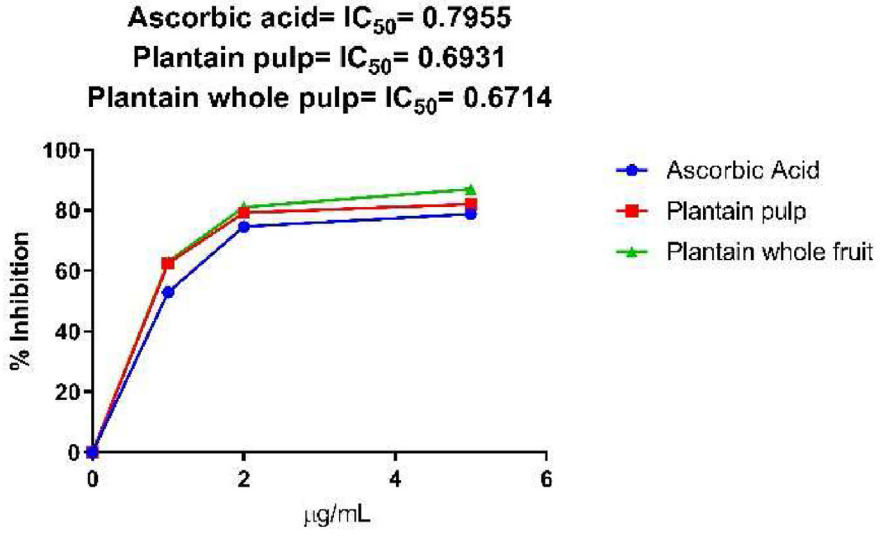

Fig. 2. FRAP activity of the extracts of whole fruit or pulp extracts of unripe plantain or ascorbic acid. Data are mean values of three replicates ± SD.

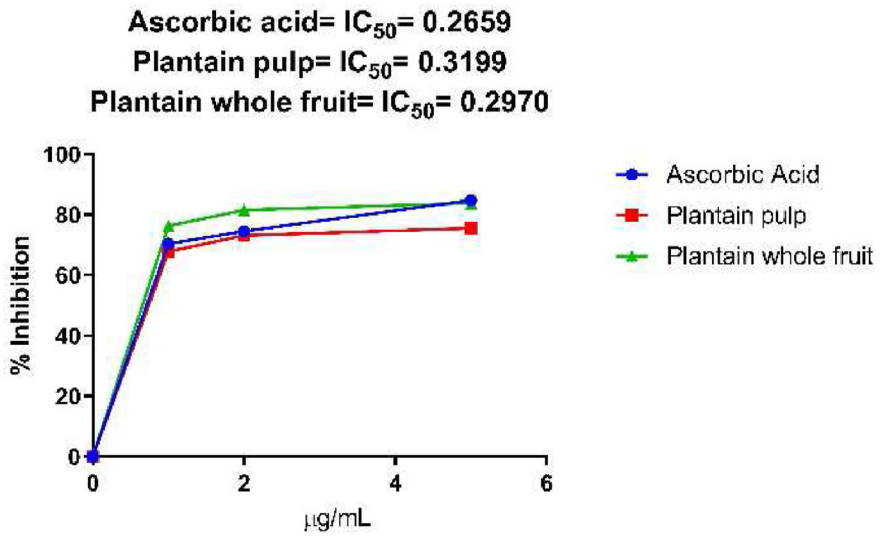

Fig. 3. Hydroxyl scavenging activity of whole fruit or pulp extracts of unripe plantain or ascorbic acid. Data are mean values of three replicates ± SD.

(r = −0.999), K (r = −0.997), P (r = −0.998). For DPPH scavenging activities, negative correlation was noted for Mg (r = −0.184), Na (r = −0.795), K (r = −0.297), P (r = −0.195) and Cu (r = −0.88) while Fe (r = 0.011) and Ca (r = 0.834) had positive correlation. Furthermore, the hydroxyl radical ($OH^{\cdot}$) scavenging activities had negative correlation with Mg (r = −0.271), Na (r = −0.738), K (r = −0.297), P (r = −0.282), Cu (r = −0.834), while showing positive correlation for Fe (r = 0.1), Zn (r = 0.079), and Ca (r = 0.88). For the FRAP, Fe (r = 0.162), Ca (r = 0.908), and Zn (r = 0.142) had strong correlation. In contrast, FRAP had negative correlation with Mg (r = −0.331), Na (r = −0.694), K (r = −0.356), P (r = −0.341) and Cu (r = −0.798).

