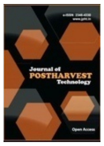

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RESEARCH ARTICLE

Comparative analysis of nutrient and phytonutrient composition of unripe banana flour from *Musa paradisiaca* L. cv. 'Peyan' and 'Monthan'

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ABSTRACT

Bananas and plantains are globally significant food crops, cultivated in over 130 countries. The structural, functional, and nutritional compositions of various banana cultivars exhibit considerable diversity and uniqueness. This study aimed to investigate the physical characteristics, nutrient content, phytonutrients, and antioxidant potential of two specific banana cultivars: Peyan (ABB) and Monthan (ABB). The selected bananas were in stage 1 of ripening, characterized by low total soluble solids (1.13-1.2ºBrix). The flour yield was 30.17% for Peyan and 23.25% for Monthan. The Monthan variety exhibited higher protein content compared to Peyan. Total carbohydrate content, starch, dietary fiber, and other non-starch polysaccharides were similar in both cultivars. Monthan showed considerably higher levels of flavonoids, while Peyan exhibited higher polyphenolic and tannin content. In the DPHH assay, the methanolic extracts of Peyan and Monthan recorded IC50 values of 5.006 mg/mL and 6.641 mg/mL, respectively. Unripe banana flours, with their high fiber content (13%), rich phytochemical profile, and antioxidant potential, are highly recommended for the development of functional foods.

Keywords: Antioxidant potential, nutrient composition, phytonutrients, unripe banana flour.

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INTRODUCTION

India boasts a rich diversity of banana cultivars cultivated in various regions throughout the country, each catering to distinct purposes such as dessert and cooking. Regrettably, approximately one fifth of harvested bananas are rejected in both the wholesale market and post-harvest stages. To address this issue, the manufacturing of unripe banana flour and its derivative products has emerged as a sustainable solution that benefits farmers while offering cost-effective opportunities for the food processing sector (Ravi and Mustaffa,2013) Given the escalating prevalence of obesity, diabetes, and cardiovascular diseases, unripe banana flour presents a promising resource for the development of healthy functional products (Wang et al., 2012).

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Furthermore, plantain varieties, which occupy around 30% of the cultivated area, are currently underutilized in terms of their nutritional potential (Ravi and Mustaffa,2013). *Musa acuminata* and *Musa balbisiana* are the primary species responsible for the vast majority of parthenocarpic edible bananas. The haploid genome of *Musa acuminata* is referred to as A, while that of *Musa balbisiana* is denoted as B. Typically, dessert varieties consist of triploids and diploids originating from *Musa acuminata*, whereas culinary varieties and plantains are triploids resulting from hybridizations between *Musa acuminata* and *Musa balbisiana* (Hazarika et al., 2014; OECD, 2009).

Peyan (ABB) is a distinctive banana variety cultivated in the regions of Tamil Nadu and Kerala. The fruits of this variety are characterized by their short length, flat sides, and prominent angled ridges. They possess a broad base and a slightly tapered apex, forming a blunt beak. The pedicel, or fruit stalk, is short in length. The skin of the fruit appears green with a subtle bloom and transitions to a dull yellow hue upon full ripening. The peel is thick and leathery, with a spongy fiber on the inner surface. The pulp of the fruit is predominantly white, and the core is easily noticeable. In terms of taste, it offers a unique combination of a mildly sweet and sour flavor, reminiscent of Chikku fruits. Due to its medicinal properties, refreshing cooling effect, and limited availability, Peyan bananas command premium prices in the market. They are particularly recommended for pregnant women, children, and individuals dealing with piles. Synonyms associated with this cultivar include *Mada Vazhai, Pey Monthan, Pey Valai, and Peyan Mayil Vazhai* (Venkataramani, 1946).

Monthan (ABB), a notable commercial banana cultivar in India, is primarily utilized for culinary purposes. However, in the northeastern states, it finds usage in both dessert and cooking applications. The fruits of Monthan measure approximately 10 inches in length and 6 inches in girth. They exhibit a slight curvature, plumpness, and irregular five-sided shape, with prominent angled ridges and flat or slightly inflated sides. The base of the fruit is broad, gradually tapering to a long and angled pedicel, while the apex is broad and features a prominent knob-shaped beak. The skin of the fruit is green, thick, and tough, possessing a significant amount of spongy fiber on the inner surface. When fully ripe, the skin transforms into a straw-yellow color. The pulp of Monthan bananas is firm, cream-colored, with a conspicuous core. The fruit offers a mildly sweet and pasty taste when fully ripe. In several regions of Tamil Nadu and Kerala, Monthan fruits are consumed by individuals suffering from chickenpox due to their perceived cooling effect on the body. Regional synonyms associated with this cultivar include *Bontha, Kanch Kela, Bankel, Bantheesa, and Kalyanakai* (Venkataramani, 1946).

This study was conducted with the objective of comprehending the physical characteristics, nutrient composition, secondary metabolites, and antioxidant capacity of unripe banana flour derived from Musa cultivars Peyan and Monthan. The valuable insights gained from this investigation have the potential to enhance the effective utilization of unripe banana flour as a functional food. The results of this study are significant for promoting the development and utilization of unripe banana flour within the food industry.

