*As. J. Food Ag-Ind.* **2011**, 4(01), 31-46

OPEN ACCESS

*Asian Journal of Food and Agro-Industry*

**ISSN 1906-3040**

Available online at www.ajofai.info

*Research Article*

# Chemical composition and antioxidant potential of peels from three varieties of banana

**Shyamala Bellur Nagarajaiah and Jamuna Prakash***

Department of Studies in Food Science and Nutrition, University of Mysore, Manasagangotri, Mysore, 570 006 India.

*Email: jampr55@hotmail.com

## Abstract

Banana (Musa *paradaisica*), is grown worldwide and consumed as ripe fruit or used for culinary purposes. Peels form about 18-33% of the whole fruit and are a waste product. With a view to exploiting banana peel as a source of valuable components, the nutritional composition, antioxidant components and activity of three varieties of banana namely *'Pachabale'*, '*Yelakkibale'* and *'Nendranbale'* were determined. The range of constituents estimated were 4.6-7.7%, 5.13-11.26%, 8.9-12.96% for protein, ether extractives and ash respectively. The iron content was high in *Pachabale* (10 mg/100g). The polyphenols were in the range of 200-850 mg equivalent of tannic acid/100g. A higher free radical scavenging activity (90%) was obtained in *Nendranbale* peel in ethanol extract compared to aqueous (64%) and methanol extract (62%). Among the three varieties *Nendranbale* peel exhibited high antioxidant activity. Results showed that banana peel had good antioxidant potential and varietal differences were observed.

**Keywords:** food waste, *Musa paradisiaca*, bioactive, polyphenol, flavonoid, β-carotene, antioxidant, India.

## Introduction

Bananas belonging to the family *Musaceae* are one of the most important tropical fruits in the world market. Global production of bananas is estimated to be around 48.9 MT. India is the largest producer of banana with a production figure of 39 thousand tons [1]. The states of Maharashtra and Gujarat in Western India, Karnataka in Southern India and Assam in the northeast are large banana growers. Bananas are used fresh or processed into many products such as chips, puree/pulp, powder, jams, juice, bar, biscuits, wine etc. Significant quantities of banana or plantain peels, equivalent to 40% of the total weight of fresh banana, are generated as a waste

product in industries producing banana based products [2]. At present, these peels are not being used for any other purposes and are mostly dumped as solid waste at large expense. It is thus significant and even essential to find applications for these peels as they can contribute to real environmental problems [3]. The manipulation of food processing wastes is now becoming a very serious environmental issue. Peels are the major by-products obtained during the processing of various fruit and some studies show that these are good sources of polyphenols, carotenoids and other bioactive compounds which possess various beneficial effects on human health [4, 5, 6]. Potential applications for banana peel depend on its chemical composition. Banana peel is rich in dietary fibre, proteins, essential amino acids, polyunsaturated fatty acids and potassium [7]. Banana and tomato peels have been reported to be a good source of carotenoids [8, 9]. Reports are also available on medicinal benefits of banana extract which include relief from pain, swelling, itching, bruising, wrinkles and sunburn [10]. However, there is limited information about the nutritional composition and antioxidant activities of banana peel [7, 11, 12, 13, 14, 15]. Hence in this study, nutritional composition and antioxidant activities of three varieties of banana grown in Southern India namely '*Pachabale*' (*Musa* paradisiaca Cv. Dwarf Cavendish, AAA), *'Yelakkibale'* (*Musa* paradisiaca Cv. Ney poovan, AB) and '*Nendranbale'* (*Musa* paradisiaca Cv. Nendran, AAB) were determined with the aim of exploiting the potential value of the peels and the possible utilization of these.

## Materials and Methods

### *Chemicals*

Chemicals used for the study were as follows: L-Ascorbic acid, β-carotene, 2,2-Diphenyl-1-picrylhydrazyl (DPPH), were from Sigma (Sigma-Aldrich, USA) chemical Co. All other chemicals were of analytical grade obtained from E-Merck, Mumbai, Qualigens Fine Chemicals, Mumbai, India. Double glass distilled water was used for all analyses. All analyses were run in triplicate and averaged.

### *Sample Preparation*

Banana of three varieties were purchased from a local market in one lot and processed. Peels from three varieties of banana namely *Pachabale* (*Musa* paradisiaca Cv. Dwarf Cavendish, AAA), *Yelakkibale* (*Musa* paradisiaca Cv. Ney poovan, AB) and *Nendranbale* (*Musa* paradisiaca Cv. Nendran, AAB) were selected. Peels were washed with distilled water and dried in oven at 50 ± 1°C and powdered using a lab grinder and stored in air-tight jars maintained at 4°C till use. A record of the yield of peel from fruit and after converting to powder was maintained.

### *Colour*

Colour is generally the first attribute which influences acceptability. Colour of fresh peel and dried powders was determined by visual observation using the methods described by Macbeth [16].

### *Estimation of bulk density*

Bulk densities of the samples were determined by the method of Wang and Kinsella [17]. 3.0 g of the finely powdered sample was placed in a 25 ml graduated cylinder and packed gently by tapping the cylinder on a rubber sheet until a constant volume was obtained. The bulk density was expressed as g of sample/100 ml.

***Water absorption capacity (WAC)***

WAC of the sample was determined by the centrifuge technique described by Janicki and Walczak [18]. A 1.0 g sample was weighed into a centrifuge tube. 5.0 ml of glass double distilled water was added gently down the side and mixed with a thin glass rod. The slurry was weighed, kept aside for 30 min with gentle stirring with a glass rod every 5 min and centrifuged at 3000 rpm for 25 min at 27°C. The amount of water retained was calculated by measurement of the difference in the weight of the sample before and after equilibration with water. The water absorption capacity was expressed as the amount of water absorbed (ml/100 g sample).

