EVALUATION OF FREE RADICAL SCAVENGING AND ANTIOXIDANT POTENTIAL OF DIFFERENT EDIBLE PARTS OF RAW AND PROCESSED *Musa paradisiaca* (L.) VAR. *Kunnan and Palayamkodan*

Jenit K. Joy *, Aathira M., Jincy C. and Siddhu Raju P.

Bioresource Technology Lab, Department of Environmental Sciences, School of Life Sciences, Bharathiar University, Coimbatore, Tamil Nadu (INDIA)

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ABSTRACT

Free radicals and Reactive Oxygen Species (ROS) are produced in human body during the normal biochemical and metabolic processes, which increases the oxidative stress linked with different human diseases. One of the major ways of combating against degenerative diseases is to improve body antioxidant status. In spite of the in-built defense mechanisms, it seems more meaningful to utilize extra antioxidants available in diets, especially from fruits, vegetables and whole grains. This has enforced the research in finding antioxidants present in foods and medicinal plants. Plantain fruits are all year round, which makes the crop a reliable all-season staple food, particularly in developing countries. But their benefits as functional food are not much explored. The presence of flavonoids and other phytochemicals raises the antioxidant potential of different parts of *M. paradisiaca*. The present study therefore evaluated the antioxidant potential of unripe fruit, flower and pseudo stem of *M. paradisiaca*. Findings of current study help to eradicate the problem of fruit waste by utilizing its high value compounds, including the dietary fibre that has a great potential in the preparation of functional foods.

Key Words: Antioxidants, Free radicals, Dietary fibre, Flavonoids, *Musa paradisiaca*

INTRODUCTION

The oxidative properties of oxygen in diverse biological functions has been reported to play double edged properties of either a decrease of cell antioxidant capacity or increased amount of reactive oxygen species (ROS) which leads to oxidative stress in organisms (Mahantesh et al., 2012). Biomedical research shows increasingly that ROS contributes to both the initiation and promotion of many major diseases. One of the major ways of fighting against degenerative diseases is to improve body antioxidant status. This could be achieved by higher consumption of vegetables and fruits. The beneficial effects of fruit and vegetables are related to the presence of antioxidants. A high fruit and vegetable intake has been shown to be low level of inflammation. Folate and antioxidants such as vitamin C and β-carotene are found in a variety of fruits and vegetables and have been related to lower levels of inflammation and oxidative stress in adults. Plant polyphenols, such as flavonoids, also found in many fruits and vegetables may play a role in this relation. Earlier researchers had proved that foods from plant origin usually contain natural antioxidants that can scavenge free radicals. Natural antioxidants have the capacity to improve food quality and can also act as nutraceuticals to terminate free radical chain reactions in biological systems. These benefits have been attributed to some of the phytochemical constituents, in particular, to polyphenols. This has enforced the research in finding natural antioxidants in plants and vegetables that may be of importance in pathologies involving reactive oxygen species, as well as preservation of food substances against oxidation.

*Musa paradisiaca* is one of the best known fruits of the world. It serves as a major staple food and particularly desired for variability in the stages of ripeness and in cooking methods. It
is available in all seasons at a price which is within everybody’s reach. It therefore contributes significantly to food and income security of people engaged in its production and trade, particularly in developing countries. The mature fruits vary in size and may be greenish, yellow or reddish in colour. Bananas provide a good source of nutrients for both human and animal consumption. They are true sources of energy and provide it primarily in the form of carbohydrate with minimal contribution to energy from fat. Any food containing carbohydrates should be the main part of our daily meals. In unripe bananas the carbohydrates are mostly starches. Banana offers great medicinal benefits. This is partly because bananas help in the body’s maintenance of calcium, nitrogen, and phosphorus, all of which work to build healthy and regenerated tissues. The fruit is also used as treatment for burns and wounds.

Byproducts from banana could be a feasible source for natural products. Previous studies done on some parts of banana byproducts of different varieties revealed the great potential of antibacterial and antioxidant properties from the fruit peels and flowers as well as antifungal from fruits. The presence of flavonoids and other phytochemicals raises the antioxidant potential of different parts of M. paradisiaca. Banana Pseudo Stem (BPS) is often used as a vegetable for culinary purposes in India. Juice from BPS is a well-known remedy for urinary disorders.

From the environmental point of view, it is essential to reuse the fruit waste because it is being improperly discarded in landfills, contributing to the generation of environmental problems, or it is left in the plantations, where it is used as a soil cover. A new study describes the use of banana peel, a commonly produced fruit waste, for the removal of Cr (VI) ions from industrial wastewater. The work explores banana peel as a cheap, economical and selective sorbent. The extraction of bioactive compounds from banana waste is an alternative method to ensure the efficient, inexpensive, and environmental friendly use of this waste. These bioactive components can be used in foods, cosmetics, and in the pharmaceutical industries.

Plantain shows great adaptation to urban consumption and exportation to specific markets. This will vary from one country to another because of prevailing eating habits. Ripe or unripe plantain pulp cooked in water or vapour, Pastry from unripe plantain cooked in water and pounded in a mortar, Elastic pastry prepared from plantain flour, Ripe or unripe plantain pulp roasted on charcoal fire, Unripe plantain pulp cooked with water, meat or fish, palm oil, salt and various spices, and Slices of unripe or ripe plantain pulp fried in palm oil or other vegetable oils. After processing only, rural people in India include edible parts of banana in their diet. Thus, it is important to investigate the changes in processing and whether processing increases or decreases the antioxidant activity. Since free radicals have been implicated to be responsible for many metabolic disorders, this study is designed to further explore the antioxidant activities in plantain product extracts in-vitro. The present study evaluated the antioxidant potential of unripe fruit, flower and pseudo stem of M. paradisiaca sp. Also it paves road to eradicate the problem of fruit waste by utilizing its high value compounds, including the dietary fibre fraction that has a great potential in the preparation of functional foods.