MATERIALS AND METHODS

Procurement and determination of ripening stage

The selected cultivars, Peyan (ABB) and Monthan (ABB), were obtained from the wholesale fruit market in Chennai, Tamil Nadu. The authenticity of the fruits was verified by the Department of Pharmacognosy, Siddha Central Research Institute (Central Council for Research in Siddha, Ministry of AYUSH, GOI), Chennai, with the assigned Form No. PCOG002-ACF. The ripening stages of the fruits were determined using the Von Loesecke (1950) scale, which categorizes the ripening process into seven stages based on the color of the peel. These stages are defined as follows: C1 - completely green; C2 - green with slight traces of yellow; C3 - predominantly green with more green than yellow; C4 - predominantly yellow with more yellow than green; C5 - yellow with green edges; C6 - fully yellow; and C7 - yellow with brown spots. For this study, bananas at stage 1 of ripening were specifically chosen.

Campuzano et al. (2018) described a method to validate the appropriate ripening stage of the samples by assessing the Total Soluble Solids (TSS). This method was adapted and implemented to reconfirm the ripening stage of the bananas. In summary, 30 g of banana pulp was blended for two minutes in 90 mL of water, and the TSS was measured using a handheld Atago refractometer, which has a scale ranging from 0 to 30 °Brix.

Physical characteristics

The physical characteristics of the unripe green banana fruits were assessed using the methodology outlined by Dadzie and Orchard (1997). Measurements were conducted on 12 fruits selected from the second and third hands within each bunch. Fruit length was measured from the distal end to the outer curve using a measuring tape. Additionally, the circumference of each fruit was measured at its widest midpoint. The weight of the entire fruit, as well as the individual weights of the pulp and peel, were determined using a digital weighing balance.

Preparation of unripe banana flour and its yield

The unripe bananas were carefully washed and peeled by hand using a steel knife. The peeled bananas were then sliced into 1 cm thick pieces. To prevent enzymatic browning, the slices were rinsed in a solution of citric acid (0.3g/100mL). Following this, the slices were dried in a tray drier at a temperature of 50ºC until they became brittle. Once dried, the slices were pulverized for 120 seconds, sieved through a 60-mesh sieve, and the resulting powder was collected. The powder was then cooled and stored in HDPE bags at ambient temperature (Kumar et al., 2019). Figure 1 and Figure 2 depict the visual representation of the selected cultivars Peyan and Monthan, respectively. The percentage yield of unripe banana flour (UBF) was calculated using the following formula given: UBF yield (%) = (Fresh weight of the pulp -Moisture content of the pulp)/ Fresh weight of the pulp x 100.

Fig 1: ***Musa paradisiaca*** **'Peyan'**

Fig. 2: ***Musa paradisiaca*** **'Monthan'**

Proximate composition

The proximate composition of the unripe banana flours, as well as the pH and titratable acidity, were determined following the methods outlined by AOAC (2005). The moisture content of both the unripe fruit and unripe banana flour was determined using method 925.10. Titratable acidity and pH were assessed using methods 942.15 and 981.12, respectively. An 8% suspension of unripe banana flour (UBF) was prepared and stirred for approximately 5-7 minutes. The suspension was then allowed to stand for 30 minutes, filtered, and the pH of the filtrate was measured (Sundaralingam and Ravindran,1993). Additionally, using the same slurry, Total Soluble Solids (TSS) were estimated using a refractometer (Salvador et al., 2007).

The total mineral content of the samples was determined by ashing at 525°C for 5-6 hours using a muffle furnace (923.03). Protein estimation was carried out using the Kjeldahl method with the conversion factor Nx6.25 (978.04), while fat was extracted using petroleum ether in Soxhlet apparatus (960.39). Total dietary fiber was estimated using the Sigma TDF 100A kit, following the procedures outlined in the AOAC 15th edition (1990). The cellulose content was determined according to the protocol provided by Sadasivam and Manickam (2008). Crude fiber was quantified using the residue obtained after acid and alkali digestion and pectin content was reported as calcium pectate. Total carbohydrate and starch were determined using the Anthrone method (Sadasivam and Manickam, 2008). Soluble sugars were extracted using 80% hot ethanol (80°C). The supernatants were pooled together, and the ethanol was evaporated. The residues were then reconstituted with water. Total sugars were analyzed using the Phenol-sulfuric acid assay, while reducing sugars were assayed using the Nelson-Somogyi method (Nelson, 1994).

Secondary Metabolites

One gram of unripe banana flour (UBF) was combined with a 25 mL mixture of methanol and water (v/v, 20:5). The resulting mixture was subjected to orbital shaking at 100×g for 8 hours at a temperature of 37ºC. Subsequently, it was centrifuged at 4000×g for 10 minutes, and the liquid fraction was gathered for the estimation of secondary metabolites and the DPPH assay (Savlak et al., 2016).

Preliminary qualitative screening for phytochemicals was performed using standard methods (Sorescu et al., 2018). The Folin-Ciocalteu reagent method (Singleton and Slinkard, 1997) was employed to assess the overall phenolic content of UBF. The findings were expressed as milligrams of gallic acid equivalents (GAE) per 100 grams of UBF (based on its dry weight). Total tannins were quantified using the Folin-Denis method with Tannic acid as the standard (Schanderl,1970). The estimation of flavonoids was conducted using the aluminium chloride colorimetric technique (Alothman et al., 2009) and expressed as milligrams of quercetin equivalents (QE) per 100 g of UBF (dry weight). The method introduced by Davies and Reid (1979) was employed to assess the levels of phytic acid.