***Estimation of moisture, fat, protein, dietary fibre and total ash***

Dried peel samples were analysed for proximate composition. Percentages of moisture by vacuum oven (method 926.12, 41.1.02), total ether extractives by Soxhlet apparatus using petroleum ether (method 948.22, 40.1.05), protein by Kjeldahl nitrogen (method 960.52, 12.1.07) and ash by direct analysis (method 942.05, 4.1.10), were determined according to the Association of Official Analytical Chemists [19] and dietary fibre consisting of insoluble and soluble fractions were estimated by enzymatic gravimetric method [20]. Total carbohydrates were calculated by difference from the other components from 100.

***Estimation of vitamin C and carotenoids***

Ascorbic acid was estimated by 2, 6-dichlorophenol indophenol visual titration method, which is based on reduction of the dye colour from blue to pale pink by ascorbic acid [21]. For estimation of carotenoids, the peels were extracted in acetone and transferred to petroleum ether phase. Total carotene was read colorimetrically using petroleum ether for baseline correction. β-carotene was separated by column chromatography and read colorimetrically [21].

***Estimation of phosphorus, iron and calcium***

Phosphorus analysis was carried out by measuring the blue colour, which is formed when the ash solution was treated with ammonium molybdate. The phosphomolybdate thus formed was reduced and read colorimetrically [22]. Iron was determined colorimetrically making use of the fact that ferric iron gives a blood red colour with potassium thiocyanate [23]. For calcium estimation, it was precipitated as calcium oxalate, the precipitate dissolved in hot dilute $H_2SO_4$ and titrated against standard potassium permanganate [24].

***Analysis of antinutrients***

Oxalates were extracted with hydrochloric acid, precipitated as calcium oxalate from the deproteinised extract and estimated by subsequent titration with potassium permanganate [25]. Phytic acid was extracted and determined according to the supernatant difference method [26].

***Preparation of sample extracts in solvents***

For estimation of polyphenol, flavonoids and antioxidant activity, samples were extracted with ethanol, methanol and aqueous medium. 1.0 g of sample was suspended with 100 ml solvent, allowed to extract for 3 hr with agitation, centrifuged with 3000 rpm and filtered. All analysis was carried out in freshly collected extracts.

***Analysis of total polyphenol content***

Samples were analyzed for total polyphenol content according to the Folin-Ciocalteu method [27]. To 0.5 ml aliquot of the extract solution, 0.2 ml of Folin-Ciocalteau reagent, and a saturated

solution of $Na_2CO_3$ (0.5 ml) was added. This was increased to 10 ml with distilled water and incubated at 27°C for 30 min. Optical density was measured at 765 nm using a spectrophotometer. The concentration was calculated using tannic acid as a standard and the results were expressed as tannic acid equivalents/100 g of sample.

***Analysis of total flavonoid content***

The total flavonoid content was determined using the Dowd method [28]. 5.0 ml of 2% aluminium trichloride ($AlCl_3$) in methanol was mixed with the same volume of the extract solution. Absorption readings at 415 nm after 10 min against a blank sample consisting of 5 ml extract solution with 5 ml methanol without $AlCl_3$ were taken. The total flavonoid content was determined using a standard curve with quercetin as the standard. Total flavonoid content was expressed as mg of quercetin equivalents/100 g of sample.

***Analysis of tannin content***

Tannins were estimated by colorimetric method based on the measurement of blue colour formed by the reduction of phosphotungstomolybdic acid by tannin like compounds in alkaline solution [29].

***Total antioxidant activity by phosphomolybdenum method***

This assay is based on the reduction of Mo (VI) to Mo(V) by the sample analyte and the subsequent formation of green phosphate/Mo(V) complex at acidic pH [30]. An aliquot of 0.1 ml sample was combined with 1.0 ml of reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The tubes were capped and incubated at 95ºC for 90 min. After the samples had cooled to room temperature, the absorbance was measured at 695 nm against a blank. A typical blank contained 1.0 ml of reagent solution and the appropriate volume of the same solvent used for the sample and was incubated under the same conditions as the rest of the samples. For samples of unknown composition, antioxidant capacities were expressed as equivalents of ascorbic acid (µmol/ g of sample).

***Free radical scavenging activity using DPPH***

DPPH, a commercial oxidizing radical is reduced by antioxidants. The disappearance of the DPPH radical absorption at a characteristic wavelength is monitored by a decrease in optical density [31]. Different concentrations of extract were taken in different test tubes. The volume was adjusted to 1000 µL by adding MeOH. Four milliliters of a 0.1 mM methanol solution of DPPH was added to these test tubes and shaken vigorously. The tubes were then incubated in the dark at room temperature for 20 min. A control sample was prepared as above without extract, and methanol was used for the baseline correction. Changes in the absorbance of the samples were measured at 517 nm. Radical scavenging activity was expressed as the inhibition percentage and was calculated using the following formula:

Radical scavenging activity (%) = (Control OD – Sample OD/Control OD) × 100.

***Reducing power***

In this assay, $Fe^{3+}$/ferricyanide complex is reduced to the ferrous form by antioxidants. The $Fe^{2+}$ formed is monitored by measuring the formation of Perl's Prussian blue at 700 nm [32]. Different amounts of sample in 1.0 ml of distilled water were mixed with phosphate buffer (2.5 ml, 0.2M, pH 6.6) and potassium ferricyanide [$K_3Fe(CN)_6$] (2.5 ml, 1%). The mixture was incubated at 50°C

for 20 min. A portion (2.5 ml) of trichloroacetic acid (10%) was added to the mixture, which was then centrifuged at 3000 rpm for 10 min. The upper layer of the solution (2.5 ml) and $FeCl_3$ (0.5 ml, 0.1%) were mixed and the absorbance was measured at 700 nm. Increased absorbance of the reaction mixture indicated increased reducing power.

