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FUNCTIONAL PROPERTIES OF UNRIPE BANANA (*MUSA PARADISIACA)* FLOUR OF PEYAN AND MONTHAN CULTIVARS

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ABSTRACT

This research, carried out during the year 2022-2023, comprehensively investigated the physicochemical and functional properties of unripe banana flours derived from the *Musa paradisiaca* cv Peyan and Monthan (genome ABB). Stage-1 unripe bananas were processed into flour using tray drying at 55 °C.Standard protocols were employed to evaluate the functional properties of the unripe banana flours. The bulk density of the unripe banana flour ranged from 0.68 to 0.69 g/mL. The Peyan and Monthan varieties exhibited emulsion activities of 6.45 ± 0.97% and 8.15 ± 1.35%, respectively. The hydration properties of the flour were highest at 70 °C and 90 °C for both varieties. Storage at 4 °C during a five-day period resulted in decreased light transmittance and increased syneresis, with significant differences between cultivars. Partial gelation occurred at 10% starch concentration, while complete gel formation was observed at 12%.These results add to the limited literature on the underexplored Peyan and Monthan cultivars, highlighting their potential as functional ingredients in healthy, value-added food products.

Keywords: Functional properties, Physicochemical properties, Unripe banana flour

INTRODUCTION

Banana (Musa spp.) ranks among the major cultivated tropical fruits globally, encompassing more than 1,000 varieties. The *Musa cavendish* variety is particularly significant, accounting for approximately 45% of the global banana market. Its dominance is largely due to high per-hectare yields and resilience to environmental fluctuations (FAO, 2022). Another notable group within the banana family is *Musa paradisiaca*, which includes over 100 cultivars.Edible bananas are typically categorized into dessert (AA, AAA, AAB) and cooking types (AAB, ABB, BBB). Cooking bananas, consumed at various ripeness stages, are less sweet when raw due to their firm and granular texture. They are recognized for their rich nutritional composition, providing significant amounts of dietary fiber, essential vitamins, and minerals (Pereira and Maraschin, 2015).

Bananas are usually harvested at developmental maturity while unripe, leading to significant post-harvest losses during transportation, handling, and storage (Al-Dairi *et al.,* 2022). Available method for reducing post-harvest losses is the dehydration of unripe bananas, followed by processing them

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into banana flour for use in various innovative products. This strategy promotes increased banana consumption andcontributes significantly tohealth, nutrition, and sustainable food supply.

Banana flour is a promising alternative to conventional flours used in bakery and cereal-based products (Marta *et al*., 2022). Its high content of bioactive compounds, particularly resistant starch, supports its use in functional and gluten-free food formulations (Khoozani*et al*., 2019). To effectively utilize unripe banana flour in the formulation of novel foods and translate them into marketable products, a thorough understanding of its functional properties is essential, given the substantial variation across different banana varieties.

The *Musa paradisiaca* cultivar Peyan (ABB), native to South India, holds medicinal significance in the indigenous food practices of Tamil Nadu. *Musa paradisiaca* cultivar Monthan (ABB), a commercially important cultivar in India, is primarily used for cooking but also serves both dessert and culinary purposes in north-eastern states. Despite their importance, little research has been conducted on thefunctional properties of these cultivars.The present study examined *Musa paradisiaca* cultivars Peyan and Monthan to address potential differences in functional properties among banana varieties. Specifically, it aimed to evaluate the physicochemical properties, as well as the hydration and gelation characteristics, of unripe banana flours derived from these cultivars.

MATERIAL AND METHODS

Procurement and Processing of Unripe Banana Flour

The *Musa paradisiaca*cv. Peyan and Monthan (genome ABB) were sourced from a local market in Chennai, Tamil Nadu. Authentication of the fruits was obtained from the Siddha Central Research Institute, Chennai (Form No. PCOG002-ACF).Stage-1 unripe bananas (fully green) were selected using the Von Loesecke scale, with ripening status confirmed by total soluble solids (TSS) analysis (Campuzano *et al*., 2018). The unripe pulp showed TSS values of 1.13–1.20 °Brix, consistent with early ripening. Peyan (PUBF) and Monthan (MUBF) flours were processed by the Campuzano *et al*. (2018) method.

Functional Properties of Unripe Banana Flour

Physicochemical properties

The physicochemical characteristics of the UBFwere evaluated following the methodology described by Wani *et al*. (2015).