Antioxidant potential

The DPPH (1,1-Diphenyl-2-Picrylhydrazyl) Free Radical Scavenging Activity Assay was conducted following the method. The sample extracts were diluted with aqueous methanol to obtain different concentrations. A mixture of 1 mL of 0.1 mM DPPH in methanol and 2 mL of sample extracts was prepared and incubated in the dark for 30 minutes at ambient temperature. The absorbance of the mixture was then measured at 517 nm using a spectrophotometer. A control solution of 1 mL of DPPH solution with methanol was also prepared. The percentage of scavenging activity of each extract on the DPPH radical was calculated as the % inhibition of DPPH (I%) using the following equation: $I\% = [(Ao - As) / Ao] \times 100$, where Ao represents the absorption of the control and As represents the absorption of the tested extract solution. Ascorbic acid was used as the reference standard (Carciochi et al., 2014).

Statistical analysis

The physical characteristics were measured using 12 fruits, and all experimental analyses were conducted in triplicates. The results are presented as Mean ± SD. To determine significant differences between the Peyan and Monthan cultivars, an independent t-test (two-tailed) was performed. Data analysis was conducted using Microsoft Excel 2019.

RESULTS AND DISCUSSION

Fruit Characteristics

Table 1 presents the physical characteristics and flour yield of the selected cultivars. Fruit length and circumference showed variations between the cultivars, with Monthan exhibiting significantly greater values. This trend was also reflected in fruit weight, pulp weight, and peel weight, where Monthan had higher measurements. The pulp/peel ratio for Monthan was determined to be 2.10 ± 0.19, indicating a relatively higher proportion of pulp compared to the peel. In contrast, Peyan had a thicker peel and a lower pulp/peel ratio of 1.70 ± 0.24. Previous research studies have reported a pulp/peel ratio of 1.9 for Monthan (Sundaralingam and Ravindran, 1993; Kumar et al., 2019). The selected samples for analysis were in stage 1 of ripening, characterized by a completely green appearance. The moisture content of fresh unripe bananas from Peyan and Monthan cultivars was measured at 69.56 ± 1.48 and 76.80 ± 2.49, respectively.

Table 1: Physical characteristics and Yield

Fruit Characteristics and Yield	**Peyan**	**Monthan**	***p* value***
Fruit length (cm)#	12.16 ±1.01	18.75 ±0.45	.00001
Fruit Circumference (cm) #	12.68± 0.62	15.98 ±0.73	.00001
Fruit wt (g) #	74.42 ±4.15	192.71±4.81	.00001
Pulp wt (g) #	46.75±3.21	130.39±6.53	.00001
Peel wt (g) #	27.68 ±2.57	62.31±3.35	.00001
Pulp/ Peel ratio#	1.70±0.24	2.10±0.19	.00018
Moisture Content (%) $	69.56 ±1.48	76.80 ± 2.49	.00001
Total Solids (%) $	30.44 ±1.47	23.20±2.49	.0023
Brix(°Brix) $	1.13±0.11	1.2 ±0.2	.6433
Flour Yield (%)$	30.17 ±0.40	23.25 ±0.07	.0017

Data presented are mean value of 12 measurements ± standard deviation (n = 12)

$Data presented are mean value of triplicates ± standard deviation (n = 3)

*t test (Independent samples, two tailed) p value <0.05 significant

TSS, which represents the soluble solid content, tends to increase as the bananas ripen (Bugaud et al., 2006). In the case of the unripe bananas used in this study at stage 1 of ripening, TSS values of 1.13 ± 0.11 ºBrix for Peyan and 1.2 ± 0.2 ºBrix for Monthan unripe fresh fruit were obtained. Previous research studies have reported TSS values ranging from 1.0 to 2.1 ºBrix for green bananas (Campuzano et al., 2018; Alkarkhi et al., 2011). The lower TSS content in green bananas is expected, as various enzymes are involved in starch breakdown and the formation and accumulation of soluble sugars occur during the ripening process (Emaga et al., 2007).

Flour Yield

The banana flours obtained from both cultivars had a creamy pale-yellow color. The flour yield for Peyan was determined to be 30.17 ± 0.40%, while for Monthan it was 23.25 ± 0.07%. Achieving a higher yield of quality flour is important for obtaining better prices for the finished products. In a previous research study, flour yields of 25.5% and 31.3% were reported for Monthan and Alukehel varieties, respectively (Sundaralingam and Ravindran,1993). The lower flour yield observed in the Monthan variety compared to Peyan can be attributed to its relatively high moisture content (76.81%) and the well-developed vascular tissue present in the fruit. The flours were coded as PUBF (Peyan unripe banana flour) and MUBF (Monthan unripe banana flour), and the results of the proximate analysis are presented in Table 2.