***Statistical analysis***

The data was analysed for mean and standard deviation. ANOVA was used to determine significant differences in polyphenols, flavonoids, tannins and antioxidant activity in banana peel of different varieties. Correlation coefficient test was applied to test the association between the antioxidant components and the antioxidant activity of the peels using a statistical package SPSS 10.0. Probability level was fixed to $P< 0.05$.

## Results and Discussion

***Physical characteristics of the peels***

The physical characteristics of peels are given in Table 1. Fresh banana peels were yellow in colour, but a significant darkening was observed on drying. This was different in each variety with shades varying from olive to olive brown. The yield of peel obtained (as % of whole fruit) was more in *Nendranbale* with 33% followed by *Pachabale,* 29% and *Yelakkibale,* 18%. The yield of dry powder ranged from 11-17%. Water absorption capacity was high for all the three varieties ranging from 600 to 690 ml. This could be due to high fibre content of peels which consist of a large number of hydrophilic groups that absorb water. The bulk density of the peels ranged from 62 to 66 g/100 ml showing that the samples were light in weight.

**Table 1. Physical characteristics of the peels.**

| Samples | Physical characteristics | | | | | |
|---|---|---|---|---|---|---|
| | Colour* | | Yield | | Water Absorption Capacity of dry powder (ml/100g) | Bulk Density of dry powder (g/100ml) |
| | Fresh | Dry | As % of whole fruit | As dry powder (%) | | |
| ***Pachabale*** | 5Y 8/8 Yellow | 5Y 4/4 Olive | 29.10 | 11.67 | 610.00 ±14.14 | 66.65 ±0.01 |
| ***Yelakkibale*** | 5Y 8/8 Yellow | 2.5Y 5/4 Light olive brown | 18.84 | 14.44 | 600.00 ±0.00 | 64.52 ±0.00 |
| ***Nendranbale*** | .5Y 8/8 Yellow | 2.5Y 4/4 Olive brown | 33.12 | 17.06 | 690.00 ±14.14 | 62.50 ±0.00 |

* Munsell color charts (2000).

***Proximate composition***

Table 2 summarizes the proximate composition of the three varieties of banana peel. Moisture content of peel was high in three varieties i.e. 82 - 88%. Moisture content of oven dried and powdered samples varied from 1.45 - 1.71%. Protein content was in the range of 4.6 - 7.7% on dry weight basis (DW) with the highest value in *Yelakkibale* peel and lowest in *Nendranbale* peel. Ether extractives of *Yelakkibale* (11.26%) were in close agreement with the results observed for Yankambi Km5 (11.60%) variety [33]. The other two varieties of *Pachabale* and *Nendranbale* had lower fat content of 6.21 and 5.13% respectively. The ash content ranged from 8.9-12.96%. *Yelakkibale* had the highest ash value (12.96%). The elemental composition shows that calcium content was higher in all three varieties of banana peel in comparison to phosphorus. The iron content ranged from 3.33 to 10 mg/100 g of sample with *Pachabale* having the highest content. Emaga, *et al.* [7] studied the composition of banana peel varieties and indicated that the increase of dry matter content in different varieties increases crude fat from 4.6 to 5.9% for French Clair and from 6.3% to 10.9% for Grande Naine and crude protein from 8.3 to 9.1% for French Clair and 6.3 to 8.1% for Yankambi Km5. They also reported ash content of fruit peels, which ranged from 6.4% to 12.8% and were in close agreement with this study. Essien, *et al.* [33] studied sweet ripened banana, without specifying its variety and obtained a value of 7.8% for crude protein.

**Table 2. Chemical composition of banana peels (per 100 g dry weight basis).**

| Parameters | *Pachabale* | *Yelakkibale* | *Nendranbale* |
|---|---|---|---|
| **Moisture* (g)** | 88.9 ±0.00 | 88.2 ±0.15 | 82.6 ±0.04 |
| **Moisture (g)** | 1.71 0.01 | 1.45 0.01 | 1.47 0.00 |
| **Protein (g)** | 6.77 ±0.00 | 7.76 ±0.08 | 4.60 ±0.08 |
| **Ether extractives (g)** | 6.21 ±0.07 | 11.26 ±0.05 | 5.13 ±0.01 |
| **Ash (g)** | 12.90 ±0.01 | 12.96 ±0.05 | 8.98 ±0.01 |
| **Carbohydrate (By difference)** | 26.4 ±0.00 | 9.8 ±0.00 | 41.9 ±0.00 |
| **Iron (mg)** | 10.00 ±0.00 | 3.33 ±0.00 | 4.00 ±0.00 |
| **Phosphorus (mg)** | 145.66 ±0.57 | 212.00 ±0.00 | 140.00 ±0.00 |
| **Calcium (mg)** | 166.54 ±0.93 | 244.68 ±0.88 | 204.80 ±0.00 |

(*Fresh weight basis)