**MATERIAL AND METHODS**

**Plant samples**

Unripe fruit, flower, and pseudo-stem of M. paradisiaca var. Kunnan and Palayamkodan were collected from their natural vicinity at Palakkad, Kerala, India.

**Preparation of plant extract**

The whole unripe fruits, flowers and pseudo stem were chopped into pieces. Then, the samples were divided into two portions, one portion was taken for processing and the other portion was taken as fresh without any treatment. The unripe fruits, flowers and pseudo stem of M. paradisiaca var. Kunnan and Palayamkodan were boiled separately at 100°C using sample: water in the ratio of 1:10 (w/v) for 15 mins. The samples were dried in the room temperature. The raw and boiled
samples were ground to fine powder using laboratory blender and stored in screw capped bottles for further analysis. Both raw and processed samples were subjected to extraction. Before extraction, the samples (15 g) were defatted with petroleum ether for 24 h. The samples were filtered and residues were collected and dried. The sample residues were extracted by stirring with 70% acetone and 80% methanol (1:7 w/v) for 48 h at room temperature in a shaker. Then the supernatant was filtered with Whatmann No.1 filter paper. The residues were re-extracted with corresponding solvent (1:5 w/v) for another 24 h. The solvent extracts obtained were dried at 40 °C in an incubator. The dried extract was used for analysis.

**Chemicals**

Ferric chloride, 2, 2'-Diphenyl-1Picryl Hydrazyl (DPPH), Potassium persulfate, 2, 2 Azinobis (3-ethyl Benzo-Thiozoline-6- Sulfonylic acid) disodium salt (ABTS), 6-hydroxy -2,5,7,8-tetra-methylchroman 2-carboxylic acid (trolox), ferrous chloride, Ammonium thiocyanate, Hydrogen peroxide, ferrous ammonium sulfate, Ethylene Diamine Tetra Acetic Acid (EDTA) disodium salt were obtained from Hi Media, Merck and Sigma. All analysis was performed with UV-visible spectrophotometer (Cyberlab-UV 100, USA).

**Determination of total phenolics and tannins content**

The total phenolics and tannins were measured as Tannic Acid Equivalents (TAE)\(^{19}\) from tannic acid standard curve (3–15 µg range). An aliquot (100 µl) of sample extract was transferred to a test tubes and 0.5 ml of Folin-Ciocalteau reagent and 2.5 ml of sodium carbonate solution (20 % w/v) were added. After an incubation period of 40 min in dark and the absorbance was recorded at 725 nm against the reagent blank. For tannin estimation, the sample extracts were incubated with Polyvinyl Polypyrrolidone (PVPP) (100 mg) at 4° C for 4 h. The supernatant was centrifuged and using the same method of phenolics, tannins were estimated. The phenolics and tannins were expressed as mg tannic acid equivalents (TAE)/g extract.

\[
\text{Tannin (\%) = Total phenolics (\%) - Non-tannin phenolics (\%)}
\]

**Determination of total flavonoid content**

The total flavonoid content was measured according to the method of Zhishen et al.\(^{20}\). Sample was added with 0.3 ml of 5 % NaNO\(_2\) and well mixed. After 5 min of incubation, 0.3 ml of 10 % AlCl\(_3\) solution was added. Then, after 6 min, 2 ml of 1M NaOH was added to the mixture and made up the volume to 10 ml with water. The absorbance was measured at 510 nm. The content of total flavonoids was expressed as mg rutin equivalents (RUT)/g extract.

**Free radical scavenging activity on DPPH**

The antioxidant activity of extracts and standards (BHA, rutin and Ascorbic acid) was measured in terms of hydrogen donating ability using a stable, commercially available organic nitrogen radical DPPH by the method of Brand-Williams et al.\(^{21}\) with slight modifications. Sample extracts were prepared in methanol was mixed with 3.9 mL of DPPH\(^{+}\) (0.25g/L) and incubated in dark for 30 min. The absorbance was measured at 515 nm. The trolox standared was prepared in the range of 0 – 2.5 mM. The concentration of DPPH was calculated from trolox standard graph and expressed as mmol trolox equivalents/g extract.

**Antioxidant activity by the ABTS**\(^{+}\) assay

The ABTS\(^{+}\) radical cation decolourization assay was performed to evaluate the radical scavenging ability of crude extracts by the method of Re et al.\(^{22}\). ABTS radical cation (ABTS\(^{+}\)) was generated by adding 2.45 mM Potassium persulfate to 7 mM ABTS and incubated in dark at room temperature for 12-16 h. This stock solution of ABTS\(^{+}\) was diluted with ethanol to give an absorbance of 0.70 (± 0.02) at 734 nm, which act as a positive control. 10 µl of crude extract (Prepared in ethanol) was mixed with 1 mL of diluted ABTS\(^{+}\) solution and incubated at 30°C for 30 min. The absorbance value was estimated at 734 nm. Trolox standards were also prepared (in ethanol: 0 – 1.5 mM) to get the concentration response curve. The unit of trolox equivalent antioxidant activity (TEA) was defined as the concentration of Trolox.
having the equivalent antioxidant activity expressed as mmol/g of extracts. The TEA of Ascorbic acid BHA and rutin were also measured by ABTS \(^+\) method for comparison.

**Ferric reducing antioxidant power (FRAP) assay**

FRAP assay can be used to evaluate the electron donating ability of antioxidants according to the method of Benzie and Strain\(^2\). An aliquot of 30 µl sample was mixed with 90 µl of water and 900 µl of FRAP reagent (2.5 mL of 20 mmol/L of TPTZ in 40 mM of HCl, 2.5 ml of 20 mmol/L of FeCl\(_3\).6H\(_2\)O, 25 ml of 0.3 mol/L of acetate buffer (pH - 3.6)) and incubated at 37º C for 30 min. After incubation the absorbance values were recorded at 593 nm. Known FeSO\(_4\).7H\(_2\)O concentrations ranging from 400 to 2000 µmol were used to generate the calibration curve. From the graph, the ferrous ions reduced by the sample were calculated using regression equation. The antioxidant activity was expressed as amount of extract required to reduce 1 mmol of ferrous ions. The antioxidant activity of sample was compared with the following standards: rutin, BHA and ascorbic acid.