4. Discussion

Phytochemicals are naturally occurring bioactive substances found in plants linked to numerous medicinal values including anti-inflammatory, antioxidant, and disease-preventive effects [25,26]. Our present investigation identified phenols, terpenoids, flavonoids, cardiac glycosides, reducing sugars, alkaloids, and steroids in the whole fruit and pulp extracts of the unripe plantain. These secondary metabolites could contribute to the pharmacological properties of the plantain. For example, terpenoids could reduce hyperglycemia [27]. Meanwhile, antioxidant, free radical scavenging, anti-inflammatory, and anti-carcinogenic activities

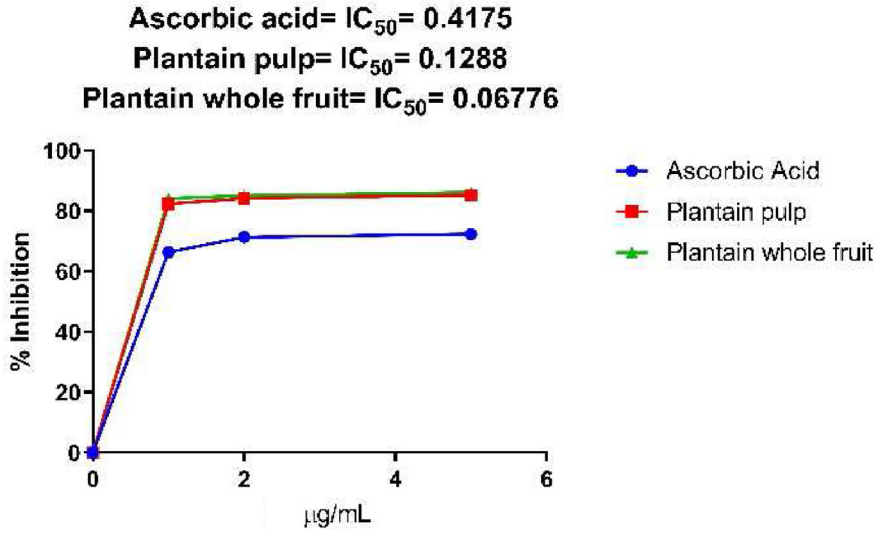

Fig. 4. NO scavenging activity of whole fruit or pulp extracts of unripe plantain or ascorbic acid. Data are mean values of three replicates ± SD.

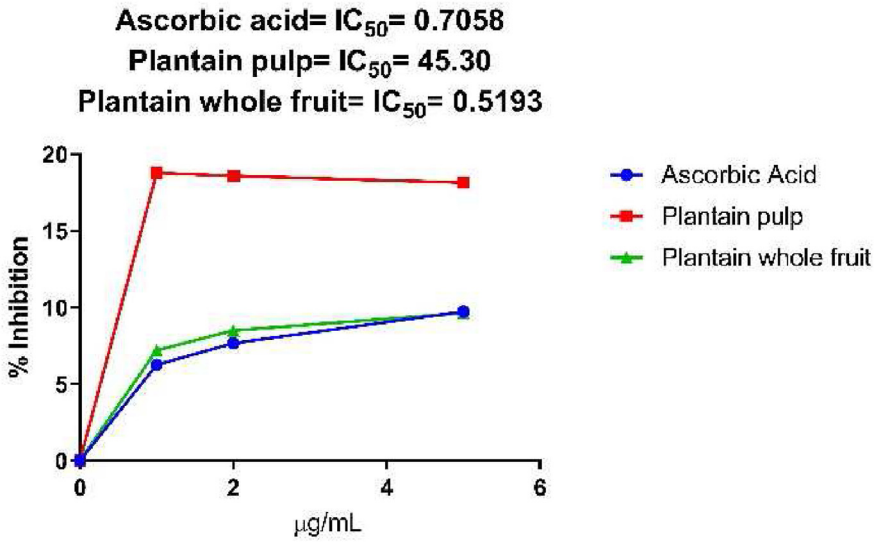

Fig. 5. TAC activity of the extracts of whole fruit or pulp extracts of unripe plantain or ascorbic acid. Data are mean values of three replicates ± SD.