***Antioxidant components and antinutrients***

Table 3 presents the antinutrient and antioxidant components of the samples. Total carotenes ranged from 1-3 mg/100 g for the samples. It was high in *Pachabale* and low in *Nendranbale*. β-carotene content was high in *Pachabale* (1.86 mg) and it was almost negligible in *Nendranbale* (0.49 mg). Vitamin C content was high in *Yelakkibale* (17.83 mg/100 g) compared to the other two varieties which had only 1.8 mg**.** Kanazawa, *et al.* [13] found that the ascorbic acid content of banana was constant at around 10 mg/100 g in both peel and pulp, regardless of the stage of ripening**.** Tannins were high in *Nendranbale* followed by *Yelakkibale* and *Pachabale* (1114, 1075 and 516 mg/100 g). The total and water soluble oxalates in the samples were negligible except with *Yelakkibale* which recorded 2.83 mg/100 g of total oxalate and 1.86 mg/100 g of water soluble oxalates respectively. The phytic acid content of the samples ranged between 49-90 mg /100 g. *Yelakkibale* had highest among the three peels (90.13 mg). Dietary fibre, i.e insoluble dietary fibre (IDF), ranged from 35-50% and soluble dietary fibre (SDF) contents ranged from 2.23% to 6.83%. In all varieties IDF was the dominant fibre fraction. A similar result was observed by Emaga, *et al.* [7] when they studied the effects of stage of maturation on chemical composition of banana and plantain peels and found that the stage of maturation did not affect TDF, IDF and SDF of varieties in a consistent manner.

**Table 3. Antioxidant and antinutrient components in the peels (per 100 g).**

| Parameters | *Pachabale* | *Yelakkibale* | *Nendranbale* |
|---|---|---|---|
| Total carotenes (mg) | 3.12 ±0.14 | 2.35 ±0.04 | 1.27 ±0.01 |
| β-carotene (mg) | 1.86 ±0.01 | 1.52 ±0.01 | 0.49 ±0.01 |
| Vitamin-C (mg) | 1.79 ±0.00 | 17.83 ±0.28 | 1.80 ±0.00 |
| Tannins (mg) | 517 ±5.77 | 1073 ±3.46 | 1114 ±14.72 |
| Total oxalate (mg) | 0.089 ±0.00 | 2.83 ±0.02 | 1.05 ±0.05 |
| Water soluble oxalate (mg) | 0.045 ±0.00 | 1.86 ±0.07 | 0.16 ±0.01 |
| Phytic acid (mg) | 69.31 ±0.89 | 90.13 ±1.44 | 49.79 ±2.29 |
| Insoluble dietary fibre (g) | 41.8 ±0.57 | 49.93 ±1.61 | 35.6 ±1.03 |
| Soluble dietary fibre (g) | 4.13 ±0.23 | 6.83 ±0.63 | 2.23 ±0.11 |

***Total polyphenols, flavonoids and total antioxidant activity***

Banana peels were extracted with methanol, ethyl alcohol and aqueous media separately and the phenolic contents in the extracts were determined. The results are presented in Table 4. Polyphenol contents in methanol extracts varied from 520 to 850 mg equivalents tannic acid/100

g. Compared to methanol extract, ethanol and aqueous extracts showed less total polyphenols which ranged from 200 to 750 mg equivalents tannic acid/100 g.

**Table 4. Total polyphenols and flavonoid contents and total antioxidant activity of banana peels in different extracts.**

| Extracts | *Pachabale* | *Yelakkibale* | *Nendranbale* | F-ratio | P-value |
|---|---|---|---|---|---|
| **Total Polyphenols (mg equivalents to tannic acid/100 g sample)** | | | | | |
| Methanol | 520.00 ±0.00 | 750.00 ±0.00 | 850.00 ±0.00 | | |
| Ethanol | 430.00 ±10.95 | 750.00 ±0.00 | 680.00 ±0.00 | 0.642564 | 0.558653 $^{ns}$ |
| Aqueous | 200.00 ±0.00 | 220.00 ±0.00 | 290.00 ±0.00 | | |
| **Total flavonoids (mg equivalents to quercetin/100 g sample)** | | | | | |
| Methanol | 535.41 ±30.83 | 385.41 ±9.54 | 1035.42 ±20.09 | | |
| Ethanol | 222.91 ±3.60 | 316.66 ±21.94 | 818.75 ±6.25 | 9.936922 | 0.01247* |
| Aqueous | 577.08 ±31.45 | 350.00 ±10.82 | 714.58 ±34.42 | | |
| **Total antioxidant activity (µmoles of ascorbic acid/g of sample)** | | | | | |
| Methanol | 63234.42 ±198.22 | 48577.67 ±384.79 | 66727.75 ±120.77 | | |
| Ethanol | 47572.5 ±161.57 | 44558.75 ±80.51 | 47670.00 ±330.97 | 0.369273 | 0.705919 $^{ns}$ |
| Aqueous | 94803.33 ±535.32 | 74080.75 ±40.25 | 89484.75 ±241.27 | | |

Total phenolics were reported by Someya, *et al.* [14] and were found to be more abundant in peel (907 mg/100 g dry weight) than in pulp (232 mg/100 g dry weight). Pulp of Cavendish subgroup cultivars had a phenolic compound content of around 30-60 mg/100 g fresh matter [34] and these were present in greater quantity in skin than in pulp**.** Gallocatechin was more abundant in peel (158 mg/100 g dry weight) than in pulp (29.6 mg/100 g dry weight) and the better antioxidant content was attributed to a higher content of gallocatechin in peel [14]. Total flavonoids were high in both the solvent and aqueous extract of *Nendranbale* peel (714 - 1035 mg equivalents to

quercetin/100 g), in *Yelakkibale* peel extracts, it ranged from 316 - 385 mg and it was low in *Pachabale* peel ethanol extract i.e, 222 mg (Table 4).

