

Antioxidant Activities, Nutrient Composition and Sensory Properties of Unripe Plantain-Purple Skinned Sweet Potato Flour Blends

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Abstract

The functional properties of plant foods have received much attention in recent times. Therefore, the present study sought to assess the antioxidant potential and nutrient composition of unripe plantain (UP) and purple skinned sweet potato (PP) composite blends (UP: PP); (100:0, 80:20, 60:40, 40:60, 20:80 and 0:100) and also to evaluate the sensory properties of the porridge prepared from the blends. HPLC/DAD analyses revealed the presence of some flavonoids and phenolic acids. The evaluated antioxidant indices increases progressively as the percentage inclusion of sweet potato increases, and the highest antioxidant activities was recorded for 100% sweet potato. Whereas, the evaluated proximate indices, with exception of moisture content, increases as the inclusion of unripe plantain increases in the blend; and the highest carbohydrate (78.51%), protein (13.35%), fiber (0.19%) and fat (5.56%) were recorded for 100% unripe plantain. The 100% potato recorded the highest level of Ca, Mg, P and Fe, while the highest level of Na and K was recorded for 100% unripe plantain. The result of the sensory properties of the porridge showed a varied rating with respect to the evaluated sensory parameters; however, better overall acceptability was recorded for porridge from two blends (60UP:40PP, 40UP:60PP). Result from this investigation showed that combination of these plant foods can be harnessed as functional food, most especially two of the blends; (60UP:40PP, 40UP:60PP) and these could be a valuable blend that could be explored in the management of free radical mediated diseases.

Keywords: Antioxidant potential; Nutritional value; Phenolic composition; Sensory properties; *Solanum tuberosum*; *Musa paradisiaca*

1. Introduction

The use of traditional medicine is widespread, and plants still present a large source of natural antioxidants that might serve as leads for the development of novel drugs. Natural products are considered to be less toxic with fewer side effects when compared with synthetic drugs (Geetha *et al.*, 1996; Rao *et al.*, 2003). In searching for novel natural antioxidants, some plant foods have been extensively studied in the past few years for their antioxidant and radical scavenging components (Huang *et al.*, 2005).

Plantain belongs to the *Musaceae* family, a rhizomatous perennial crop and is cultivated in many tropics and subtropical countries of the world. It ranks third after yams and cassava for sustainability in Nigeria (Akomolafe and Aborisade, 2007). The nutritional potential and functional properties of starch of ripe and unripe plantains have been evaluated (Izunfuo and Omuaru 2006). Unripe plantain meals are usually consumed by Nigerian diabetics to reduce postprandial glucose level because of its low glycemic index (Eleazu *et al.*, 2010; Eleazu and Okafor, 2012). This is because the propensity of individuals to develop diabetes and obesity is due to the increased consumption of carbohydrate rich foods with high glycemic index (Willett *et al.*, 2002). Carotenoid-rich foods like plantain protect against certain chronic diseases, including diabetes, heart disease and cancer (Ford *et al.*, 1999).

Sweet potatoes originated from Central America and were brought to Western Europe in 1942 (Srisuwan *et al.*, 2006). Sweet potatoes are rich sources of vitamins (B1, B2, C and E), minerals (zinc, magnesium, potassium and calcium), carbohydrate, dietary fibre, and non-fibrous complex (Suda *et al.*, 2003). β -carotene is one of the most important dietary compounds found in sweet potatoes and this pigment is responsible for the characteristic orange color of sweet potatoes and represents 86.4 to 89.0% of the carotenoids in yellow, purple and orange fleshed sweet potatoes (Woolfe, 1992).

Research has showed the health benefits of sweet potato phenolic extracts in the management of diabetes, hypertension and anemia (Shimozono *et al.*, 1996; Rabah *et al.*, 2004). The use of white skinned sweet potato in Shikoku, Japan as folk medicine for the treatment of diabetes (Kusano *et al.*, 2001; Ludvick *et al.*, 2004; Kusano *et al.*, 2005), its use in improving glucose abnormality and lipid metabolism in obese fatty rats

(Kusano and Abe, 2000) have been documented. Investigations on the health benefits of purple-fleshed sweet potatoes showed that the presence of anthocyanins confer on it a good radical scavenging ability, hepatoprotective properties, anti-inflammatory action, antimicrobial potential and ability to reduce blood pressure (Suda *et al.*, 1997; Yoshimoto *et al.*, 1999; Oki *et al.*, 2002; Suda *et al.*, 2003).

In the 1960s and 1970s, composite blends very often found themselves at the focus of attention in European and International research (Bugusu *et al.*, 2001). In the developing countries the use of composite blends offers a better use of domestic agricultural products (Bugusu *et al.*, 2001), with the overall effect of enhancing the use of the food product as a functional food. Recently, consumers' awareness of the need to eat high quality and healthy foods is increasing (Ndife and Abbo, 2009).

Previous reports have established the nutraceutical potentials of unripe plantain and sweet potato (Kusano *et al.*, 2001; Ludvick *et al.*, 2004; Kusano *et al.*, 2005; Eleazu *et al.*, 2010; Eleazu and Okafor, 2012). Therefore, as part of effort to produce nutritionally adequate foods with good antioxidant potential from blends of Nigerian indigenous food crops, the present study is designed to evaluate the antioxidant potential, nutritional value of the composite flour blends of unripe plantain and purple skinned sweet, and the sensory properties of the porridge prepared from the blends, with an overall aim of developing a suitable functional food that could be explored in the management of free radical mediated diseases.

2. Materials and Methods

2.1. Collection and Identification of Samples

Purple skinned sweet potato (*Ipomoea batatas* L.) and unripe plantain (*Musa paradisiacae* L.) were obtained from Aba Oyo Market, Akure, Ondo State and the authentication of the samples was carried out at the Department of Crop, Soil and Pest Management (CSP), Federal University of Technology, Akure, Nigeria. The chemicals used were of analytical grade while the water was glass distilled.

2.1.1 Extraction of Sample for Antioxidant Assay

The samples of both unripe plantain and purple skinned sweet potato were washed thoroughly with clean water, peeled and sliced into small pieces. The sliced portions were soaked in warm water to prevent subsequent browning and then sundried for about 10 days. The dried samples were blended into powder separately, the two blends were then mixed into different proportions; Unripe Plantain (UP): Purple Skinned Sweet Potato (PP): 100:0, 80:20, 60:40, 40:60, 20:80, 0:100, respectively, transferred into plastic buckets with cover and labeled accordingly.