Table 4. Correlation coefficients for antioxidant activity and mineral contents of plantain pulp.

	NO	DPPH	OH	TAC	FRAP	Fe	Mg	Na	Ca	K	P	Cu	Zn
NO	1												
DPPH	0.357	1											
OH	0.013	0.939	1										
TAC	−0.626	−0.952	−0.788	1									
FRAP	0.376	−0.731	−0.922	0.488	1								
Fe	0.504	−0.626	−0.857	0.359	0.99	1							
Mg	−0.786	0.297	0.608	0.009	−0.868	−0.93	1						
Na	0.472	−0.655	−0.875	0.393	0.994	0.999	−0.916	1					
Ca	0.397	0.999	0.923	−0.964	−0.702	−0.593	0.256	−0.622	1				
K	−0.887	0.115	0.45	0.194	−0.761	−0.846	0.983	−0.826	0.073	1			
P	0.224	0.99	0.977	−0.901	−0.819	−0.729	0.427	−0.753	0.984	0.252	1		
Cu	−0.376	0.731	0.922	−0.488	−1	−0.99	0.868	−0.994	0.702	0.761	0.819	1	
Zn	−0.719	0.392	0.686	−0.093	−0.914	−0.963	0.995	−0.952	0.353	0.959	0.517	0.914	1

Table 5. Correlation coefficients for antioxidant activity and mineral contents of plantain whole fruit.

	NO	DPPH	OH	TAC	FRAP	Fe	Mg	Na	Ca	K	P	Cu	Zn
NO	1												
DPPH	0.123	1											
OH	0.211	0.997	1										
TAC	0.034	0.997	0.985	1									
FRAP	0.272	0.989	0.999	0.972	1								
Fe	0.994	0.011	0.1	−0.079	0.162	1							
Mg	−0.999	−0.184	−0.271	−0.096	−0.331	−0.985	1						
Na	0.506	−0.795	−0.738	−0.846	−0.694	0.599	−0.451	1					
Ca	0.65	0.834	0.88	0.782	0.908	0.561	−0.696	−0.328	1				
K	−0.997	−0.21	−0.297	−0.122	−0.356	−0.98	1	−0.428	−0.715	1			
P	−0.998	−0.195	−0.282	−0.107	−0.341	−0.983	1	−0.442	−0.704	1	1		
Cu	0.366	−0.88	−0.834	−0.919	−0.798	0.467	−0.307	0.988	−0.471	−0.282	−0.297	1	
Zn	0.992	−0.011	0.079	−0.1	0.142	1	−0.981	0.616	0.544	−0.976	−0.979	0.486	1

of plant could be due to the presence of flavonoids and phenols [28]. In addition, the presence of phenolic constituents in plants contributes to the color, olfactory, and antioxidant qualities of food [29]. In addition, alkaloids may provide essential biochemical functions in biological systems [26], including antimicrobial activity [30]. Steroids could improve nitrogen retention in osteoporosis patients

and animals dying from dietary deficiency [31]. Cardiac glycosides are crucial in reducing cardiac arrest. Consumption of plants containing cardiac glycosides increases cardiac output through increased heart contraction [32]. Thus, the presence of these medicinal phytochemicals demonstrates the therapeutic potential of the whole fruit and pulp extracts of unripe plantain. Krishna Kumar, Pradeepa, Kumar and Kumar [33], also reported that ethanol extracts of plantain had beneficial biological components such as glycosides, flavonoids, terpenoids, and tannins. However, only the whole fruit extract had tannin and this might be a result of its presence in the peel as reported by Ighodaro [34].

The mineral analysis revealed the presence of eight essential minerals (Cu, Zn, P, Mg, Fe, Na, K, and Ca). The whole fruit extract was richer in some minerals like Fe, Na, Ca, P, Cu and Zn. These minerals are therapeutically significant and necessary for regular growth, development, and proper functioning [35]. For example, the normal bone growth and development in humans require calcium. The plantain samples had a considerable amount of calcium, making them suitable calcium sources. The finding is consistent with earlier report, which showed that plantain flour had considerable amount of calcium [36]. Magnesium was present in both whole fruit and pulp extracts. Mg is required for normal heart function and the prevention of diabetes in its early stages, bone and tooth structural strength, detoxification, and nerve impulse transmission [37]. Magnesium level in the pulp extract was moderate, similar to that reported earlier by Oyeyinka and Afolayan [38].