**Metal chelating activity**

The chelating activities of samples, standards like BHA and α – tocopherol were estimated by the method of Dinis et al.\(^24\) An aliquot of 0.1 mL sample, 0.6 mL of distilled water and 0.1 mL of ferrous chloride (2 mmol /L) were well mixed and incubated for 30 s. Then, 0.2 mL of ferrozine (5mmol/L) was added to the above mixture and incubated for 10 min at room temperature and the absorbance was recorded at 562 nm with UV–visible spectrophotometer. EDTA (0 – 2 µg) was used as standard for the preparation of calibration curve. Metal chelating ability of antioxidant was expressed as mg EDTA/ g extract.

**Statistical analysis**

Results were expressed as the mean ± Standard deviation (SD) of at least three independent experiments. Differences are estimated by the analysis of variance (ANOVA) followed by Duncan’s multiple range test. Differences were considered to be significant at \(P < 0.05\). All statistical analyses were performed using the statistical software SPSS 13.0 version (SPSS Inc., Chicago, Illinois, USA).

**RESULTS AND DISCUSSION**

**Total phenolics and tannins**

Polyphenols form a large group of phytochemicals which are produced by plants as secondary metabolites to protect them from photosynthetic stress and reactive oxygen species\(^25\). Tannins or polymeric polyphenolics are also potent antioxidant than simple monomeric phenolics and thus may be important dietary antioxidants\(^26\). Most of the antioxidant potential in vegetables, herb and spices is due to the redox properties of phenolic compounds which allow them to act as reducing agents, hydrogen donors and singlet oxygen quenchers. So, it is reasonable to determine the phenolics and tannins in selected plant extracts. Bananas are the only fruit to contain the amino acid Tryptophan and Vitamin B6, which together help the body produce serotonin - the natural chemical which helps you not to feel depressed. Banana flower and pseudostem are known to be rich in bioactives like dopamine, N-acetyl-serotonin, flavonoids like catechins, etc.\(^27,28\). Experimental evidences and characterization of chlorogenic acid, 4-epicyclomusalenone and cycloeucaalenol acetate indicated that bio-waste (viz., pseudostem and rhizome) of banana var. *Nanjanagudu rasbale* could be a potential source of nutraceuticals\(^29\). The presence of these functional components makes regular consumption of green banana flour beneficial to the human health.

Processed samples expressed highest phenolic and tannin contents than raw samples (Table 1). Phenolics and tannins were resistant to thermal processing and the phenolic content of raw samples was 33.63–186.67 mg TAE/g extract and processing samples were 81.93–537.93 mg TAE/g extract respectively. The values of tannins were within the range of 15.61–36.48 mg TAE/g extract. All processed samples were observed to contain higher amount of phenolics and tannins than their respective raw samples. Processing increased 1.6–3.5 times of phenolics and 1.2–5.2 times of tannins than their raw samples. Among each
species, the processed flower in Kunnam and processed fruit in Palayamkodan showed higher phenolics and tannins. Similar increase in phenolic content during thermal processing were observed in banana peel\textsuperscript{30,31}, leafy vegetables and corn. High dietary fiber and phenolic content of banana peels makes them promising for variety of applications in nutraceuticals and medicinal. Polyphenolic and related bioactive compounds are higher in peel than pulp part of banana fruit.

The total amount of phenolic compounds in banana peel has been reported from 0.90 to 3.0 g/100g dry weight\textsuperscript{32}. Recent studies demonstrated that banana peel generally include higher phenolic compounds than that of banana pulps\textsuperscript{33,34}. Someya \textit{et al.} attributed antioxidant properties of banana peel to its gallocatechin content. There have been several studies indicated that banana contain the important phenolic acid. Phenolic acids are simple compounds of non-flavonoid family constituting as a large group of phenolic compounds\textsuperscript{35}. They have excellent antioxidant activities, which are higher than those of vitamins C and E against reactive oxygen\textsuperscript{36}.

The present report showed higher phenolic content than \textit{Ensete glauca} ripe fruit (1.27 mg/g)\textsuperscript{37}, \textit{Musa sapientum} fruit (0.51 mg/g)\textsuperscript{38} and \textit{M. paradisiaca} flower\textsuperscript{39}. Hence, this increase could be due to the release of bound phenolic acids from the breakdown of cellular constituents and cell walls during processing, disassociation of conjugate phenolic forms and formation of by-products\textsuperscript{40,41}. Other reasons could also be due to Maillard reaction (non-enzymatic browning), caramelization, chemical oxidation of phenolics and maderisation\textsuperscript{42}. It must also be kept in mind that certain complications arise when recovering phytochemical compounds from plant by-products due to their high enzyme activity. The pH of the water can determine the degree of solubility of water-soluble compounds and also influence the possible solubilization of the hydrolysable fraction\textsuperscript{43}.

**Total Flavonoids content**

Flavonoids, mainly present as coloring pigments in plants and also function as potent antioxidants at various levels and could protect membrane lipids from oxidation\textsuperscript{44}. Variation in flavonol content was shown in Table 2. In the present study, total flavonoid content of acetone extract was ranged from 24.83 – 27.44 mg RUE/g extract and the methanol extract was in the range of 25.5 - 48.55 mg RUE/g extract. As like phenolics and tannins all processed samples showed higher flavonoid content than raw. The highest flavonoids were found in fruit extract followed by pseudo stem and flower extract of \textit{M. paradisiaca}. The increasing concentration of these bioactive molecules might be due to the release of bound flavonoid compounds and the decreasing or solubilization of macromolecules during the hydrothermal processing. And their loss is caused by the thermal degradation of compounds. Similar increases in flavonoid content were shown in leafy vegetables after cooking and oak acorns during thermal treatment\textsuperscript{45}.