2.2 HPLC-DAD Phenolic Analyses

2.2.1 Sweet Potato

Reverse phase chromatographic analyses were carried out under gradient conditions using C₁₈ column (4.6 mm x 150 mm) packed with 5µm diameter particles; the mobile phase was water containing 2% acetic acid (A) and methanol (B), and the composition gradient was: 5% of B until 2 min and changed to obtain 25%, 40%, 50%, 60%, 70% and 100% B at 10, 20, 30, 40, 50 and 60 min, respectively, following the method described by Peroza *et al.* (2013) with slight modifications. Identification of the compounds was performed by comparing their retention time and UV absorption spectrum with those of the commercial standards. The flow rate was 0.7 ml/min, injection volume 40 µl and the wavelength were 254 nm for gallic acid, 280 nm catechin and epicatechin, 327 nm for caffeic, caffeic derivative, ellagic and chlorogenic acids, and 365 nm for quercetin, isoquercitrin, quercitrin, rutin and kaempferol. The samples and mobile phase were filtered through 0.45 µm membrane filter (Millipore) and then degassed by ultrasonic bath prior and injected into the HPLC for analyses. The chromatography peaks were confirmed by comparing its retention time with those of reference standards and by DAD spectra (200 to 500 nm).

2.2.3 Unripe Plantain

Reverse phase chromatographic analyses were carried out under gradient conditions using C₁₈ column (4.6 mm x 150 mm) packed with 5µm diameter particles; the mobile phase was water containing 1% acetic acid (A) and acetonitrile (B), and the gradient program was started with 13% of B until 10 min and changed to obtain 20%, 30%, 50%, 70% and 100% B at 20, 30, 40, 50 and 60 min, respectively, following the method described by Boligon *et al.* (2012), with slight modifications. *Plantain* extract was analyzed at a concentration of 20 mg/mL. The flow rate was 0.6 ml/min, injection volume 40 µl and the wavelength were 254 nm for gallic acid, 327 nm for caffeic and ellagic acids, and 365 nm for quercetin, isoquercitrin, and rutin. The samples and mobile phase were filtered through 0.45 µm membrane filter (Millipore) and then degassed by ultrasonic bath and injected into

the HPLC for analyses. The chromatography peaks were confirmed by comparing its retention time with those of reference standards and by DAD spectra (200 to 500 nm).

2.2.4 Quantification of compounds by HPLC-DAD in Unripe Plantain and Millet

Calibration curves of the standards were prepared and all chromatographic operations were carried out at ambient temperature and in triplicate. The limit of detection (LOD) and limit of quantification (LOQ) were calculated based on the standard deviation of the responses and the slope using three independent analytical curves, as defined by Boligon *et al.* (2012). LOD and LOQ were calculated as 3.3 and $10 \sigma/S$, respectively, where σ is the standard deviation of the response and S is the slope of the calibration curve.

2.3 Antioxidant indices

2.3.1 Total phenolic content

The total phenolic content of the methanol/water extracts was determined by the Folin-Ciocalteu assay as described by Waterman and Mole (1994). The hydro-alcoholic extract (0.25 ml), was placed in a 25 ml volumetric flask and 5 ml distilled water was added. Folin-Ciocalteu's phenol reagent (1.25 ml) was added and mixed. After 2 min, 3.75 ml 20% (w/v) sodium carbonate solution was added. The contents were mixed and distilled water was added to volume and mixed. The mixture was left to stand for 2 h after addition of the sodium carbonate for which the absorbance of the mixture was measured at 760 nm using a Lambda EZ150 spectrophotometer (Perkin Elmer, USA). The standard used was tannic acid and the results which were determined in triplicates were expressed as mg tannic acid equivalents per gram of the sample.

2.3.2 Total flavonoid content

The total flavonoid content of the extract was determined using a slightly modified method reported by Meda *et al.* (2005). Briefly, 0.5 mL of appropriately diluted sample was mixed with 0.5 mL methanol, 50 μ L of 10% AlCl_3 , 50 μ L of 1 mol L^{-1} potassium acetate and 1.4 mL water, and allowed to incubate at room temperature for 30 min. Thereafter, the absorbance of each reaction mixture was subsequently measured at 415 nm. The total flavonoid was calculated using quercetin as standard by making use of a seven point standard curve (0-40 μ g/ml or 0-100 μ g/ml), the total flavonoids content of samples was determined in triplicates and the results were expressed as mg quercetin equivalent per gram of the sample.

2.3.3 Reducing antioxidant power

The reducing power of the extracts was determined by assessing the ability of each extract to reduce FeCl_3 solution as described by Oyaizu (1986). Briefly, appropriate dilution of each extract (2.5 ml) was mixed with 2.5 ml 200 mM sodium phosphate buffer (pH 6.6) and 2.5 ml 1% potassium ferricyanide. Each mixture was incubated at 50°C for 20 min and then 2.5 ml 10% trichloroacetic acid was added. This mixture was centrifuged at 353 x g for 10 min. Five millilitres of the supernatant was mixed with an equal volume of water and 1 ml of 0.1% ferric chloride. The absorbance was measured at 700 nm. The ferric reducing antioxidant power was determined in triplicate and expressed as mg ascorbic acid equivalent/g of the sample.

2.3.4 ABTS antiradical assay

Antioxidant activity of the extracts was determined using the 2, 2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) ABTS antiradical assay (Awika *et al.* 2003). The ABTS^{*+} (mother solution) was prepared by mixing equal volumes of 8 mM ABTS and 3 mM potassium persulphate ($\text{K}_2\text{S}_2\text{O}_8$) (both prepared using distilled water) in a volumetric flask, which was wrapped with foil and allowed to react for a minimum of 12 h in a dark place. The working solution was prepared by mixing 5 ml of the mother solution with 145 ml phosphate buffer (pH 7.4). A range of trolox (6-hydroxy-2, 5, 7, 8-tetramethylchroman-carboxylic acid) standard solutions (100–1000 μ M) were prepared in acidified methanol. The working solution (2.9 ml) was added to the methanolic extracts (0.1 ml) or Trolox standard (0.1 ml) in a test tube and mixed with a vortex. The test tubes were allowed to stand for exactly 30 min. The absorbance of the standards and samples were measured at 734 nm with a Lambda EZ150 spectrophotometer. The results which were determined in triplicates were expressed as μ mol Trolox equivalents/g sample, on dry weight basis