Table 2: Proximate composition of unripe banana flour

Proximate Composition (Per 100g on dry weight basis)	**Peyan (PUBF)**	**Monthan (MUBF)**	***p*value***
Moisture (%)	3.95 ±0.75	8.67 ±0.67	.000371
Total Solids (%)	96.05± 0.67	91.33 ±0.67	.000371
pH	4.54 ± 0.02	6.4±0.11	.00001
Brix(°Brix)	2.86 ±0.11	1.97±0.05	.00027
Titratable acidity (as % citric acid)	0.22±0.01	0.43±0.01	.000015
Ash (%)	3.89 ±0.24	4.51±0.187	.006408
Protein (g)	4.89±0.18	6.15±0.52	.007849
Fat (g)	1.96 ±0.07	1.36 ± 0.29	.028044
Total Carbohydrate (g)	88.03 ±1.16	86.70±1.71	.305105
Total Starch (g)	84.76 ± 1.67	82.58 ±1.60	.109106
Total Sugar (g)	2.87 ±0.05	2.94±0.05	.292893
Reducing sugar (g)	1.16±0.02	1.03±0.38	.582414
Dietary Fiber (g)	13.77 ±0.53	13.41 ±0.43	.40901
Crude Fiber (g)	1.17±0.51	1.52±0.28	.360199
Cellulose(g)	2.12±0.05	3.11±0.39	.071022
Pectin as calcium pectate (%)	0.144 ±0.01	0.176 ±0.05	.448023

Data presented are mean value of triplicates ± standard deviation (n = 3)

*t test (Independent samples, two tailed) p value <0.05 significant

Proximate Composition

The moisture content of dried food products plays a crucial role in their storage stability. Higher moisture content can negatively impact the textural, chemical, and biochemical properties of the product and promote microbial growth (Traynham et al., 2007).

Typically, a moisture content of around 10% is considered ideal for ensuring good shelf life (FAO, 2004). In this study, the moisture content of unripe banana flours was found to be 3.95 ± 0.75% for Peyan and 8.67 ± 0.67% for Monthan. These moisture content values suggest that unripe banana flour has good potential for maintaining its quality and stability during storage. In a different study, the moisture content of plantain flours from hybrid plantain varieties ranged from 6.15% to 7.27% (Anajekwu et al., 2020) Another scientific study reported a moisture content of 6.0% for unripe banana flour (Rodrı´guez-Ambriz et al., 2008).

The pH of the unripe banana flours ranged from 4.54 ± 0.02 (Peyan) to 6.4 ± 0.11 (Monthan). A titratable acidity of 0.22- 0.43 % was obtained. In a similar study, a pH of 5.0 ± 0.10 and 5.78 ± 0.20 was reported for Nendran and Popoulu varieties. Titratable acidity of 0.61 ± 0.03 and 0.85 ± 0.02 g of citric acid/100 g d.w was reported for Saba and Nendran variety (Kumar et al., 2019). Oxo-acids present such as malic, oxalic, and citric contribute to the acidity of the flour (Wyman and Palmer, 1964). The ash content in food is widely recognized as an indicator of the total mineral content, representing the inorganic residue left after organic matter is burned (Ferreira and Tarley, 2020). In the selected cultivars, the ash content ranged from 3.89% to 4.51%. Kumar et al. (2019) reported an ash content of 3.25 g/100g for Monthan and 2.06-2.50 g/100g for other varieties in their research study. Another study reported ash content of 4.2 ± 0.5% and 3.3 ± 0.2% (d.w.) for Monthan and Alukehel, respectively (Sundaralingam and Ravindran,1993).

Proteins play a crucial role in various metabolic reactions during the ripening and senescence of fruits (Shi et al., 2014) and the total crude protein content is determined by the balance between protein synthesis and degradation (Toledo et al., 2012). In this study, Peyan fruit showed a protein content of 4.89±0.18 g/100g, while Monthan had a significantly($p<0.05$) higher value of 6.15±0.52 g/100g. Another study reported a protein content of 3.69 ± 0.07 g/100g for ripening stage 1 Banana Cavendish of *Musa acuminata* (AAA) (Campuzano et al., 2018). The protein content of unripe banana flour of Awak ABB variety was recorded as 6.77 g/100g (Haslinda et al., 2009). In the case of Monthan variety (ABB), a protein content of 4.89 ± 0.21 g/100g was reported (Kumar et al., 2019). According to da Mota et al. (2000), the difference in protein content is primarily influenced by the inherent characteristics of dessert and plantain bananas. It is worth noting that the protein content of UBF is lower compared to wheat flour (10.99 ± 0.69 g/100 g d.w.) as reported by Traynham et al. (2007). The fat content of Peyan and Monthan was found to be 1.96 ± 0.07 g/100g and 1.36 ± 0.29 g/100g, respectively. Another study reported a lipid content of 0.89 ± 0.04 g/100g for *Musa acuminata* AAA variety (Menezes et al., 2011).

During the pre-climacteric period, the starch content of bananas, which typically ranges from 70% to 80%, reduces to 1% or lower by the conclusion of the climacteric phase, while the sugar content increases to more than 10% of the fruit's fresh weight (Zhang et al., 2005). The total sugar content in green banana flour is generally lower and is significantly influenced by the fruit's maturity stage (Brand-Miller et al., 2009). In the current study, unripe bananas in stage 1 of ripening were found to have a total carbohydrate content ranging from 88.03 g/100g to 86.70 g/100g, with a total starch content ranging from 84% to 82%. The recorded values for total sugars were lower, averaging between 2.87 g/100g and 2.94 g/100g, and reducing sugars ranged from 1.16 g/100g to 1.03 g/100g. The composition of these components in the two varieties showed some similarity. In a previous study, the total sugar content of banana flour was reported to average between 2.9% and 2.7% for the varieties 'Alkuehel' and 'Monthan', respectively (Sundaralingam and Ravindran,1993). Another study by Menezes et al. (2011) reported a relatively modest quantity of soluble sugars (1.81 g/100g) for *Musa acuminata* var. Nanicão.