The total antioxidant activity was high in samples in water extract (74080 – 94803 µmoles) followed by methanol (48577- 66727 µmoles) and ethanol (44558 – 47670 µmoles) extracts. However, values were closer to each other for 3 varieties of banana peel in ethanol extract. When the data were subjected to ANOVA, it was found that there were no significant differences in total polyphenol contents of extracts in three varieties of peel or in total antioxidant activity. However, total flavonoid content differed marginally in extracts of three varieties (P value – 0.01247).

***Free radical scavenging activity***

DPPH has been used extensively as a free radical to evaluate reducing substances and is a useful reagent for investigating the free radical scavenging activities of compounds. Peel extract of *Pachabale* and *Yelakkibale* showed antioxidant activity at higher concentration of 5-20 mg (Figure 1). Methanol extract of *Pachabale* peel showed higher activity (61%) compared to ethanol and aqueous extracts (49% and 31%) respectively. In aqueous extract there was no activity at low concentrations of 5 mg. A similar trend was observed in case of *Yelakkibale* where methanol extract had activity of 92% compared to ethanol and aqueous extracts (59 and 34%) respectively. In *Nendranbale* peel the activity was exhibited at a lesser concentration (1 to 4 mg) compared to the other two varieties. In this the ethanol extract showed higher activity of 90% compared to aqueous and methanol extract (64 and 62%) respectively. Among the three varieties *Nendranbale* peel exhibited higher antioxidant activity at lesser concentration. As reported in the literature, the strong antioxidative properties of banana extracts could be due to different antioxidant components present in them. Dopamine was found in a large amount in both peel and pulp of banana [13]. Peel contained 10 mg of dopamine along with two more antioxidative phytochemicals, namely flavanone glycoside- naringin and flavonol glycoside-rutin at 10 mg/100 g at all ripening stages. The banana peel extract, with more gallocatechin than the pulp, showed stronger antioxidant activity than the pulp extract. In addition, banana peel was also reported to have flavonoids and catecholamines. Similar findings have also been reported by Sojo, *et al.* [35] who stated that the peel contained antioxidative arginine, flavonoids and catecholamines, and probably others, with a large amount of dopamine in both peel and pulp. The amount of dopamine is said to decrease with ripening and remained between 80-560 mg/100 g of peel and between 2.5-10 mg/100 g of pulp. Dopamine is known to play important roles as neurotransmitter and precursor of norepinephrine and epinephrine. In another study by Kanazawa, *et al.* [13] antioxidative potency of several fruit were examined and they found that tropical fruit had strong activity, for example, banana water-extract suppressed the autoxidation of linoleic acid by 65-70% after 5-day incubation in an emulsion system, as determined from the peroxide value and thiobarbituric acid reactivity.

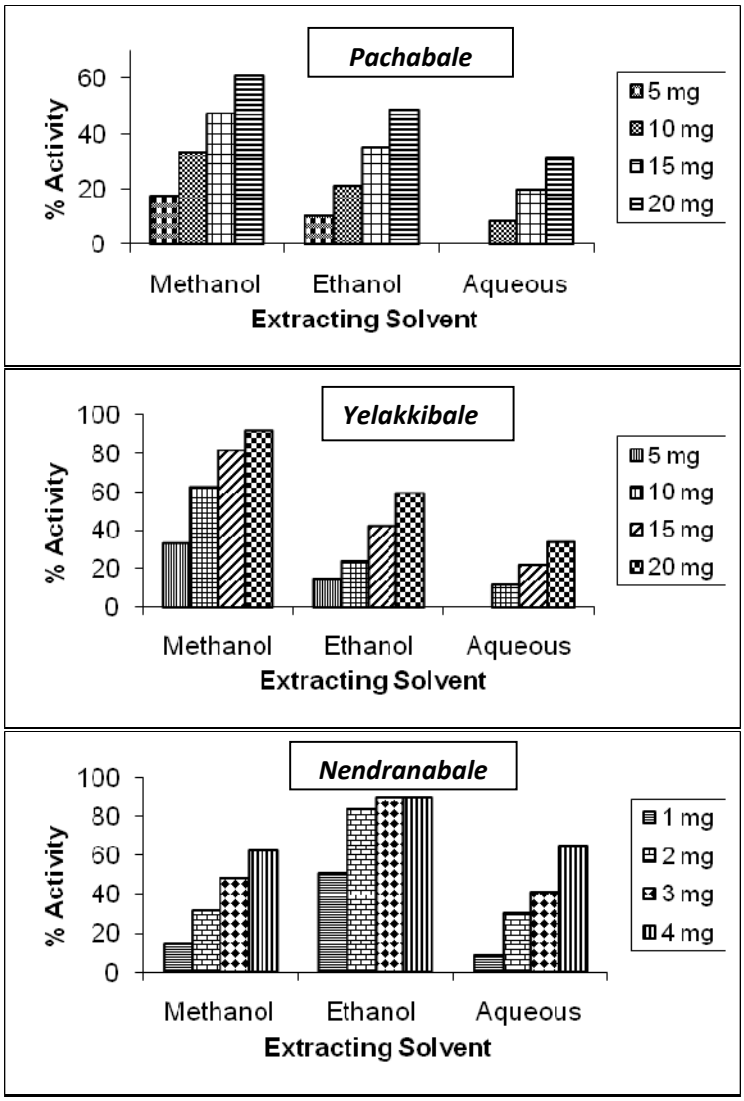


**Figure 1. Free radical scavenging activity in different banana peel extracts.**

***Reducing Power***

Concentration dependency of antioxidant activity was investigated as a function of reducing power as this gives a general view of reductones present in the sample (Figure 2). It was observed that at any concentration between 2- 8 mg, methanol and ethanol extracts of *Nendranbale* peel had higher reducing power than the other two varieties. Both *Yelakkibale* and *Pachabale* in methanol and ethanol extract had a similar reducing power at different concentration. The reducing power assay of aqueous extract of all the three samples were in similar range.