2.3.5 DPPH antiradical assay

The DPPH assay was done according to the method of Brand-Williams *et al.* (1995), with some modifications. The stock solution was prepared by dissolving 24 mg DPPH with 100 mL methanol and then stored at -20°C until needed. The working solution was obtained by mixing 10 mL stock solution with 45 mL methanol to obtain an absorbance of 1.1 units at 515 nm using the spectrophotometer. Phenol extracts (300 mL) were allowed to react with 2700 mL of the DPPH solution for 6 h in the dark. Then the absorbance was taken at

515 nm. Results which were determined in triplicates were expressed in $\mu\text{mol Trolox Equivalent/g}$ sample. Additional dilution would be needed if the DPPH value measured was over the linear range of the standard curve.

2.3.6 *OH Radical scavenging ability*

The ability of the extract to prevent $\text{Fe}^{2+}/\text{H}_2\text{O}_2$ induced decomposition of deoxyribose will be carried out using the method of Halliwell and Gutteridge (1985). Briefly, freshly prepared extract (0-100 μl) was added to a reaction mixture containing 120 μl , 20mM deoxyribose, 400 μl , 0.1M phosphate buffer pH 7.4, 40 μl , 20mM hydrogen peroxide and 40 μl , 500mM FeSO_4 , and the volume was made to 800 μl with distilled water. The reaction mixture was incubated at 37 $^\circ\text{C}$ for 30min and then stopped by the addition of 0.5ml of 2.8% TCA. This was followed by the addition of 0.4ml of 0.6% TBA solution. The reaction tubes were subsequently incubated in boiling water for 20min. The absorbance will be measured at 532nm using a spectrophotometer and the percentage radical inhibition which was determined in triplicates were subsequently calculated.

2.4 *Proximate Analysis*

Proximate composition (moisture, proteins, fat, carbohydrates and ash) of the various proportions of unripe plantain-sweet potato blends were determined by the standard methods (AOAC, 1990). The crude protein content ($\text{N} \times 6.25$) of the samples was estimated by the macro-Kjeldahl method; the crude fat was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus; the ash content was determined by incineration at 600 \pm 15 $^\circ\text{C}$. Total carbohydrates were calculated by difference.

2.5 *Mineral Elements Determination*

Sample product (2g) was ashed in a muffle furnace. 15ml of 20% (v/v) of nitric acid solution was ashed in the crucible to break up the ash. This was boiled and filtered and acid-washed through Whatman paper. The residue and the paper were washed 3 times with distilled de-ionized water into a standard 100ml volumetric flask, and diluted to 100ml with distilled de-ionized water. Atomic absorption spectrophotometer (Pye Unicam sp. 9 AAS) was used for determination of calcium, magnesium, iron, sodium, manganese, phosphorous and potassium.

2.6 *Sensory Evaluation*

Sensory evaluation was carried out on the porridge obtained from various blends of the unripe plantain-sweet potato based on the 9-points hedonic scale. The various proportions were prepared using the conventional method by mixing and turning in 200ml hot water and made into pastes. A 10-man panel tasted and evaluated the pastes and indicated the degree of acceptance of the food samples.

2.7 *Statistical Analysis*

All experiments were performed in triplicates. Analysis at every time point from each experiment was carried out in triplicate. Means, standard errors and standard deviations were calculated from replicates within the experiments and analyzed using Microsoft Excel XP.

3. **Result and discussion**

3.1 *Phenolic Composition*

In searching for novel natural antioxidants, some plants have been extensively studied in the past few years for their antioxidant and radical scavenging compounds. These include anthocyanin (Espin *et al.*, 2000), flavonoids and phenolic acids (Herrmann, 1976; Herrmann, 1988; Herrmann, 1989; Rice-Evans, 1997). Plant foods such as vegetables, fruits, roots and spices are natural sources of antioxidants (Herrmann, 1976; Herrmann, 1988; Herrmann, 1989; Rice-Evans, 1997). The prevention of degenerative diseases such as cancer, cardiovascular diseases and diabetes by plant foods is by virtue of their anti-oxidative properties.

The qualitative and quantitative estimates of phenolic compounds in purple fleshed sweet potato and unripe plantain are as shown in Figure 1 and Table 1. The result revealed the presence of gallic acid, caffeic acid, ellagic acid, rutin, quercetin and isoquercetin in purple skinned sweet potato and unripe plantain. However, purple skinned sweet potato has other phenolic compounds (chlorogenic acid, quercetin, kaempferol, epicatechin and catechin) not found in unripe plantain.

Sweet potatoes have been reported to contain chlorogenic acids (Bellail, *et al.*, 2012) and several caffeoylquinic and dicaffeoylquinic acids. Chlorogenic acids are a large family of esters formed between quinic acid and one to four residues of certain trans- cinnamic acids, most commonly; caffeic, p-coumaric, ferulic, sinapic and dimethoxycinnamic acid (Clifford, 2000; Clifford, 2003). Chlorogenic acids have interesting properties *in vitro*, such as inhibition of Na^+ -dependent D-glucose uptake in rat intestinal brush border membrane

vesicles (Welsch *et al.*, 1989). The presence of gallic acid and catechin in *Musa paradisiaca* has been previously reported (Mendez *et al.*, 2003).

3.2 Antioxidant properties

The result of the total phenolic content of the various blends of the composite flour is as shown in Figure 2. The result revealed an increasing phenolic content in the blends as the inclusion of purple skinned sweet potato increases with respect to unripe plantain. The total phenolic content of the 100% unripe plantain-0% purple skinned sweet potato blend recorded the least phenolic content (0.459mg/g) while the highest phenolic content (1.272mg/g) was recorded for 0% unripe plantain-100% purple skinned sweet potato blend. This observation could be attributed to the relative abundance of polyphenols in purple skinned sweet potato (Best, 1984) compared with unripe plantain.