**Free radical scavenging activity on DPPH**

DPPH is one of the free radicals widely used for testing preliminary radical scavenging activity of a compound or a plant extract. The model system of scavenging DPPH free radicals is a simple and acceptable method to evaluate the antioxidative activity of antioxidants. It is accepted that the DPPH free radical scavenging by antioxidants is due to their hydrogen donating ability\textsuperscript{46}. In its radical form DPPH absorbs at 515nm, but upon reduction by an antioxidant or a radical species, the absorption disappears. The antioxidant activities of the individual compounds, present in the extracts may depend on structural factors, such as the number of phenolic hydroxyl or methoxyl groups, flavone hydroxyl, keto groups, free carboxylic groups and other structural features\textsuperscript{47}. Kaczmarski \textit{et al.} reported that among the antioxidative compounds (vitamin C, E, A, selenium and carotenoids), ascorbic acid (Vitamin C) shows very strong intensity of antioxidative activities\textsuperscript{48}.

Sample extract react very quickly with DPPH, reducing a number of DPPH molecules equal to their number of available hydroxyl groups. DPPH radicals react with suitable reducing agents, during which the electrons become paired off and the solution loses colour.
stoichiometrically depending on the number of electrons taken up. In the experiment, the solution progressively reduced to a yellow coloured product, diphenylpicryl hydrazine, with the addition of the extracts in a concentration-dependent manner. The DPPH activity of all samples was presented in Table 3. In the present study, total DPPH activity of acetone extract of both variety were ranged between 20778.58 and 31062.44 mmol TEA/g extract, and the methanol extracts were in the range of 24266.01-35677.21 mmol TEA/g extract. All samples showed lower scavenging activity than standards because the interference of many compounds in the crude extract and purity of standards used. All processed samples registered higher DPPH activity than raw. Antioxidant activity toward DPPH was found to correlate with their tannin content \( r^2= 0.745 \) and \( P<0.05 \) (Table 3). Tannins are highly polymerized and have many phenolic hydroxyl groups with molecular weights of between 500 and 30,000 Da. It is much more potent antioxidants than are simple monomeric phenolics and scavenge DPPH efficiently. *Palayamkodan* variety observed to have higher scavenging activity than *Kunnan*. The present results showed higher DPPH scavenging activity than *Musa sapientum* fruit extracts, stem and flower of *Musa paradisiaca*. The number of DPPH\(^{\cdot}\) radical is reduced by available hydroxyl groups in the phenolic constituents of sample extract.

**Antioxidant activity by ABTS\(^{\cdot}\)+ assay**

Proton radical scavenging is an important attribute of antioxidants. ABTS, a protonated radical has characteristic absorbance maxima at 734 nm which decreases with the scavenging of proton radicals. ABTS\(^{\cdot}\)+ is a radical generated from Potassium persulphate and ABTS\(^{\cdot}\) in dark for 16h and forms a blue green chromophore. The increase in concentration of extracts decreases the absorbance. The decolorization of ABTS radical cation reflects the capacity of antioxidants to donate electrons or hydrogen atoms to deactivate the radical species. This may be due to variation in types of phenolic compounds that differ significantly in their reactivity towards ABTS. The ABTS activity of all samples was presented in Table 3. Similar results were reported in *M. acuminate* peel extract and leafy vegetables the ABTS activity was increased with temperature. All the processed samples registered higher ABTS radical scavenging activity than raw samples. Processed samples reported to have high phenolic content and it might be responsible to scavenge ABTS radical efficiently than raw sample. The range of ABTS radical scavenging activity of *M. paradisiaca* (var. *Kunnan*) was ranged between 13936.37 and 137032.43 mmol TEA/g extracts and the activity were decreased in the order of flower (F2> F1> F4> F3), unripe fruit (V2>V1>V4>V3) and pseudo stem (S2>S1>S4>S3). *M. paradisiaca* (var. *Palayamkodan*) showed ABTS activity in the range of 24505.23 – 134338.41 mmol TEA/g extracts, and the activity were decreased in the order of flower (F6> F5> F8> F7), unripe fruit (V6> V5> V8> V7) and pseudo stem (S6> S5> S8> S7). Processed samples of both the varieties registered higher ABTS activity than reported banana stem and flower. In the earlier studies, banana has been found to exhibit higher ABTS radical scavenging activity than cherries, grapes, oranges, peach etc. and lower than that of plums, strawberries, apples and lemons.

**Ferric reducing antioxidant power assay**

FRAP measures the ferric reducing ability of the samples at a low pH, forming an intense blue colour as the ferric tripipridyltriazine (Fe\(^{3+}\)-TPTZ) complex is reduced to the ferrous (Fe\(^{2+}\)) form and absorbance is measured at 593 nm (Gil et al., 2000). The reductants present in the sample extract causes the reduction of ferric to ferrous. The ferric reducing antioxidant activity of all sample extracts was shown in Table 4. The ferric reducing ability of methanol extract of *M. paradisiaca* were ranged between 13105.40 and 133362.36 mmole Fe (II)/g extract and acetone extract were in the range of 1364.87 - 14138.0 mmole Fe (II)/g extract. All sample extracts showed higher reducing power than *Musa sapientum* fruit residues and *Ensete glauca* ripe fruit. Previous reports showed that the reducing power of bioactive compounds associated with the antioxidant activity. All the processed samples recorded higher reducing properties than raw samples.
Table 1: Extract yield, Total phenolics and tannins content of *M. paradisiaca* var. (*Kunnan* and *Palayamkodan*) edible parts