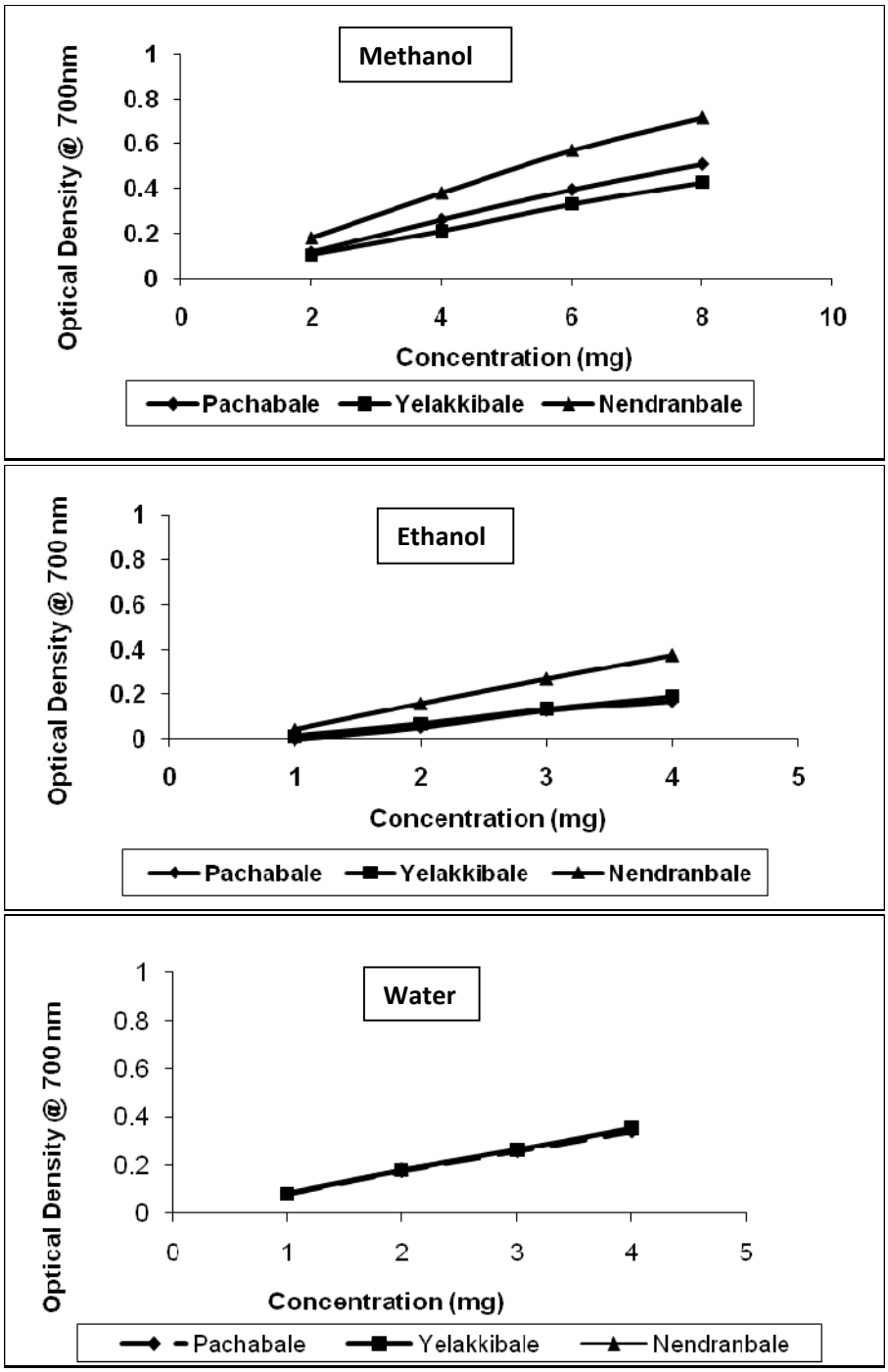


**Figure 2. Reducing power of banana peels in different extracts.**

***Correlation between antioxidant components and antioxidant activities***

To estimate the inhibitory capacity of these compounds against reactive oxygen species data correlating antioxidant activity and phenolics concentration are commonly reported. The antioxidant activities of banana peels as determined by three different assays were correlated with their antioxidant components and the results are presented in Table 5.

**Table 5. Correlation between antioxidant components and antioxidant activities of banana peel extracts as measured by three methods.**

| | Antioxidant components in banana peels | | | | |
|---|---|---|---|---|---|
| **Extracts** | **Total carotene** | **β-carotene** | **Tannins** | **Polyphenols** | **Flavonoids** |
| **Free radical scavenging activity** | | | | | |
| Methanol extract | -0.79 | -0.93 | 0.748 | 0.884 | 0.886 |
| Ethanol extract | -0.69 | -0.97 | 0.647 | 0.809 | 0.942 |
| Aqueous extract | -0.6 | -0.99 | 0.552 | 0.734 | 0.975 |
| **Reducing Power** | | | | | |
| Methanol extract | -0.34 | -0.98 | 0.284 | 0.503 | 0.997 |
| Ethanol extract | -0.7 | -0.97 | 0.657 | 0.716 | 0.938 |
| Aqueous extract | -0.86 | -0.87 | 0.828 | 0.937 | 0.818 |
| **Total antioxidant activity** | | | | | |
| Methanol extract | 0.215 | -0.73 | -0.28 | -0.04 | 0.801 |
| Ethanol extract | 0.363 | -0.62 | -0.42 | -0.19 | 0.699 |
| Aqueous extract | 0.604 | -0.38 | -0.65 | -0.46 | 0.476 |