The selected cultivars exhibited a significant dietary fiber content of 13%. In a study involving the Banana Awak ABB variety, the total dietary fiber content was reported as 7.53%, while unpeeled banana flour had 11.27% (Haslinda et al., 2009). The crude fiber content of Peyan was recorded as 1.17 ± 0.51 g/100g, and for Monthan, it was 1.52 ± 0.28 g/100g. The crude fiber content of Terra (*Musa paradisiaca*) was reported as 1.18 ± 0.07 g/100g (Pelissari et al., 2012). The cellulose content of Peyan was 2.12

± 0.05 g/100g, while for Monthan, it was 3.11 ± 0.39 g/100g. The estimated pectin content, measured as calcium pectate, ranged from 0.144% to 0.176%. In the case of Alukehel, an indigenous Sri Lankan variety, the cellulose content was reported as 3.2 ± 0.7 g/100g, while Monthan recorded 2.9 ± 0.6 g/100g (Sundaralingam and Ravindran,1993).

Secondary Metabolites

After the qualitative analysis of phytochemicals in this study confirmed the presence of alkaloids, flavonoids, tannins, phenolic compounds, and volatile oils, additional quantitative analysis was conducted and the results are summarized in Table 3. Among these phytonutrients, phenolic compounds stand out as crucial antioxidants found in plants. They serve as primary antioxidants and effectively terminate peroxy radicals (Sulaiman et al., 2011). It is worth mentioning that the composition of bioactive compounds can differ based on several factors, including the banana variety, genomic group, and the prevailing climatic and soil conditions (Anyasi et al., 2015).

Table 3: Phytonutrient composition

Secondary Metabolites (per 100g on d.w)	Peyan (PUBF)	Monthan (MUBF)	p* value
Polyphenols (mg GAE)	118.85±4.19	87.15±6.17	.026628
Tannins (mg TAE)	611.62±5.19	461.32±7.14	.001719
Phytic acid (g)	0.598±0.04	0.129±0.08	.004471
Flavanoids (mg QE)	112.78±13.47	178.89±6.73	.001606

Data presented are mean value of triplicates ± standard deviation (n = 3)

*t test (Independent samples, two tailed) p value <0.05 significant

In the present study, the selected cultivar Peyan exhibited a significantly higher total phenolic content (TPC) of 118.85±4.19 mg GAE/100g compared to Monthan, which had a TPC of 87.15±6.17 mg GAE/100g. Tsamo et al. (2014) reported that the pulp of "Pelipita" had the highest TPC (319.5 ± 70.4 mg GAE/100g FW) among the varieties tested, surpassing "Niangafelo" and "Moto Ebanga". In another study, Monthan exhibited a lower polyphenolic content of 44.50 ± 0.76 mg GA/100g (Kumar et al., 2019).

Tannins, which are water-soluble polyphenols found in plant foods (Sehrawat et al., 2006), possess functional properties (Mazni et al., 2016). The presence of tannins in bananas contributes to the unpleasant astringent taste, with higher levels typically found in the peels compared to the pulp. The decrease in astringency observed in ripe fruits is more likely attributed to alterations in the structure of tannins rather than a reduction in their overall levels (Hubbard et al., 1990). In this study, the tannin content was measured as 611.62±5.19 mg TAE/100g for Peyan and 461.32±7.14 mg TAE/100g for Monthan.

A statistically significant difference was observed in the phytic acid content between the two cultivars, with Monthan exhibiting a lower value. Similar findings were reported for phytic acid content (5.1-7.6 mg/g) in commercial raw banana flour samples (Ferreira and Tarley, 2020). The concentration of phytic acid in *M. sinensis* and *M. paradisiaca* was within the range of 2.26-

2.46% (Oyeyinka and Afolayan, 2019). Phytic acid concentrations in various cereals, vegetables, seeds, and fruits have been reported to range from 0.1 to 17.9 mg/g (Lott et al., 2000). Tannins and phytates have been associated with blood glucose reduction and improved insulin response (Thompson, 1993). Additionally, the concentration of phytic acid, polyphenolic compounds, or tannins in starchy foods is inversely correlated with the in-vitro rate of starch digestion (Yoon et al., 1983).

Flavonoids, which belong to the polyphenol family and possess diphenyl propane skeletons, have been extensively studied for their potential health benefits, including anti-inflammatory, hypolipidemic, hypoglycemic, and antioxidant activities (Vijayakumar et al., 2008). Previous research has identified the presence of flavonoids such as epicatechin and myricetin 3-O-rhamnosyl-glucoside in banana flour derived from cultivars like "Mabonde," "Luvhele," and "M-red" (Anyasi et al., 2015).

In this study, the selected cultivars demonstrated a noteworthy content of flavonoids. Monthan exhibited a significantly higher value (178.89±6.73 mg QE/100g) compared to Peyan (112.78±13.47 mg QE/100g) in terms of flavonoid content, as determined by the analysis.

In vitro antioxidant potential

A lower IC50 value in the DPPH assay indicates a higher ability to scavenge free radicals and disrupt free radical chain reactions (Frankel, 1991). The IC50 values were determined by employing Quest Graph™ IC50 Calculator (AAT Bioquest, 2023) based on a logistic regression model. In this study, the methanolic extracts of Peyan and Monthan recorded IC50 values of 5.006 mg/mL and 6.641 mg/mL, respectively. The reference ascorbic acid standard exhibited an IC50 value of 10.13 µg/mL. Figure 3 illustrates the DPPH free radical scavenging activity of UBFs and Vitamin C.