<table>
<thead>
<tr>
<th>Sample</th>
<th>Extract Yield (%)</th>
<th>Total Phenolics (mg TAE/g extract)</th>
<th>Tannins (mg TAE/g extract)</th>
<th>Sample</th>
<th>Extract Yield (%)</th>
<th>Total Phenolics (mg TAE/g extract)</th>
<th>Tannins (mg TAE/g extract)</th>
<th>Sample</th>
<th>Extract Yield (%)</th>
<th>Total Phenolics (mg TAE/g extract)</th>
<th>Tannins (mg TAE/g extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>0.99</td>
<td>151.83±4.45</td>
<td>23.68±0.44</td>
<td>F1</td>
<td>1.28</td>
<td>74.96±3.59</td>
<td>25.60±0.39</td>
<td>S1</td>
<td>1.35</td>
<td>65.33±2.91</td>
<td>23.77±0.44</td>
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<tr>
<td>V2</td>
<td>0.19</td>
<td>207.85±2.45</td>
<td>24.84±0.50</td>
<td>F2</td>
<td>0.52</td>
<td>226.96±4.01</td>
<td>25.94±0.37</td>
<td>S2</td>
<td>0.31</td>
<td>85.30±2.35</td>
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<tr>
<td>V3</td>
<td>0.17</td>
<td>186.67±2.40</td>
<td>15.60±0.42</td>
<td>F3</td>
<td>0.78</td>
<td>65.33±2.91</td>
<td>24.22±0.44</td>
<td>S3</td>
<td>1.07</td>
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<td>V4</td>
<td>0.15</td>
<td>192.70±4.03</td>
<td>21.86±0.50</td>
<td>F4</td>
<td>0.49</td>
<td>110.22±4.44</td>
<td>25.46±0.44</td>
<td>S4</td>
<td>0.88</td>
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<td>V5</td>
<td>0.26</td>
<td>111.11±4.07</td>
<td>32.37±0.25</td>
<td>F5</td>
<td>2.02</td>
<td>104.00±2.35</td>
<td>23.36±0.21</td>
<td>S5</td>
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<td>198.03±0.93</td>
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<td>V7</td>
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<td>V8</td>
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<td>1.72</td>
<td>85.78±3.47</td>
<td>23.24±0.44</td>
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Note: Each value is expressed as mean ± standard deviation (n=3). V1-M. paradisiaca unripe fruit (*Kunnan*) raw methanol extract. V2-M. paradisiaca unripe fruit (*Kunnan*) boiled methanol extract; V3-M. paradisiaca unripe fruit (*Kunnan*) raw acetone extract; V4-M. paradisiaca unripe fruit (*Kunnan*) boiled acetone extract; V5-M. paradisiaca unripe fruit (*Palayamkodan*) raw methanol extract; V6-M. paradisiaca unripe fruit (*Palayamkodan*) boiled methanol extract; V7-M. paradisiaca unripe fruit (*Palayamkodan*) raw acetone extract; V8-M. paradisiaca unripe fruit (*Palayamkodan*) boiled acetone extract. F1-M. paradisiaca flower (*Kunnan*) raw methanol extract; F2-M. paradisiaca flower (*Kunnan*) boiled methanol extract; F3-M. paradisiaca flower (*Kunnan*) raw acetone extract; F4-M. paradisiaca flower (*Kunnan*) boiled acetone extract; F5-M. paradisiaca flower (*Palayamkodan*) raw methanol extract; F6-M. paradisiaca flower (*Palayamkodan*) boiled methanol extract; F7-M. paradisiaca flower (*Palayamkodan*) raw acetone extract; F8-M. paradisiaca flower (*Palayamkodan*) boiled acetone extract. S1-M. paradisiaca pseudo stem (*Kunnan*) raw methanol extract; S2-M. paradisiaca pseudo stem (*Kunnan*) boiled methanol extract; S3-M. paradisiaca pseudo stem (*Kunnan*) raw acetone extract; S4-M. paradisiaca pseudo stem (*Kunnan*) boiled acetone extract; S5-M. paradisiaca pseudo stem (*Palayamkodan*) raw methanol extract; S6-M. paradisiaca pseudo stem (*Palayamkodan*) boiled methanol extract; S7-M. paradisiaca pseudo stem (*Palayamkodan*) raw acetone extract; S8-M. paradisiaca pseudo stem (*Palayamkodan*) boiled acetone extract.
Table 2: Flavonoid content of *M. paradisiaca* var. (Kunnan and Palayamkodan) edible parts

<table>
<thead>
<tr>
<th>Sample</th>
<th>Flavonoid (mg of RUE/g extract)</th>
<th>Sample</th>
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<th>Sample</th>
<th>Flavonoid (mg of RUE/g extract)</th>
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<tr>
<td><em>M. paradisiaca</em></td>
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<td><em>M. paradisiaca</em></td>
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<td><em>M. paradisiaca</em></td>
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<tr>
<td>unripe fruit</td>
<td></td>
<td>flower</td>
<td></td>
<td>pseudo stem</td>
<td></td>
</tr>
<tr>
<td>V1</td>
<td>30.94 ± 1.75</td>
<td>F1</td>
<td>25.5 ± 1.66</td>
<td>S1</td>
<td>26 ± 1.66</td>
</tr>
<tr>
<td>V2</td>
<td>48.05 ± 1.83</td>
<td>F2</td>
<td>41.55 ± 27.81</td>
<td>S2</td>
<td>28.16 ± 1.66</td>
</tr>
<tr>
<td>V3</td>
<td>25.5 ± 2.02</td>
<td>F3</td>
<td>24.83 ± 1.66</td>
<td>S3</td>
<td>25.16 ± 1.66</td>
</tr>
<tr>
<td>V4</td>
<td>27.44 ± 1.84</td>
<td>F4</td>
<td>25.33 ± 1.66</td>
<td>S4</td>
<td>25.33 ± 1.66</td>
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<td>F5</td>
<td>28.66 ± 1.66</td>
<td>S5</td>
<td>28.63 ± 1.66</td>
</tr>
<tr>
<td>V6</td>
<td>25.33 ± 1.66</td>
<td>F6</td>
<td>48.55 ± 1.93</td>
<td>S6</td>
<td>31.27 ± 1.76</td>
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<tr>
<td>V7</td>
<td>26 ± 1.66</td>
<td>F7</td>
<td>26 ± 1.66</td>
<td>S7</td>
<td>25.66 ± 1.66</td>
</tr>
<tr>
<td>V8</td>
<td>26 ± 1.66</td>
<td>F8</td>
<td>26 ± 1.66</td>
<td>S8</td>
<td>25.77 ± 0.96</td>
</tr>
</tbody>
</table>