High correlations between free radical scavenging activity with tannins, polyphenols and flavonoids were observed. Total and β-carotene were negatively correlated with free radical scavenging activity. Reducing power assay also showed similar results where tannins,

polyphenols and flavonoids were positively correlated and no association was found with total and β-carotene. In the case of total antioxidant activity, positive associations were observed for total carotenoids and flavonoids. These results indicate that peels have different antioxidative components which exhibit antioxidant activities in different assays. It is well recognized that phenolics are the major contributors to the total antioxidant capacity of fruit, vegetables and grains. High correlations between antioxidant activity and total phenolics ($R^2 > 0.7$) were obtained for genotypes of sweet potatoes, peaches and mashua and oca tubers, while low correlations ($R^2 < 0.7$) were obtained for plums and native potatoes from Peru [36, 37]. It is realized that for determination of correlation between antioxidant component and activity, both the nature of components and their amounts are important factors. In addition to these, they are also influenced by the processing treatments. Several studies using correlation analysis have been conducted on fresh produce and food products without considering the phenolic profiles factor [38, 39]. The antioxidant activity of a specific phenolic compound is related with the number of available hydroxyl groups present in the chemical structure. Therefore, the manner in which these compounds neutralize free radicals will depend on their relative concentrations in the sample matrix. In addition, phenolic compounds can act synergistically, additively, or antagonistically to inhibit reactive species [40, 41].

## Conclusions

The nutritional compositional analysis of banana peel indicated that among the three varieties analysed, protein and ether extractives were high in *Yelakkibale* peel. The peels were a good source of calcium. For iron content, *Pachabale* was specifically high with 10 mg/100g, and if used as a supplement, the peel can provide natural iron and calcium. Among all three varieties, *Nendranbale* peel exhibited high antioxidant activity. It can be concluded that banana peel had good antioxidant potential, though varietal differences were observed. The antioxidant activity of peels could be correlated positively with polyphenols, flavonoids and tannins. Hence banana peel can be exploited for their nutritional and antioxidant components.

## Acknowledgement

The source of funding for this study, the Council of Scientific and Industrial Research (CSIR) – New Delhi, India, is gratefully acknowledged.

## References

1. Agricultural Statistics at a glance. (2009). 4th advance estimates, Horticulture division, Govt. of India. Retrieved March 1, from: http://dacnet.nic.in/eands/Book_Setup_4.pdf.

2. Tchobanoglous, G., Theisen, H. and Vigil, S. (1993). Integrated solid waste management: Engineering principles and management issues. McGraw-Hill, New York, pp. 3-22.

3. Zhang, P., Whistler, R.L., BeMiller, J.N. and Hamaker, B.R. (2005). Banana starch: production, physicochemical properties, and digestibility – a review. ***Carbohydrate Polymers,*** 59 (4), 443-458.

4. Larrauri, J.A., Ruperez, P. and Saura-calixto, F. (1999). New approaches in the preparation of high dietary fibre from fruit by-products. ***Trends in Food Science and Technology,*** 29, 729-733.

5. Rodriguez de Sotillo, D., Hadley, M. and Holm, E.T. (1994a). Potato peel waste stability and antioxidant activity of freeze dried extract. ***Journal of Food Science,*** 59, 1031-1033.

6. Wolfe, K., Xianzhong, W.U. and Liu, R.H. (2003). Antioxidant activity of apple peels. ***Journal of Agricultural and Food Chemistry,*** 51*,* 609-614.

7. Emaga, T.H., Andrianaivo, R.H., Wathelet, B., Tchango, J.T. and Paquot, M. (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. ***Food Chemistry,*** 103, 590-600.

8. Baysal, T., Ersus, S. and Starmans, D.A.J. (2000). Super critical $CO_2$ extraction of β-carotene and lycopene from tomato paste waste. ***Journal of Agricultural and Food Chemistry,*** 48, 5507-5511.

9. Subaigo, A., Morita, N. and Sawada, S. (1996). Carotenoids and their fatty acid esters in banana peel. ***Journal of Nutriscience and Vitaminology,*** 42, 553-566.

10. Edwards, B. (1999). Banana peel extract composition and method for extraction, Patent No. WO 99/38479.

11. Adisa, V.A. and Okey, E.N. (1987). Carbohydrate and protein composition of banana pulp and peel as influenced by ripening and mold contamination. ***Food Chemistry,*** 25, 85-91.

12. Emaga, T.H., Robert, C., Ronkart, S.N., Wathelet, B. and Paquot, M., (2008). Dietary fibre components and pectin chemical features of peels during ripening in banana and plantain varieties. ***Bioresource Technology,*** 99, 4346-4354.

13. Kanazawa, K. and Sakakibara, H. (2000). High content of dopamine, a strong antioxidant, in Cavendish banana. ***Journal of Agricultural and Food Chemistry,*** 48, 844-848.

14. Someya, S., Yoshiki, Y. and Okubo, K. (2002). Antioxidant compounds from bananas (*Musa Cavendish*). ***Food Chemistry,*** 79, 351-354.

15. Gonzalez-Montelongo, R., Gloria Lobo, M. and Gonzalez, M. (2010). Antioxidant activity in banana peel extracts: Testing extraction conditions and related bioactive compounds. ***Food Chemistry,*** 119, 1030-1039.