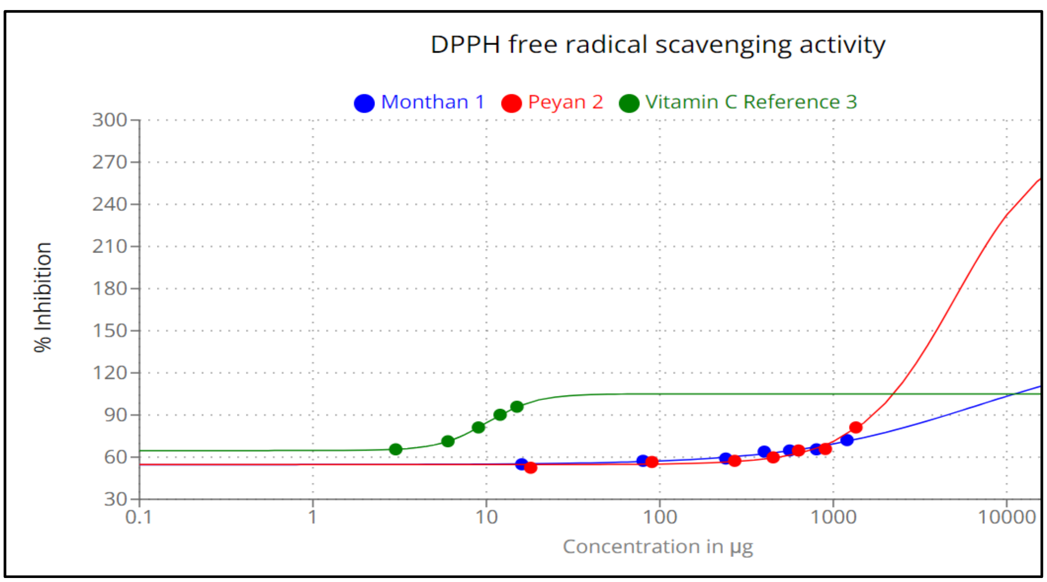

Fig. 3: DPPH free radical scavenging activity of UBFs and Vitamin C

In a study on Musa ABB cv. Kluai namwa, the IC50 values in the DPPH assay were found to be 5.46 mg/mL and 2.54 mg/mL for the ethanolic and methanolic extracts of unripe banana flour (Jannoey et al., 2012). The considerable capacity for scavenging free radicals observed in this study can be ascribed to the advantageous phytonutrient profile of the chosen cultivars.

CONCLUSION

This study presents a thorough examination of the nutrient composition and phytonutrients found in unripe banana flours derived from the Peyan and Monthan cultivars. These flours, rich in dietary fiber and abundant phytonutrients, exhibit a high antioxidant capacity, making them a promising supplement for the development of functional foods. Incorporating banana flour into various convenience and ready-to-eat food products can not only offer consumers healthier choices but also provide a sustainable solution for utilizing excess or rejected bananas. The findings of this study encourage further exploration of the potential of Peyan and Monthan banana flour as a functional ingredient, enabling the development of nutritious and appealing food options.

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REFERENCES

Ravi, I., and Mustaffa, M.M. 2013. Starch and amylose variability in banana cultivars. Indian Journal of Plant Physiology, 18: 83–87. https://doi.org/10.1007/s40502-013-0014-2

Wang, Y., Zhang, M., and Mujumdar, A.S. 2012. Influence of green banana flour substitution for cassava starch on the nutrition, color, texture and sensory quality in two types of snacks. LWT-Food Science and Technology, 47(1): 175–182.

Hazarika, B.N., Sankaran, M., RemaMenon., Sudha. R., Jai Prakash, P., Suresh Kumar, K.N., Shiva, S., Romen Singh., and Rabha, A. 2014. Chapter: 4. Banana. In: Tropical and Sub tropical Fruit Crops Crop Improvement and Varietal Wealth (Ghosh S N) Jaya Publishing House, Delhi, p. 66.

OECD. 2009. Consensus Document on the Biology of Bananas and Plantains (Musa spp.) ENV/JM/MONO 43 (http://www.oecd.org/biotrack)

Venkataramani, K.S. 1946. Studies on Indian Bananas. Proceedings of the Indian Academy of Sciences, 23: 113– 128. https://doi.org/10.1007/BF03049665

Von Loesecke, H.W. 1950. Bananas: chemistry, physiology, technology. Interscience Publishers, No. 634.772/V947.

Campuzano, A., Rosell, C.M., Cornejo. F. 2018. Physicochemical and nutritional characteristics of banana flour during ripening. Food Chemistry, 256: 11-17. https://doi.org/10.1016/j.foodchem.2018.02.113

Dadzie, B.K., and Orchard, J.E. 1997. Routine Post-Harvest Screening of Banana/Plantain Hybrids: Criteria and Methods. INIBAP Technical Guidelines 2, International Plant Genetic Resources Institute, Montpellier, pp. 75-85.