Figure 3 showed the total flavonoid content (mg/g) of the composite flour blends. The result revealed an increasing value of flavonoid content with increase in the inclusion of purple skinned sweet potato with respect to unripe plantain. The 100% unripe plantain-0% purple skinned sweet potato blend had the least flavonoid content (881.111mg/g) while 0% unripe plantain-100% purple skinned sweet potato blend had the highest flavonoid content (2724mg/g). Purple skinned sweet potatoes have been associated with high levels of flavonoids unlike unripe plantain which has been shown to have a relatively low level of flavonoids (Goel *et al.*, 1986).

The ferric reducing power of the various blends is as shown in Figure 4. Similarly, an increasing inclusion of purple skinned sweet potato flour into the blend with respect to the unripe plantain resulted in increasing value of the ferric reducing power. The result showed that 100% unripe plantain-0% purple skinned sweet potato blend had the least reducing power (0.911mg/g) while the 0% unripe plantain-100% purple skinned sweet potato blend has the highest reducing power (1.962mg/g). Reports have shown a positive correlation between total phenolic content and antioxidant indices of plant foods (Dlamini, 2007; Siatka and Kašparová, 2010).

Reducing power has been used as one of the antioxidant ability indicators of medicinal plants (Duh and Yen, 1997). Antioxidant properties of phenolic compounds are due to their redox properties which allow them to act as reducing agents, hydrogen donors and singlet oxygen quenchers (Rice-Evans *et al.* 1996).

The result of the hydroxyl radical scavenging activities (%) is as shown in Figure 5. The result showed that the 100% unripe plantain-0% purple skinned sweet potato blend have the least ability to reduce hydroxyl radicals (11.282%) while the 0% unripe plantain-100% purple skinned sweet potato blend had the highest ability to scavenge hydroxyl radicals (86.086%). Also, the result of ABTS radical scavenging ability of the composite flour blend as presented in Figure 6 showed that the 0% unripe plantain-100% purple skinned sweet potato blend had the highest radical scavenging activity of $(3.43 \times 10^{-6} \mu\text{mol/g})$ while the 100% unripe plantain-0% purple skinned sweet potato blend had the least radical scavenging activity $(7.91 \times 10^{-7} \mu\text{mol/g})$. This observation could also be ascribed to the reported positive correlation between total phenolic content and antioxidant indices of plant foods (Dlamini 2007; Siatka & Kašparová 2010).

The result of the DPPH radical scavenging activity of various blends is as shown in Figure 7. The DPPH radical scavenging activity showed that the 100% unripe plantain-0% purple skinned sweet potato blend had the highest scavenging activity $(1.19067 \times 10^{-5} \mu\text{mol/g})$ while the 0% unripe plantain-100% purple skinned sweet potato blend recorded the least radical scavenging activity $(4.68 \times 10^{-6} \mu\text{mol/g})$. The deviation from the expected trend might be associated with antagonistic action of some constituent polyphenols in sweet potato which in turn made it to have a lower radical scavenging action compared with 100% unripe plantain.

3.3 Proximate Composition

The proximate composition of the various blends is presented on Table 2. The 100% unripe plantain-0% purple skinned sweet potato blend had the least percentage moisture content (5.81%) and a highest carbohydrate (78.51%), protein (13.35%), fiber (0.19%) and fat (5.56%) content compared to whole purple sweet potato and the other blends. The result showed a progressive decrease in the level of carbohydrate, protein, fiber and fat content with a corresponding increase in the composition of sweet potato in the blends. The result also showed that blends with high unripe plantain content were found to contain low quantities of ash. This is in agreement with previous investigations, where plantains have been reported to contain low quantities of minerals which are associated with the ash content. The carbohydrate and fat content of whole unripe plantain flour compared favorably with previous reports (Fagbemi, 1999; Arisa *et al.*, 2013) though with a relatively higher level of protein.

The samples with high unripe plantain content were found to contain low quantities of ash which was reflected their low mineral contents. Plantains have been reported to contain low quantities of minerals (Ketiku, 1973; Ahenkora, 1996). It can be inferred from the result that unripe plantain is a very good source of dietary starch, protein and fat and the inclusion in sweet potato will make is a good energy supplying source in addition to its antioxidant potentials. Hiroshi *et al.* (2000), Ojeniyi and Tewe (2001) and Antia *et al.* (2006) also reported that the consumption of plantain and sweet potato should be encouraged because they contain fat that is easily metabolized by the body system.

3.4 Mineral Composition

The result of the mineral content (mg/g) of the various blends is as presented in Table 4. The result showed that a high sweet potato inclusion in the blend bring about an increasing value of some evaluated minerals (Ca, Mg, P and Fe). The 100% purple skinned sweet potato blend recorded the highest level of Ca (0.179), Mg (0.174), P (0.615) and Fe (0.008) respectively, while the least amount of Ca (0.12), Mg (0.075) and P (0.395) was recorded for 100% unripe plantain. The 100% unripe plantain flour blends have the highest content of Na (0.304) and K (3.306) and this is agreement with previous reports (Libert and Franceschi 1987; Halloway *et al.* 1989).

3.5 Sensory evaluation

The sensory property of the porridge obtained from various blends is as presented on Table 4. The result showed varied rating with respect to the sensory parameters evaluated. However, three porridge samples obtained from the various blends had a relatively higher overall acceptance: 80% UP-20% WP (6.3), 60% UP-40% WP (7.4) 40% UP-60% WP (6.5). Sensory attributes of foods are highly correlated with the overall acceptability of food (Saba *et al.*, 1998).

4. Conclusion

High inclusion of purple sweet potato in the blend improves the antioxidant potential and some essential minerals, whereas the proximate indices (carbohydrate, protein, fiber and fat) were higher in the blend with high amount of unripe plantain. Thus, there exist a mid point where the blends will be useful from nutritional and antioxidant point of view. Therefore, overall assessment of the antioxidant and nutritional potential of the composite blends showed that two blends (60% UP:40% PP, 40% UP:60% PP) showed relatively consistent high antioxidant activities and also are better source of protein, carbohydrate, fat and fiber and with a better overall acceptance from sensory point of view. The result of the present investigation suggests that the two blends are potential nutraceutical supplement and could be explored as functional food in the prevention and management of free radical associated diseases.

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Table 1 Phenolic Composition (mg/g) of Unripe Plantain and Purple skin sweet potato extracts.