Note: Each value is expressed as mean ± standard deviation (n=3). V1 - *M. paradisiaca* unripe fruit (Kunnan) raw methanol extract; V2 *M. paradisiaca* unripe fruit (Kunnan) boiled methanol extract; V3 - *M. paradisiaca* unripe fruit (Kunnan) raw acetone extract; V4 - *M. paradisiaca* unripe fruit (Kunnan) boiled acetone extract; V5 - *M. paradisiaca* unripe fruit (Palayamkodan) raw methanol extract; V6 *M. paradisiaca* unripe fruit (Palayamkodan) boiled methanol extract; V7 - *M. paradisiaca* unripe fruit (Palayamkodan) raw acetone extract; V8 *M. paradisiaca* unripe fruit (Palayamkodan) boiled acetone extract. F1 - *M. paradisiaca* flower (Kunnan) raw methanol extract; F2 - *M. paradisiaca* flower (Kunnan) boiled methanol extract; F3 - *M. paradisiaca* flower (Kunnan) raw acetone extract; F4 - *M. paradisiaca* flower (Kunnan) boiled acetone extract; F5 - *M. paradisiaca* flower (Palayamkodan) raw methanol extract; F6 - *M. paradisiaca* flower (Palayamkodan) boiled methanol extract; F7 - *M. paradisiaca* flower (Palayamkodan) raw acetone extract; F8 - *M. paradisiaca* flower (Palayamkodan) boiled acetone extract. S1 - *M. paradisiaca* pseudo stem (Kunnan) raw methanol extract; S2 - *M. paradisiaca* pseudo stem (Kunnan) boiled methanol extract; S3 - *M. paradisiaca* pseudo stem (Kunnan) raw acetone extract; S4 - *M. paradisiaca* pseudo stem (Kunnan) boiled acetone extract; S5 - *M. paradisiaca* pseudo stem (Palayamkodan) raw methanol extract; S6 - *M. paradisiaca* pseudo stem (Palayamkodan) boiled methanol extract; S7 - *M. paradisiaca* pseudo stem (Palayamkodan) raw acetone extract; S8 - *M. paradisiaca* pseudo stem (Palayamkodan) boiled acetone extract.

Table 3: DPPH and ABTS radical scavenging activity of *M. paradisiaca* var. (Kunnan and Palayamkodan) edible parts.

<table>
<thead>
<tr>
<th>Samples</th>
<th>DPPH (mmol/g extract)</th>
<th>ABTS (mmol/g extract)</th>
<th>Samples</th>
<th>DPPH (mmol/g extract)</th>
<th>ABTS (mmol/g extract)</th>
<th>Sample</th>
<th>DPPH (mmol/g extract)</th>
<th>ABTS (mmol/g extract)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>M. paradisiaca</em></td>
<td></td>
<td></td>
<td><em>M. paradisiaca</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unripe fruit</td>
<td></td>
<td></td>
<td>Flower</td>
<td></td>
<td></td>
<td>Sample</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V1</td>
<td>32189.78 ± 243.30</td>
<td>105947.57 ± 326.51</td>
<td>F1</td>
<td>30575.83 ± 268.00</td>
<td>124904.46 ± 3113</td>
<td>S1</td>
<td>24266.01 ± 255.57</td>
<td>105947.57 ± 3113</td>
</tr>
</tbody>
</table>

Note: Each value is expressed as mean ± standard deviation (n=3).
<table>
<thead>
<tr>
<th></th>
<th>34306.56±243.30</th>
<th>134649.25±3265.14</th>
<th>31946.47±243.30</th>
<th>137032.43±2954.42</th>
<th>0510.94±243.30</th>
<th>122629.77±3108.48</th>
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<tbody>
<tr>
<td>V2</td>
<td>20778.58±243.30</td>
<td>41601.90±3734.49</td>
<td>24979.72±26</td>
<td>66055.33±3108.48</td>
<td>21240.87±256.34</td>
<td>13936.37±3265.14</td>
</tr>
<tr>
<td>V3</td>
<td>26447.68±280.59</td>
<td>99108.90±1058.86</td>
<td>27672.34±255.57</td>
<td>87400.26±3113.66</td>
<td>21273.31±255.57</td>
<td>29996.89±3108.48</td>
</tr>
<tr>
<td>V4</td>
<td>28499.59±5.57</td>
<td>111231.99±326.30</td>
<td>26374.69±243.30</td>
<td>105222.25±3108.48</td>
<td>35117.59±3113.9</td>
<td>77867.57±3419.33</td>
</tr>
<tr>
<td>V5</td>
<td>29489.05±243.30</td>
<td>111542.8453±129.14</td>
<td>29002.43±358.41</td>
<td>134338.41±3734.49</td>
<td>35677.21±257.8</td>
<td>100663.14±3113.49</td>
</tr>
<tr>
<td>V6</td>
<td>24793.18±267.63</td>
<td>24505.23±3265.14</td>
<td>21776.15±243.30</td>
<td>73722.93±3734.66</td>
<td>28631.13±3113.9</td>
<td>35384.93±3113.73</td>
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<tr>
<td>V7</td>
<td>25766.42±725.45</td>
<td>67505.95±3265.14</td>
<td>24282.23±243.30</td>
<td>77867.57±3419.33</td>
<td>31062.44±306.15</td>
<td>64811.93±3113.48</td>
</tr>
<tr>
<td>V8</td>
<td>31364.79±681.25</td>
<td>100663.14±3113.49</td>
<td>73722.93±3734.49</td>
<td>134338.41±3734.49</td>
<td>35384.93±3113.73</td>
<td>64811.93±3113.48</td>
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### Standards