Potassium, sodium, and phosphorus concentrations were similar in both plantain whole fruit and pulp extracts. Potassium has a role in the treatment of hypertension, cardiac efficiency, and physiological processes, including the regulation of water balance [38]. Sodium is a critical electrolyte because it aids in the control of osmotic pressure balance and water balance. The sodium level of plantain whole fruit and pulp extracts was quite higher than the other minerals. Phosphorus helps build teeth and bone and increases the absorption of calcium. Zinc is essential for neurodevelopment, cognitive function, and tissue repair [39]. Zinc concentration was rather low in the extracts, suggesting the need for supplementing the plantain diet with zinc-rich dietary options. Oyeyinka and Afolayan [38] repotred similar results comparable to the present study. Iron is a core part of hemoglobin; its absence could cause anemia. The body requires iron for the production of oxygen-carrying proteins, including hemoglobin and myoglobin, as well as for the formation of heme enzymes [40]. The two extracts had a moderate amount of iron. The iron content in the whole fruit extract is comparable to that earlier reported for unripe plantain [36]. Copper is required for the control of red blood cells. The results obtained were similar to the analysis of unripe and ripe plantains by Shadrach, Banji and Adebayo [1].

Antioxidants are molecules that limit/hinder the generation of reactive oxygen species (ROS). In a typical healthy body, numerous antioxidative defense mechanisms effectively regulate the scavenging of prooxidants (e.g. ROS) [41]. When unfavorable physicochemical, environmental, or pathologic circumstances are encountered, the normally preserved redox balance shifts, leading to oxidative stress that is usually associated with the development of severe health disorders, including autoimmune diseases [42]. As a result, examining the antioxidant capabilities of various foods and plants to boost antioxidant levels and their activities in the body is desirable [43–46]. In a dose-dependent manner, the two plantain extracts were able to scavenge DPPH radicals (Fig. 1), with the plantain pulp extract having higher DPPH radical scavenging potential compared with the whole fruit. Additionally, the FRAP of the plantain whole fruit and pulp extracts showed a dose-dependent trend (Fig. 2); the reduction power activity was almost the same in the two extracts. The capacity of the plantain extracts to scavenge hydroxyl radicals demonstrated that both extracts were capable of scavenging ·OH generated in the Fenton reaction (Fig. 3). At various concentrations, plantain pulp had a lower capacity to scavenge ·OH than whole fruit extract. The TAC activity of the plantain pulp extract was strong and promising. Indeed, at all concentrations, the whole fruit extract had the least scavenging ability. Meanwhile, the pulp extract had a higher potential for scavenging hydroxyl and nitrogen radicals than the whole fruit extract or ascorbic acid.

Furthermore, we showed that the antioxidant capacity of the plantain whole fruit or pulp correlated with the mineral contents. In the plantain whole fruit, Ca positively and strongly correlated with all antioxidant activities, indicating that the presence of Ca may enhance the whole fruit's antioxidant potential. However, minerals such as Mg, K, and P may negatively affect the antioxidant capacity. For the plantain pulp, the presence of Fe and Na could promote the antioxidant capacity of the pulp. For Zn and Cu, it negatively correlated with NO radical, TAC, and FRAP, indicating that the presence of these minerals in the pulp could undermine its antioxidant potential. Collectively, our findings suggest that the plantain pulp could be a better

source of antioxidants and related medicinal properties than the plantain whole fruit (pulp and peel).

5. Conclusion

Based on the findings, the whole fruit and pulp extracts of the unripe plantain had considerable amounts of secondary metabolites that could benefit health. More specifically, the whole fruit and pulp extracts are particularly rich in several important nutrients such as Mg, Cu, Ca, P, and Zn, among others. Thus, plantain holds a prospect to serve as a rich source of these minerals elements in our diet. Furthermore, the scavenging properties and the presence of phenolic chemicals of the extracts may support their use as adjuvant therapy in the management and prevention of oxidative stress-related conditions.

Conflict of interest

The authors declare no conflict of interest.

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