Kumar, P.S., Saravanan, A., Sheeba, N., Uma, S. 2019. Structural, functional characterization, and physicochemical properties of green banana flour from dessert and plantain bananas (Musa spp.). LWT, 116:108524. https://doi.org/10.1016/j.lwt.2019.108524

AOAC. 2005. Official Methods of Analysis. 18th ed. Association of Official Analytical Chemists, Gaithersburg, MD.

Sundaralingam., and Ravindran. 1993. Physical and biochemical properties of green banana flour. Plant Foods for Human Nutrition, 43: 19-27.

Salvador, A., Sanz, T., Fiszman, S.M. 2007. Changes in colour and texture and their relationship with eating quality during storage of two different dessert bananas. Postharvest Biology and Technology, 43: 319–325.

AOAC. 1990. Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists, Arlington, VA.

Sadasivam., and Manickam. 2008. Biochemical Methods. 3rd ed, New Age International, New Delhi, pp.1-19.

Nelson, N. 1994. A photometric adaption of the Somogyi method for the determination of glucose. Journal of Biological Chemistry, 153: 375–380.

Savlak, N., Türker, B., Yeşilkanat, N. 2016. Effects of particle size distribution on some physical, chemical, and functional properties of unripe banana flour. Food Chemistry, 213: 180-186. https://doi.org/10.1016/j.foodchem.2016.06.064

Sorescu, A.A., Nuta, A., Ion, R.M., and Iancu, L. 2018. Qualitative Analysis of Phytochemicals from Sea Buckthorn and Gooseberry. InTech. DOI: 10.5772/intechopen.77365.

Singleton, V.L., and Slinkard, K. 1977. Total phenol analysis: Automation and comparison with manual methods. American Journal of Enology and Viticulture, 2849-55.

Schanderl, S.H. 1970. Method in Food Analysis. Academic Press, New York, p. 709.

Alothman, M., Bhat, R., and Karim, A.A. 2009. Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. Food Chemistry, 115(3): 785–788.

Davies, N.T., and Reid, H. 1979. An evaluation of phytate, zinc, copper, iron and manganese content and availability from soyabean textured vegetable protein meat substitutes or meat extruders. British Journal of Nutrition, 41:579.

Carciochi. R., Manrique, G., and Dimitrov, K. 2014. Changes in phenolic composition and antioxidant activity during germination of quinoa seeds (Chenopodium quinoa Willd.). International Food Research Journal, 21 (2):767-773.

Bugaud, C., Chillet, M., Beauté, M., and Dubois, C. 2006. Physicochemical analysis of mountain bananas from the French West Indies. Scientia Horticulturae, 108(2):167-172. https://doi.org/10.1016/j.scienta.2006.01.024

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. https://doi.org/10.1016/j.foodchem.2006.09.006

Alkarkhi, A.F., bin Ramli, S., Yong, Y.S., and Easa, A.M. 2011. Comparing physicochemical properties of banana pulp and peel flours prepared from green and ripe fruits. Food Chemistry, 129(2): 312–318.

Traynham, T.L., Myers, D.J., Carriquiry, A.L., and Johnson, L.A. 2007. Evaluation of Water-Holding Capacity for Wheat–Soy Flour Blends. Journal of the American Oil Chemists' Society, 84: 151. https://doi.org/10.1007/s11746-006-1018-0

FAO. 2004. Statistical Yearbook, Statistics Division, Food and Agriculture Organisation, Rome, Italy.

Anajekwu, E.O., Maziya-Dixon, B., Akinoso. R., Awoyale, W., Alamu, E.O. 2020. Physicochemical Properties and Total Carotenoid Content of High-Quality Unripe Plantain Flour from Varieties of Hybrid Plantain Cultivars. Journal of Chemistry, 2020. https://doi.org/10.1155/2020/5960346

Rodrı´guez-Ambriz, L., Islas-Herna´ndez, J.J., Agama-Acevedo, E., Tovar, J., Bello-Pe´rez, L.A. 2008. Characterization of a fibre-rich powder prepared by liquefaction of unripe banana flour. Food Chemistry, 107:1515–1521.

Wyman, H., Palmer, J.K. 1964. Organic Acids in the Ripening Banana Fruit. Plant Physiology, 39(4):630-3. doi: 10.1104/pp.39.4.630

Ferreira, M.P., Tarley, C.R.T. 2020. Assessment of in vitro bioacessibility of macrominerals and trace elements in green banana flour. Journal of Food Composition and Analysis, 92:103586. https://doi.org/10.1016/j.jfca.2020.103586

Shi, Y., Jiang, L., Zhang, L., Kang, R., Yu, Z. 2014. Dynamic changes in proteins during apple (Malus x domestica) fruit ripening and storage. Horticulture Research, 1: 6. https://doi.org/10.1038/hortres.2014.6

Toledo, T.T., Nogueira, S.B., Cordenunsi, B.R., Gozzo, F.C., Pilau, E.J., Lajolo, F.M., Nascimento, J.R.O. 2012. Proteomic analysis of banana fruit reveals proteins that are differentially accumulated during ripening. Postharvest Biology and Technology, 70:51-58. https://doi.org/10.1016/j.postharvbio.2012.04.005

Haslinda, W.H., Cheng, L.H., Chong, L.C., and Aziah, A.A.N. 2009. Chemical composition and physicochemical properties of green banana (Musa acuminata × balbisiana Colla cv. Awak) flour. International Journal of Food Sciences and Nutrition, 60(SUP4): 232- 239. DOI: 10.1080/09637480902915525

da Mota, R.M., Lajolo, F.M., Cordenunsi, B.R., Ciacco, C. 2000. Composition and Functional Properties of Banana Flour from Different Varieties. Starch/Starke, 52(2-3):63-68. https://doi.org/10.1002/(SICI)1521-379X(200004)52:2/3<63::AID-STAR63>3.0.CO;2-V