<table>
<thead>
<tr>
<th></th>
<th>81472.75±18706.23</th>
<th>655137.00±61415.86</th>
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<tbody>
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<td>BHA</td>
<td>814240.88±2737.22</td>
<td>99419.74±104323.56</td>
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<tr>
<td>Asc</td>
<td></td>
<td></td>
</tr>
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</table>

**Note:** Each value is expressed as mean ± standard deviation (n=3). V1-M. paradisiaca unripe fruit (Kunnan) raw methanol extract; V2-M. paradisiaca unripe fruit (Kunnan) boiled methanol extract; V3-M. paradisiaca unripe fruit (Kunnan) raw acetone extract; V4-M. paradisiaca unripe fruit (Kunnan) boiled acetone extract; V5-M. paradisiaca unripe fruit (Palayamkodan) raw methanol extract; V6-M. paradisiaca unripe fruit (Palayamkodan) boiled methanol extract; V7-M. paradisiaca unripe fruit (Palayamkodan) raw acetone extract; V8-M. paradisiaca unripe fruit (Palayamkodan) boiled acetone extract. F1-M. paradisiaca flower (Kunnan) raw methanol extract; F2-M. paradisiaca flower (Kunnan) boiled methanol extract; F3-M. paradisiaca flower (Kunnan) raw acetone extract; F4-M. paradisiaca flower (Kunnan) boiled acetone extract; F5-M. paradisiaca flower (Palayamkodan) raw methanol extract; F6-M. paradisiaca flower (Palayamkodan) boiled methanol extract; F7-M. paradisiaca flower (Palayamkodan) raw acetone extract; F8-M. paradisiaca flower (Palayamkodan) boiled acetone extract. S1-M. paradisiaca pseudo stem (Kunnan) raw methanol extract; S2-M. paradisiaca pseudo stem (Kunnan) boiled methanol extract; S3-M. paradisiaca pseudo stem (Kunnan) raw acetone extract; S4-M. paradisiaca pseudo stem (Kunnan) boiled acetone extract; S5-M. paradisiaca pseudo stem (Palayamkodan) raw methanol extract; S6-M. paradisiaca pseudo stem (Palayamkodan) boiled methanol extract; S7-M. paradisiaca pseudo stem (Palayamkodan) raw acetone extract; S8-M. paradisiaca pseudo stem (Palayamkodan) boiled acetone extract; BHA- Butylated hydroxyl anisole; Asc- Ascorbic acid.
Table 4: FRAP and Metal chelating activity of *M. paradisiaca* (var. Kunnan and Palayamkodan) edible parts

<table>
<thead>
<tr>
<th>Sample</th>
<th>FRAP (mmol Fe(II)/g Extract)</th>
<th>Metal chelating Sample activity (mg EDTA/g extract)</th>
<th>Sample</th>
<th>FRAP (mmol Fe(II)/g extract)</th>
<th>Metal chelating activity (mg EDTA/g extract)</th>
<th>Sample</th>
<th>FRAP (mmol Fe(II)/g extract)</th>
<th>Metal chelating activity (mg EDTA/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>M. paradisiaca</em> Unripe fruit</td>
<td></td>
<td></td>
<td><em>M. paradisiaca</em> Flower</td>
<td></td>
<td></td>
<td><em>M. paradisiaca</em> Pseudo stem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V1</td>
<td>13105.4±297.16 d</td>
<td>0.880fg±0.013</td>
<td>F1</td>
<td>13971.45d±142.75</td>
<td>1.751c±0.013</td>
<td>S1</td>
<td>13514.63d±171.30</td>
<td>1.114d±0.022</td>
</tr>
<tr>
<td>V2</td>
<td>133362.36 d±157.24</td>
<td>1.536hi±0.022</td>
<td>F2</td>
<td>21299.55d±1413.3</td>
<td>2.146bc±0.275</td>
<td>S2</td>
<td>13976.21d±135.68</td>
<td>1.489la±0.023</td>
</tr>
<tr>
<td>V3</td>
<td>11915.77±150.40</td>
<td>0.417j±0.022</td>
<td>F3</td>
<td>1364.87d±149.94</td>
<td>0.906hi±0.022</td>
<td>S3</td>
<td>13100.64d±150.40</td>
<td>0.605bc±0.022</td>
</tr>
<tr>
<td>V4</td>
<td>13086.37d±98.90</td>
<td>0.684e±0.022</td>
<td>F4</td>
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<td>13452.77d±105.22</td>
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<tr>
<td>V5</td>
<td>14009.52d±164.22</td>
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<td>F5</td>
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<td>S5</td>
<td>13980.97d±149.94</td>
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<td>V6</td>
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<td>0.874eg±0.022</td>
<td>F6</td>
<td>25358.55d±172.09</td>
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<td>14128.48d±142.75</td>
<td>1.648±0.022</td>
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<tr>
<td>V7</td>
<td>4825.60d±59.43</td>
<td>0.541def±0.022</td>
<td>F7</td>
<td>13643.11d±171.30</td>
<td>0.547hi±0.228</td>
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<td>13371.88d±142.75</td>
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<tr>
<td>V8</td>
<td>8513.44d±129.53</td>
<td>0.605b±0.022</td>
<td>F8</td>
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<td>S8</td>
<td>13438.5d±148.58</td>
<td>0.949k±0.022</td>
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<td>Standards</td>
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<tr>
<td>BHA</td>
<td>35076.04c±7247.67</td>
<td>10.48b±0.06</td>
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<tr>
<td>Asc</td>
<td>730073.8a±89814.83</td>
<td>12.67a±0.25</td>
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<tr>
<td>Trolox</td>
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</table>