Peak number	Compounds	mg/g	LOD	LQD
<i>(a) Unripe plantain</i>				
UP1	Galllic acid	3.75±0.01	0.015	0.049
UP2	Caffeic acid	18.90±0.02	0.018	0.059
UP3	Ellagic acid	20.65±0.02	0.036	0.119
UP4	Rutin	19.36±0.01	0.042	0.138
UP5	Isoquercitrin	40.71± 0.03	0.021	0.071
UP6	Quercetin	51.83±0.01	0.007	0.024
<i>(b) Purple skin sweet potato</i>				
PSP1	Galllic acid	9.6±0.3	0.038	0.125
PSP2	Catechin	9.1± 0.1	0.025	0.081
PSP3	Chlorogenic acid	19.5 ± 0.2	0.016	0.049
PSP4	Caffeic acid	23.2±0.3	0.009	0.030
PSP5	Caffeic acid derivative	17.3±0.1	-	-
PSP6	Ellagic acid	8.4±0.1	0.043	0.139
PSP7	Epicatechin	14.5±0.1	0.014	0.046
PSP8	Rutin	19.3±0.2	0.031	0.103
PSP9	Isoquercitrin	19.6±0.2	0.040	0.132
PSP10	Quercitrin	24.1±0.3	0.007	0.023
PSP11	Quercetin	31.3±0.1	0.021	0.071
PSP12	Kaempferol	17.2±0.1	0.005	0.016

Results are expressed as mean ± standard deviations (SD) of three determinations.

Table 2 Proximate composition (%) of unripe plantain-Sweet potato blends

Sample	Moisture	Ash	Fat	Crude fibre	Crude protein	Carbohydrate
100%UP-0%PP	5.81±0.02	2.20±0.01	5.56±0.02	0.19±0.01	13.35±0.10	78.51±0.10
80%UP-20%PP	7.19±0.01	2.95±0.01	4.42±0.02	0.22±0.02	12.96±0.10	77.49±0.13
60%UP-40%PP	7.29±0.27	2.03±0.03	3.43±0.01	0.18±0.01	12.53±0.00	74.60±0.31
40%UP-60%PP	7.62±0.01	2.35±0.01	2.55±0.02	0.16±0.01	11.61±0.40	73.92±0.02
20%UP-80%PP	7.87±0.02	2.48±0.02	1.40±0.01	0.16 ±0.01	10.68±0.30	71.75±0.13
0%UP-100%PP	7.53±0.02	3.12±0.02	1.48±0.01	0.13±0.02	9.65±0.10	71.67±0.08

Reported values are the means ± S.D (n=3). UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato

Table 3 Mineral composition (mg/g) of unripe plantain-Sweet potato blends.

Food Sample	Ca	Mg	Na	K	P	Fe
100%UP-0%PP	0.120±0.03	0.075±0.004	0.304± 0.03	3.306± 0.32	0.395± 0.03	0.0059 ±0.0003
80%UP-20%PP	0.122±0.02	0.104±0.03	0.136± 0.01	2.791± 0.24	0.477±0.01	0.0033±0.0001
60%UP-40%PP	0.127±0.04	0.112± 0.02	0.190± 0.04	2.892± 0.35	0.532± 0.04	0.0043±0.0004
40%UP-60%PP	0.134±0.01	0.153±0.03	0.207± 0.03	3.010±0.27	0.568± 0.03	0.0061±0.0002
20%UP-80%PP	0.149± 0.01	0.160±0.01	0.268±0.02	3.205± 0.11	0.596± 0.02	0.0067±0.0003
0%UP-100%PP	0.179±0.03	0.174±0.02	0.250± 0.01	3.265± 0.23	0.615± 0.0.02	0.0083±0.0002

Reported values are the means ± S.D (n=3). UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato

Table 4 Sensory Properties of Porridge obtained from Purple Sweet Potato and Unripe plantain flour blends

SAMPLE	100UP-0WP	80UP-20WP	60UP-40WP	40UP-60WP	20UP-80WP	0UP-100WP
Taste	5.73±2.45	6.4±1.06	7.6±0.93	7.7±0.75	5.9±1.23	5.2±1.32
After Taste	4.8±1.09	6.2±1.01	7.3±1.52	7.4±1.42	6.1±1.73	5.2±1.82
Appearance/Color	5.0±2.1	6.6±1.77	8.0±1.08	7.2±0.99	6.8±0.97	5.5±1.87
Aroma	4.1±1.35	6.5±1.29	7.3±0.87	7.0±1.51	5.9±1.76	5.2±1.63
Mouth Feel	4.6±2.03	5.8±1.55	6.7±0.76	7.3±0.88	5.2±1.42	4.6±2.04
Firmness	3.5±1.20	6.1±1.46	7.5±1.03	7.1±1.38	6.1±1.98	5.1±1.44
Swallow Ability	3.4±0.77	5.7±1.51	7.3±0.67	7.2±1.19	6.1±1.11	5.0±1.83
Overall Acceptability	3.5±0.94	6.3±0.77	7.4±1.69	6.5±1.18	5.4±1.17	4.5±1.62

Reported values are the means ± S.D (n=3). UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato

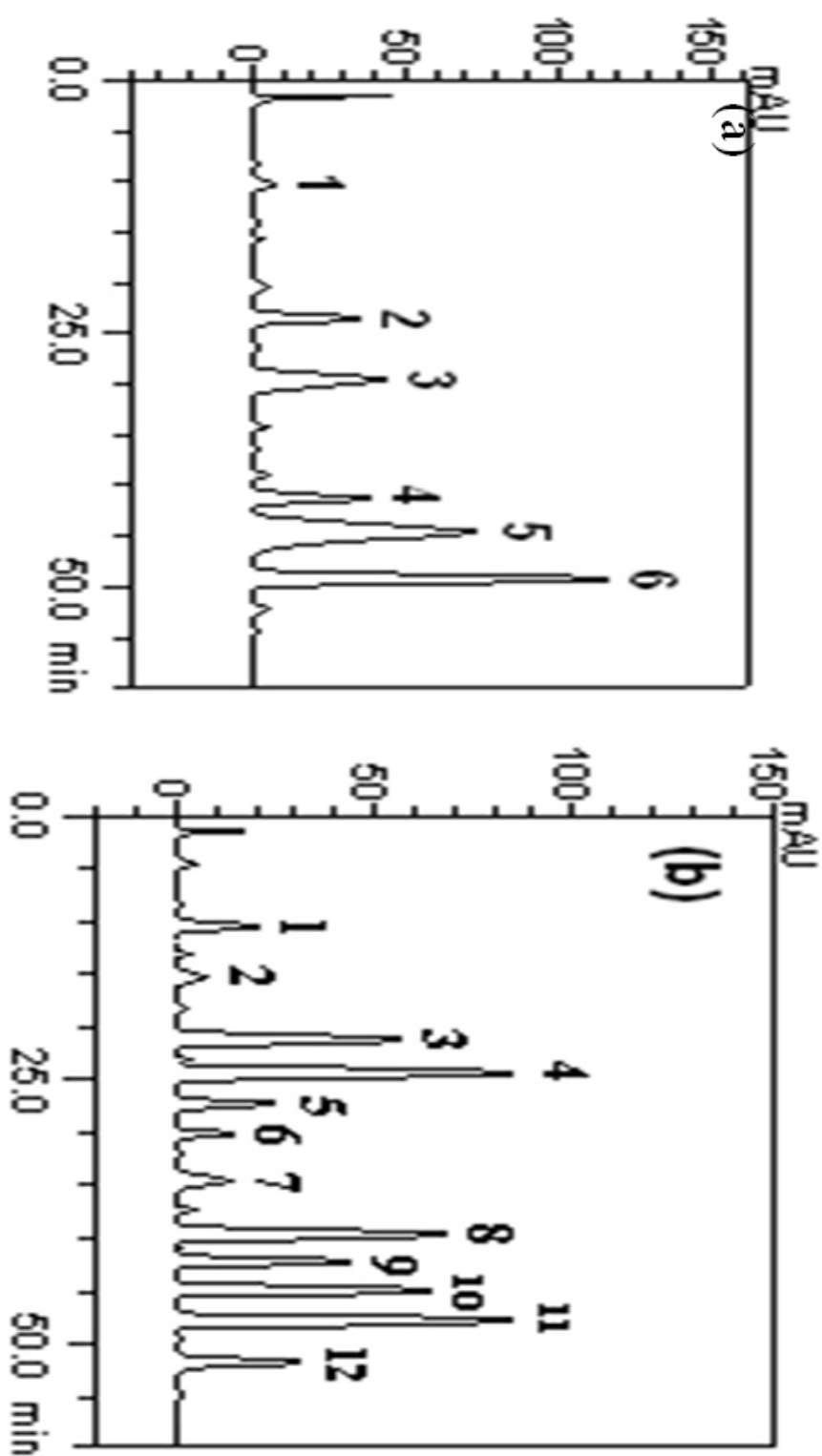


Figure 1 (a-b): Representative high performance liquid chromatography profile of (a). umrpe *Plantain* (UP) extract: Gallic acid (peak 1), caffeic acid (peak 2), ellagic acid (peak 3), rutin (peak 4), isoquercitrin (peak 5) and quercetin (peak 6). (b). Purple skin sweet potato (PSP) extracts. Gallic acid (peak 1), catechin (peak 2), chlorogenic acid (peak 3), caffeic acid (peak 4), caffeic derivative (peak 5), ellagic acid (peak 6), epicatechin (peak 7), rutin (peak 8), isoquercitrin (peak 9), quercitrin (peak 10), quercetin (peak 11) and kaempferol (peak 12).

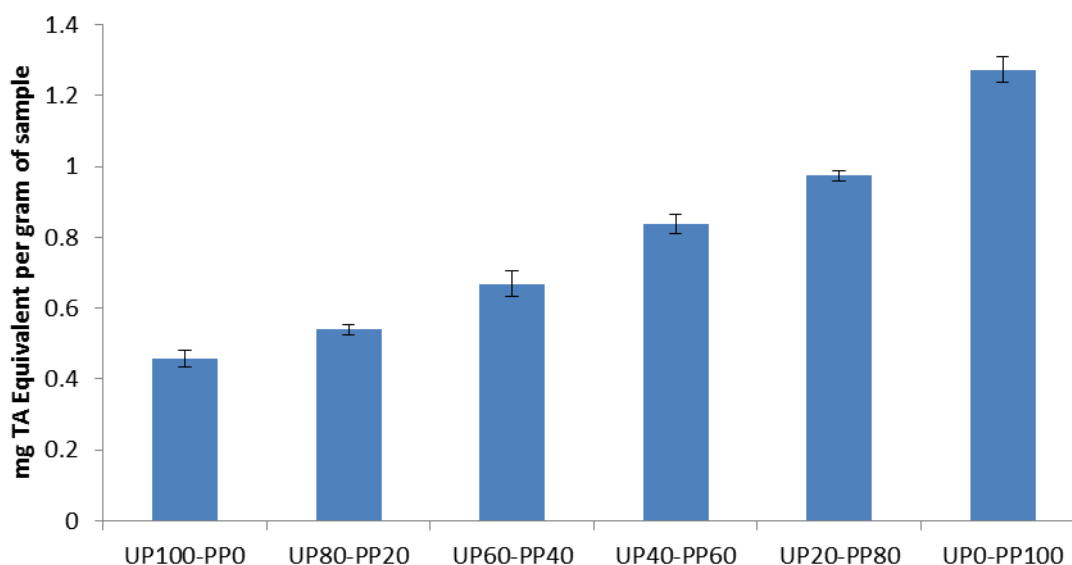


Figure 2: Total phenolic content of composite blends expressed as mg Tannic acid equivalent per gram of the sample. Reported values are the means \pm S.D (n=3). Error bars represent standard deviations. UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato

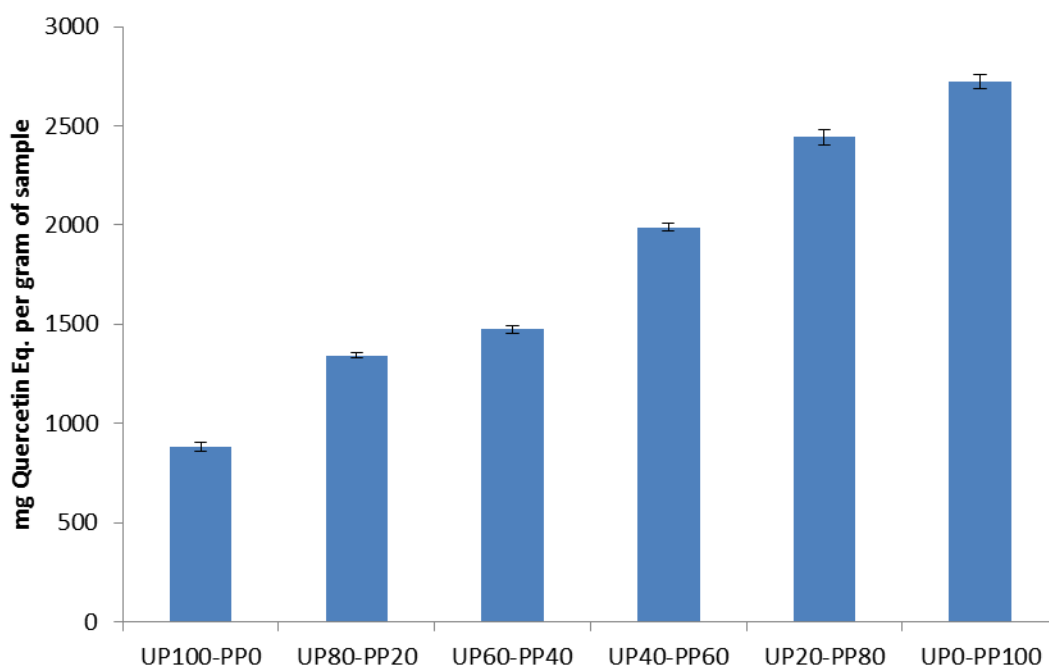


Figure 3: Total flavonoid content of composite blends expressed as mg Quercetin Equivalent per gram of the sample. Reported values are the means \pm S.D (n=3). Error bars represent standard deviations. UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato

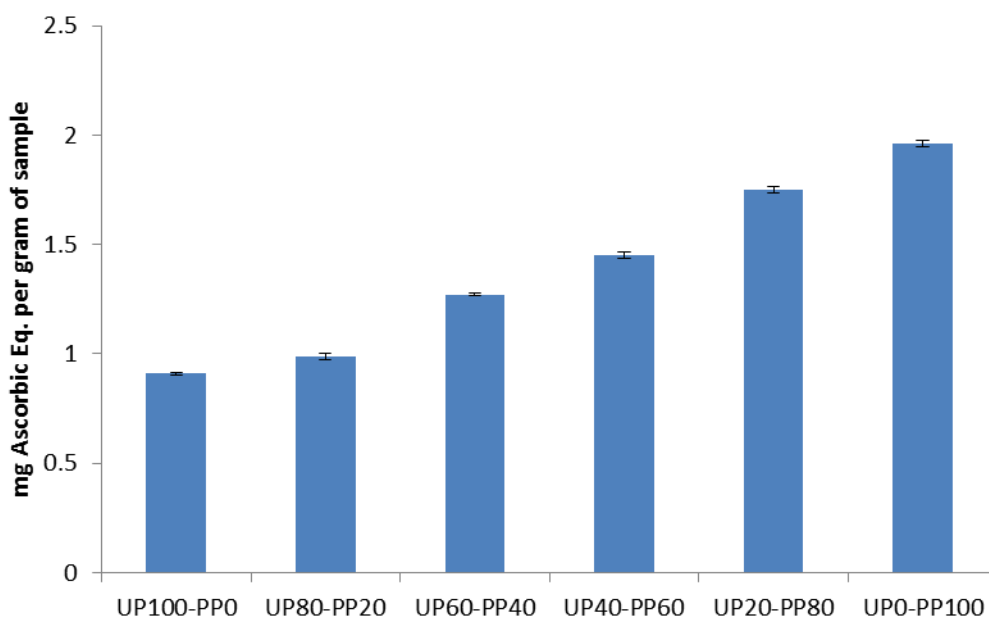


Figure 4: Reducing power, expressed as mg Ascorbic acid Equivalent per gram of the sample. Reported values are the means \pm S.D (n=3). Error bars represent standard deviations. UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato

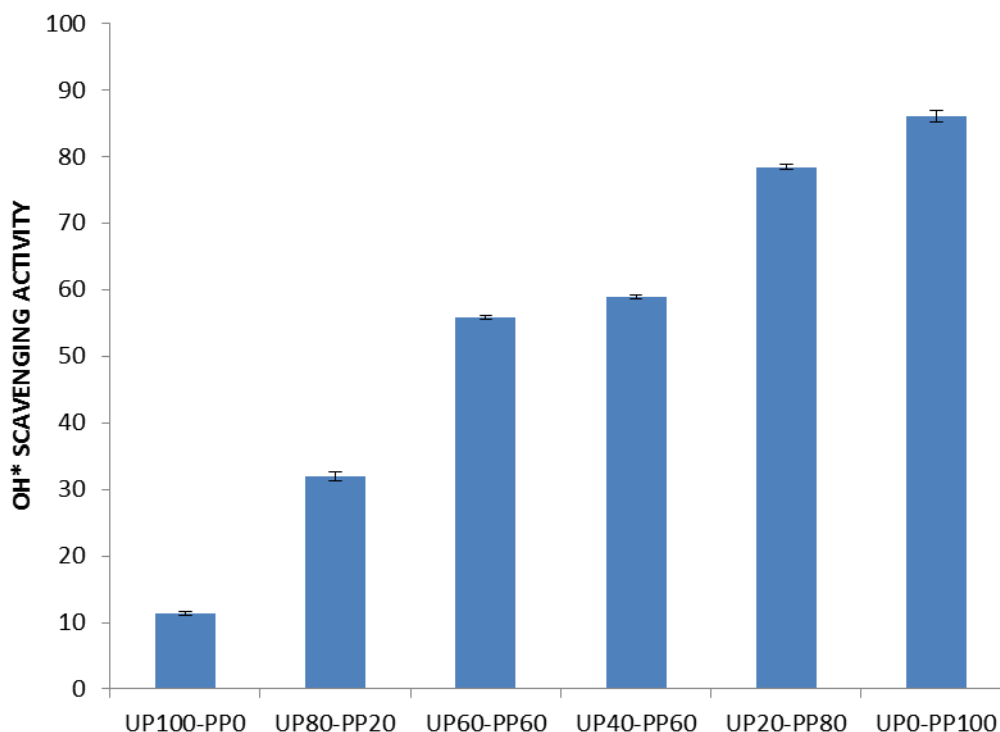


Figure 5: %Hydroxyl radical scavenging activity. Reported values are the means \pm S.D (n=3). Error bars represent standard deviations. UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato

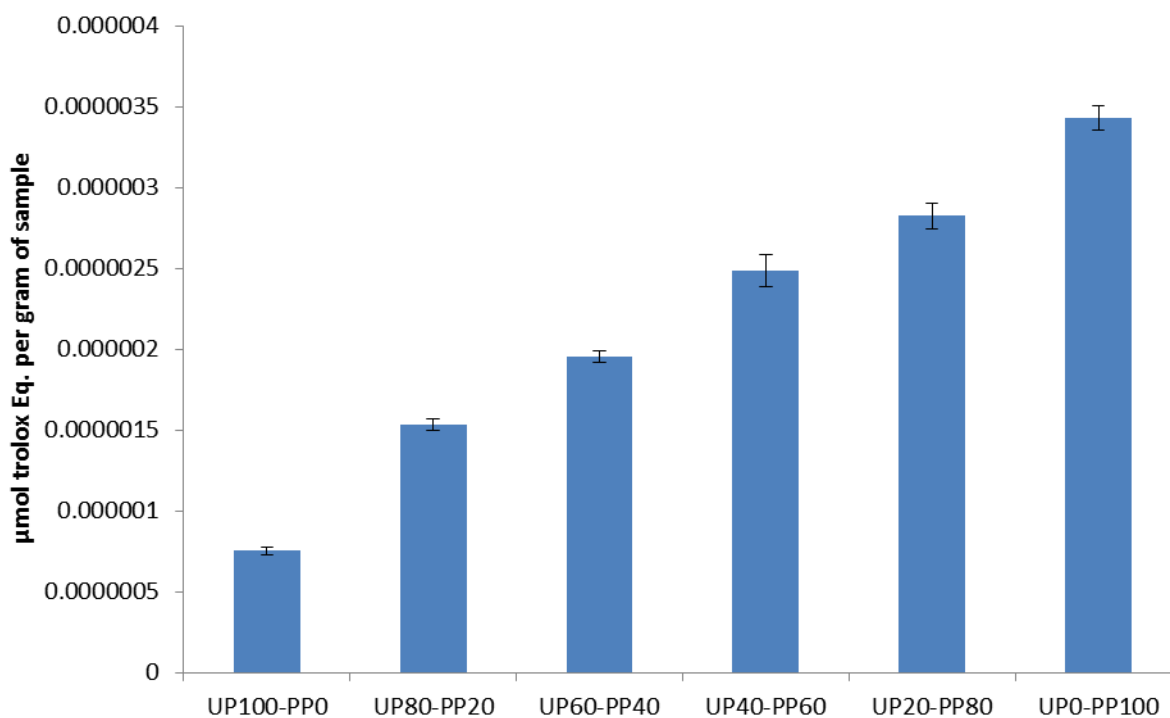


Figure 6: ABTS antiradical activity expressed as μmol Trolox Equivalent per gram of the sample. Reported values are the means \pm S.D (n=3). Error bars represent standard deviations. UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato.

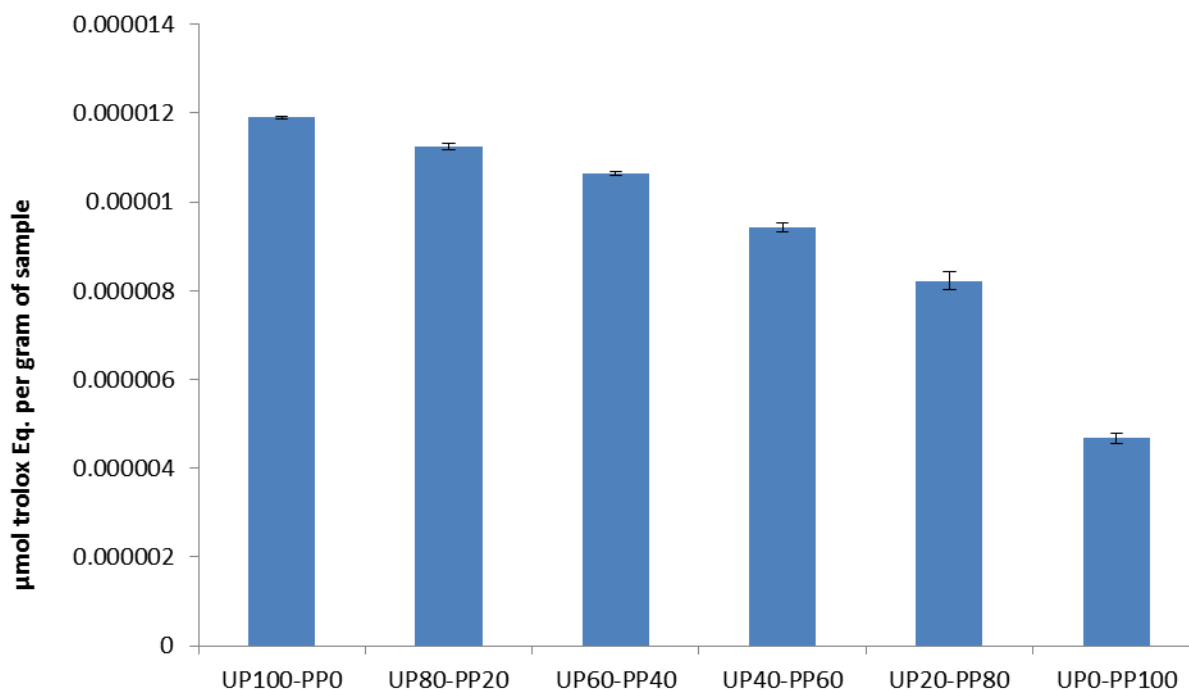


Figure 7: DPPH antiradical, expressed as μmol Trolox Equivalent per gram of the sample. Reported values are the means \pm S.D (n=3). Error bars represent standard deviations. UP100-PP0= 100% Unripe Plantain-0% Purple Sweet Potato; UP80-PP20=80%Unripe Plantain-20% Purple Sweet Potato; UP60-PP40=60%Unripe plantain-40% Purple Sweet Potato; UP40-PP60=40% Unripe Plantain-60% Purple Sweet Potato; UP20-PP80=20% Unripe Plantain-80% Purple Sweet Potato; UP0-PP100=0% Unripe Plantain-100% Purple Sweet Potato.

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