Menezes, E.W., Tadini, C.C., Tribess, T.B., Zuleta, A., Binaghi, J., Pak, N., Vera, G., Dan, M.C., Bertolini, A.C., Cordenunsi, B.R., Lajolo, F.M. 2011. Chemical Composition and Nutritional Value of Unripe Banana Flour (Musa acuminata, var. Nanicão). Plant Foods for Human Nutrition, 66: 231–237. https://doi.org/10.1007/s11130-011-0238-0

Zhang, P., Whistler, R. L., BeMiller, J.N., Hamaker, B.R. 2005. Banana starch: Production, physicochemical properties, and digestibility – a review. Carbohydrate Polymer, 59: 443– 458. https://doi.org/10.1016/j.carbpol.2004.10.014

Brand-Miller, J.C., Stockmann, K., Atkinson, F., Petocz, P., and Denyer, G. 2009. Glycemic index, postprandial glycemia, and the shape of the curve in healthy subjects: analysis of a database of more than 1000 foods. The American Journal of Clinical Nutrition, 89(1): 97-105.

Pelissari, F. M., Andrade-Mahecha, M. M., Sobral, P. J. D. A., and Menegalli, F. C. 2012. Isolation and characterization of the flour and starch of plantain bananas (Musa paradisiaca). Starch-Stärke, 64(5): 382-391. https://doi.org/10.1002/star.201100133

Sulaiman, S.F., Yusoff, N.A.M., Eldeen, I.M., Seow, E.M., Sajak, A. A.B., Supriatno, and Ooi, K.L. 2011. Correlation between total phenolic and mineral contents with antioxidant activity of eight Malaysian bananas (Musa sp.). Journal of Food Composition and Analysis, 24(1): 1–10. doi: 10.1016/j.jfca.2010.04.005

Anyasi, T.A., Jideani, A.I., Mchau, G.R. 2015. Effect of organic acid pretreatment on some physical, functional and antioxidant properties of flour obtained from three unripe banana cultivars. Food Chemistry, 172: 515-22. https://doi.org/10.1016/j.foodchem.2014.09.120

Tsamo, C.V.P., Andre, C.M., Ritter, C., Tomekpe, K., Newilah, G.N., Rogez, H., and Larondelle,Y. 2014. Characterization of Musa sp. Fruits and Plantain Banana Ripening Stages According to their Physicochemical Attributes. Journal of Agricultural and Food Chemistry, 62(34): 8705–8715. https://doi.org/10.1021/jf5021939

Sehrawat, A., Sharma, S., Sultana, S. 2006. Preventive effect of tannic acid on 2-acetylaminofluorene induced antioxidant level, tumor promotion and hepatotoxicity: a chemopreventive study. Redox Report, 11(2):85-95. https://doi.org/10.1179/135100006X101066

Mazni, A.Z., Ho, Y.W., Azizul, I., and Nurdin, A. 2016. Antioxidant, antimicrobial, and cytotoxic potential of condensed tannins from Leucaena leucocephala hybrid-Rendang. Food Science and Human Wellness, 5: 65-75.

Hubbard, N.L., Mason Pharr, D., Huber, S.C. 1990. Role of sucrose phosphate synthase in sucrose biosynthesis in ripening bananas and its relationship to the respiratory climacteric. Plant Physiology, 94:201-208.

Oyeyinka, B.O., Afolayan, A.J. 2019. Comparative Evaluation of the Nutritive, Mineral, and Antinutritive Composition of Musa sinensis L. (Banana) and Musa paradisiaca L. (Plantain) Fruit Compartments. Plants, 8(12):598. https://doi.org/10.3390/plants8120598

Lott, J., Ockenden, I., Raboy, V., and Batten. G. 2000. Phytic acid and phosphorus in crop seeds and fruits: A global estimate. Seed Sci Res, 10(1): 11-33. https://doi.org/10.1017/S0960258500000039

Thompson, L.U. 1993. Potential health benefits and problems associated with antinutrients in foods. Food Research International, 26:131-149.

Yoon, J.H., Thompson, L.U., and Jenkins, D.J.A. 1983. The effect of phytic acid on in-vitro rate of starch digestibility and blood glucose response. American Journal of Clinical Nutrition, 38: 835-42.

Vijayakumar, S., Presannakumar, G., Vijayalakshmi, N.R. 2008. Antioxidant activity of banana flavonoids. Fitoterapia, 79: 279–282. https://doi.org/10.1016/j.fitote.2008.01.007

Frankel, E.N. 1991. Recent advances in lipid oxidation. Journal of the Science of Food and Agriculture, 54: 495 https://doi.org/10.1002/jsfa.2740540402

AAT Bioquest, Inc. 2023, April 12. Quest Graph™ IC50 Calculator. AAT Bioquest. https://www.aatbio.com/tools/ic50-calculator.

Jannoey, P., Channei, D., Boonsong, T., Pimsen, S., and Nueangjumnong, N. 2012. Phytochemical Screening and Antioxidant Activity of Unripe Banana Flour, NU. International Journal of Science, 18(2): 80-102.