Density and Flowability Parameters: A sample weighing 50 g was carefully added to a 100 mL graduated cylinder and softly tapped on a laboratory table until a stable volume was reached. Bulk density was expressed in g/mL. Tapped density was measured by gently tapping the cylinder with a glass rod on a stable surface until the sample volume stabilized, after which the sample mass was divided by the final tapped volume. Flowability of the powders was evaluated through the Carr Index and Hausner ratio, with interpretations made using standard charts (Alam *et al*., 2023).

$$\text{Carr index \%} = \frac{\text{Tapped density - Bulk density}}{\text{Tapped density}} \text{ X 100}$$

$$\text{Hausner ratio} = \frac{\text{Tapped density}}{\text{Bulk density}}$$

Foaming Capacity: UBF weighing one gram was mixed with 50 mL of distilled water in a graduated cylinder. The mixture was then vigorously shaken for 5 minutes to produce foam. The volume of foam 30 seconds after whipping was expressed as foam capacity using the equation given.

$$\text{Foaming capacity \%} = \frac{\text{Volume of foam after whipping} - \text{Volume of foam before whipping}}{\text{Volume of foam before whipping}} \times 100$$

Emulsion Activity and Stability: In a calibrated centrifuge tube, an emulsion was created by combining a 1 g sample, 10 mL of distilled water, and 10 mL of refined sunflower oil. The emulsion was then subjected to centrifugation at 2000 × g for 5 minutes. Emulsion Activity (%) was calculated as the height of the emulsified layer divided by the total height of the mixture multiplied by 100. To assess the stability, the emulsion was heated at 80°C for 30 minutes in a water bath. Afterward, it was cooled for 15 minutes under running tap water and centrifuged again at 2000 × g for 15 minutes.

Oil Absorption Capacity (OAC): One gram of the sample mixed with 10 mL sunflower oil was allowed to stand at room temperature for 30 minutes, and then centrifuged for 30 minutes at 2000 × g. OAC was calculated as the weight of sediment after draining oil divided by the sample weight.

Flour Hydration Properties:

To determine the gelling properties of the flour, a method described by Cornejo and Rosell (2015) was employed. Firstly, 0.2 grams of UBF was dispersed in 20 mL of distilled water and subjected to heating at various temperatures (50- 90°C) for 15 minutes in a shaking water bath. After cooking, the resulting paste was allowed to cool down to room temperature and centrifuged at 3000 × g for 10 minutes. The supernatant was carefully poured off, and its solid content was determined by evaporating it overnight at 110°C. The sediment obtained from centrifugation was weighed.

Water Solubility Index (WSI), Water Absorption Index (WAI), and Water Holding Capacity (WHC), were calculated using the respective equations. For determining the swelling volume, 0.5 g of UBF was combined with 30 mL of distilled water and left at room temperature for 24 hours.

$$\text{Water Solubility Index (\%)} = \frac{\text{Weight of dry supernatant}}{\text{Weight of sample}} \times 100$$

$$\text{Water Absorption Index (g/g)} = \frac{\text{Weight of wet sediment}}{\text{Weight of sample}} \times 100$$

$$\text{Water Holding Capacity (g/g)} = \frac{\text{Weight of wet sediment} - \text{Weight of dry sediment}}{\text{Weight of sample}} \times 100$$

$$\text{Swelling Volume (ml/g)} = \frac{\text{Total volume of swollen sample}}{\text{Weight of sample}} \times 100$$

Flour Gelling Properties

Least Gelation Concentration: In 5 mL of distilled water, flour dispersions ranging from 2% to 30% (w/v) were prepared and heated at 90°C for 1 hour in a water bath. After cooling under tap water and keeping them at 10 ± 2°C for 2 hours, the gelation capacity was determined by visually observing the sample slipped in inverted tubes (Chandra*et al.,* 2015).

Light Transmittance: To evaluate the light transmittance, an aqueous suspension of UBF (1%) was prepared and heated in a shaking water bath at 90ºC for 30 minutes. The suspension was then cooled for 1 hour at room temperature. Samples were stored in a refrigerator at 4ºC for 5 days, and transmittance was recorded each day by determining the absorbance at 640 nm (Wani *et al.,* 2015).