16. Macbeth, G. (2000). Munsell color charts, New Windsor, New York.

17. Wang, J. and Kinsella, J.E. (1976). Functional properties of novel proteins; alfalfa leaf proteins. ***Journal of Food Science,*** 41, 18-23.

18. Janicki, N.A. and Walczak, J. (1954). Wateriness in meat and methods for its determination, in Hamm, R. Biochemistry of meat hydration. ***Advances in Food Research,*** 10, 355-394.

19. AOAC. (2005). Determination of moisture, ash, protein and fat. Official Methods of Analysis, 18th ed. AOAC International.

20. Asp, N.G., Johansson, C.G., Hallmer, H. and Siljestrom, M. (1983). Rapid enzymatic assay of insoluble and soluble dietary fiber. ***Journal of Agricultural and Food Chemistry,*** 31(3), 476-482.

21. Ranganna, S. (1986). Handbook of analysis and quality control for fruit and vegetable products. (2nd Ed.) Tata McGraw-Hill, New Delhi, India.

22. Taussky, H.H. and Shorr, E. (1953). A micro colorimetry method for determination of inorganic phosphorus. ***Journal of Biological Chemistry,*** 202, 675-685.

23. Raghuramulu, N., Nair, M.K. and Kalyansundaram, S. (2003). A manual of laboratory techniques, National Institute of Nutrition, ICMR, Jamai-Osmania, Hyderabad, India.

24. Oser, B.L. (1965). Hawks Physiological Chemistry, 14th Ed.; Tata McGraw Hill Publishing Co. Ltd., New Delhi, India, pp. 1263-1265.

25. Baker, C.J.L. (1952). The determination of oxalates in fresh plant material. ***Analyst,*** 77, 340-344.

26. Thompson, D.B. and Erdman, Jr J.W. (1982). Phytic acid determination in soybeans. ***Journal of Food Science,*** 47, 513-517.

27. Matthaus, B. (2002). Antioxidant activity of extracts obtained from residues of different oilseeds. ***Journal of Agricultural and Food Chemistry,*** 50, 3444–3452.

28. Arvouet-Grand, A., Vennat, B., Pourrat, A. and Legret, P. (1994). Standardisation d'un extrait de propolis et identification des principaux constituants. ***Journal de Pharmacie de Belgique,*** 49, 462- 468.

29. AOAC. (1970). Estimation of tannins. Official Methods of Analysis, 11thed. Washington, D.C., USA.

30. Prieto, P., Pineda, M. and Aguilar, M. (1999). Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of Vitamin E. ***Analytical Biochemistry,*** 269, 337-341.

31. Oktay, M., Culcin, I. and Kufrevioglu, O. I. (2003). Determination of in vitro antioxidant activity of fennel (*Foeniculum vulgare*) seed extracts. ***Lebensmittel-Wissenschaft und-Technologie,*** 36, 263–271.

32. Oyaizu, M. (1986). Studies on product of browning reaction prepared from glucose amine. ***Japanese Journal of Nutrition,*** 44, 307–315.

33. Essien, J.P., Akpan, E.J. and Essien, E.P. (2005). Studies on mold growth and biomass production using waste banana peel. ***Bioresource Technology,*** 96*,* 1451-1456.

34. Verde Mendez, C.M., Forster, M.P., Rodriguez-Delgado, M.A., Rodriguez-Rodriguez, E.M. and Diaz Romero, C. (2003). Content of free phenolic compounds in bananas from Tenerife (Canary Islands) and Ecuador. ***European Food Research and Technology,*** 217(4), 287- 290.

35. Sojo, M.M, Nunez-Delicado, E., Sanchez-Ferrer, A. and Garcia-Carmona, F. (2000). Oxidation of salsolinol by banana pulp polyphenol oxidase and its kinetic synergism with dopamine. ***Journal of Agricultural and Food Chemistry,*** 48, 5543-5547.

36. Campos, D., Noratto, G., Chirinos, R., Arbizu, C., Roca, W. and Cisneros-Zevallos, L. (2006). Antioxidant capacity and secondary metanbolites in four species of Andean tuber crops: native potato (*Solanum* sp.), mashua (*Tropaeolum tuberosum* Ruiz and Pavon), Oca (*Oxalis tuberose* Molina) and Ulluco (*Ullucus tuberosus* Caldas). ***Journal of Agricultural and Food Chemistry,*** 86 (10), 1481-1488.

37. Teow, C.C., Truong, V.D., McFeeters, R.F., Thompson, R.L., Pecota, K.V. and Yencho, G.C. (2007). Antioxidant activities, phenolic and β–carotene contents of sweet potato genotypes with varying flesh colours. ***Food Chemistry,*** 103, 829-838.

*38.* Prior, R.L., Wu, X. and Schaich, K. (2005). Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. ***Journal of Agricultural and Food Chemistry,*** 53, 4290-4302.

39. Gu, L., House, S.E., Wu, X., Ou, B. and Prior, R. (2006). Procyanidin and catechin contents and antioxidant capacity of cocoa and chocolate products. ***Journal of Agricultural and Food Chemistry,*** 54, 4057-4061.

40. Heo, H.J., Kim, Y.J., Chung, D. and Kim, D.O. (2007). Antioxidant capacities of individual and combined phenolics in a model system. ***Food Chemistry,*** 104, 87-92.

41. Cirico, T.L. and Omaye, S.T. (2006). Additive or synergetic effects of phenolic compounds on human low-density lipoprotein oxidation. ***Food Chemistry and Toxicology,*** 44, 510-516.