Note: Each value is expressed as mean ± standard deviation (n=3). V1 - *M. paradisiaca* unripe fruit (Kunnan) raw methanol extract; V2 - *M. paradisiaca* unripe fruit (Kunnan) boiled methanol extract; V3 - *M. paradisiaca* unripe fruit (Kunnan) raw acetone extract; V4 - *M. paradisiaca* unripe fruit (Kunnan) boiled acetone extract; V5 - *M. paradisiaca* unripe fruit (Palayamkodan) raw methanol extract; V6 - *M. paradisiaca* unripe fruit (Palayamkodan) boiled methanol extract; V7 - *M. paradisiaca* unripe fruit (Palayamkodan) raw acetone extract; V8 - *M. paradisiaca* unripe fruit (Palayamkodan) boiled acetone extract. F1 - *M. paradisiaca* flower (Kunnan) raw methanol extract; F2 - *M. paradisiaca* flower (Kunnan) boiled methanol extract; F3 - *M. paradisiaca* flower (Kunnan) raw acetone extract; F4 - *M. paradisiaca* flower (Kunnan) boiled acetone extract; F5 - *M. paradisiaca* flower (Palayamkodan) raw methanol extract; F6 - *M. paradisiaca* flower (Palayamkodan) boiled methanol extract; F7 - *M. paradisiaca* flower (Palayamkodan) raw acetone extract; F8 - *M. paradisiaca* flower (Palayamkodan) boiled acetone extract. S1 - *M. paradisiaca* pseudo stem (Kunnan) raw methanol extract; S2 - *M. paradisiaca* pseudo stem (Kunnan) boiled methanol extract; S3 - *M. paradisiaca* pseudo stem (Kunnan) raw acetone extract; S4 - *M. paradisiaca* pseudo stem (Kunnan) boiled acetone extract; S5 - *M. paradisiaca* pseudo stem (Palayamkodan) raw methanol extract; S6 - *M. paradisiaca* pseudo stem (Palayamkodan) boiled methanol extract; S7 - *M. paradisiaca* pseudo stem (Palayamkodan) raw acetone extract; S8 - *M. paradisiaca* stem (Palayamkodan) boiled acetone extract. BHA - Butylated hydroxyl anisole; Asc - Ascorbic acid.
All sample extract showed lower activity than standards compared. The presence of antioxidants like polyphenols in the samples would result in the reduction of Fe $^{3+}$ to Fe $^{2+}$ by donating an electron. The reducing power of extracts appears to be more related to the degree of hydroxylation and the extent of conjugation in polyphenols. Antioxidants are strong reducing agents and this is principally based on the redox properties of their hydroxyl groups and the structural relationships between different parts of their chemical structure. The antioxidant activity has been reported to be concomitant with the development of reducing power (Akinmoladun et al.,). The reducing properties are generally associated with the presence of reductones (Pin-Der-Duh, 1998), which have been shown to exert antioxidant action by breaking the free radical chain by donating a hydrogen atom.

**Metal chelating activity**

Metal chelating activity is the most commonly used method for the evaluation of antioxidant activities. Chelating agents are not antioxidants. They serve as scavengers of metals which catalyze oxidation. The transition metal ion Fe$^{2+}$ possesses the ability to perpetuate the formation of free radicals by gain or loss of electrons. Therefore, reduction of the formation of reactive oxygen species can be achieved by the chelation of metal ions with chelating agents. Elemental species such as ferrous iron (Fe$^{2+}$) can facilitate the production of ROS within living system and these reduced metals may form highly reactive hydroxyl radicals and there by contribute to oxidative stress by Fenton reaction. The chelating properties were examined against Fe$^{2+}$. Ferrozine can quantitatively form complexes with Fe$^{2+}$ ions. The formation of complex is probably distributed by the chelating property in sample extract which would result in the reduction of the formation of coloured complex. Measurement of the rate of reduction of the colour, therefore, allows estimation of chelating activity of the extracts. The metal chelating activity was expressed as mg EDTA equivalents/g extract, and the results are presented in Table 4. All samples were exhibited lower metal chelating activity than standard (BHA). The metal chelating activity of acetone extracts of *M. paradisiaca* were in the range of 0.417 - 1.657 mg EDTA equivalents/g extract and the methanol extracts were in the range of 0.611 - 2.146 mg EDTA equivalents/g extract. The metal chelating activity of samples was found to be better with methanolic extracts. *M. paradisiaca* (var. *Kunnan*) flower has registered better activity. The results showed lowest activity than *Musa paradisiaca* stem, *Ney mannan* banana stem, *Safed velchi* banana stem and *Giant cavendish* banana stems (Saravanan and Aradhya, 2011). Chelating agents may serve as secondary antioxidants because they reduce the redox potential thereby stabilizing the oxidized form of metal ions. Accordingly, it is suggested that the ferrous ions chelating effects of these fractions would be somewhat beneficial to protect against oxidative damage.

**CONCLUSION**

Banana is the world’s fourth most valued fruit crop for its nutritive value with high carbohydrates, fiber, protein, less fat and water. There are many varieties of banana among them *Musa paradisiaca* have high medicinal value and are used for the treatment of various diseases including anti-diabetic, diarrhea, scabies and inflammation in folklore medicine. Current study is a novel approach to reveal the effect of hydrothermal processing on nutritional and nutraceutical potential of three edible parts (green fruit, flower and pseudostem) of *M. paradisiaca* (var. *Kunnan* and *Palayamkodan*) as they are mostly consumed by people after cooking. Based on the relative order of potency in the above assays tested the processed samples showed higher polyphenol content than raw. They also exhibited more potent antioxidant activity against some radicals and similar activity on others and this might be due to the presence of phenolic compounds including flavonoids. The present investigation suggests that processing has enhanced the functionality and improves availability of bioactive substances present in the edible parts of *Musa paradisiaca*. In various studies, it may be shown that processing decreases the antioxidant activity. This study may be a contradiction to these reports. Therefore the findings opens way to encourage consumption of processed bananas...
as functional food and this study will be useful to investigate their potential in alleviating diseases and maximizing their use in food industry and, thereby promoting innovation for producing value added products from banana. Also it paves road to sustainable management through the minimizing waste production by utilizing each and every part of the plant. Further investigations regarding in vivo studies and toxicity assessment will be focused to understand and promote banana as healthy functional food ingredients are also needed.

ACKNOWLEDGEMENT

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REFERENCES


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