Syneresis: For measuring syneresis, unripe banana flour suspensions (2% w/w) were heated at 90 °C for 30 minutes in a water bath with constant stirring. The suspensions were stored at 4 °C for a period ranging from 1 to 5 days. Syneresis was quantified as the percentage of water released after centrifugation at 3000 × g for 10 minutes (Wani *et al.,* 2015).

Statistical Analysis

Analyses were done in triplicate on a dry weight basis. To assess significant differences between the PUBF and MUBF, an independent t-test (two-tailed) was carried out. Data were analyzed using Microsoft Excel 2019.

RESULTS AND DISCUSSION

The unripe banana flours (UBFs) exhibited a creamy-yellow color, with moisture contents of 3.95 ± 0.75% for PUBF, while MUBF had a higher moisture content of 8.67 ± 0.67%.Around 10% moisture content is generally regarded as optimal for maintaining shelf stability (Zambrano *et al.,* 2019). The higher moisture in Monthan may reflect cultivar-specific differences in fruit moisture content.

Physicochemical Properties

Table 1depicts the physicochemical properties of unripe banana flour.

Density and Flowability Parameters

The bulk and tapped density values were comparable between cultivars, indicating no significant cultivar-dependent variation. These moderate values support good packing efficiency and handling in dry mixes. A bulk density range of 0.72 to 0.77 g/cm^{3}was recorded for green banana flours (Anajekwu*et al.*, 2020).The Carr Index of PUBF was 3.17 ± 0.71%, while MUBF showed 2.74 ± 0.03%. The Hausner Ratio for both flours ranged from 1.02 to 1.03. These values indicate that both flours are “excellent” or “very free-flowing”. Such flow properties are beneficial for industrial applications involving automated blending and packaging.

Foaming Capacity, Emulsion Activity and Stability: Foaming capacities were low for both cultivars, confirming that UBFs lack the protein quality required for interfacial film formation. The marginal cultivar difference has limited technological relevance. Poor foaming ability restricts their utility in aerated food systems but is typical for starch-dominant plant flours with low surface-active protein fractions.

Emulsion activities were low for both cultivars (6.45 ± 0.97% for PUBF; 8.15 ± 1.35% for MUBF), and complete destabilization occurred during stability testing. The limited emulsifying ability, likely due to low protein and surface-active components, makes UBFs unsuitable as primary emulsifiers but useful as supplementary ingredients for viscosity, fiber enrichment, or when blended with hydrocolloids.Qadir and Wani (2023) reported emulsion capacities of 9.52% and 2.32% in brown and polished rice flour, stating low emulsion stability. The emulsion activity of banana flours was relatively low compared to values reported for cereal and legumeflours (Chandra *et al.,* 2015).

Oil Absorption Capacity: The OAC of UBFs was 1.71 to 1.75 g/g, indicating good potential for enhancing flavor retention and mouthfeel in bakery products and reconstituted mixes. In a research, banana starch had an OAC of 1.16–1.22 g/g (Thanyapanich*et al*., 2021).

Flour Hydration and Gelling Properties

Flour hydration is influenced by the interaction between amylopectin and amylose, as well as by the granular structure of the starch. In UBF, this property is particularly important, as it affects product consistency, bulk, and performance, especially in baking and other processed foods. Gelation properties govern the texture, structural

Table 1. Physicochemical Properties of Unripe Banana Flours

Physicochemical properties	Peyan (PUBF)	Monthan (MUBF)	*p-v*alue
Bulk Density (g/ mL)	0.69 ±0.01	0.68±0.01^{NS}	.671242
Tapped Density (g/ mL)	0.71±0.01	0.70±0.01^{NS}	.370414
Carr Index %	3.17±0.71	2.74±0.03^{NS}	.355687
Hausner ratio	1.03±0.00	1.02±0.01^{NS}	.355914
Foaming capacity (%)	0.73±0.12	0.67±0.12 ^{NS}	.518519
Emulsion Activity (%)	6.45±0.97	8.15±1.35 ^{NS}	.151714
Emulsion Stability (%)	0	0	-
Oil absorption capacity (g/g)	1.71±0.02	1.75±0.02 ^{NS}	.113523
Swelling volume ml/g	3.49 ±0.21	6.20± 0.87*	.006426

Values areMean ± SD (n = 3),*p-value* <0.05, significant independent t-test (two-tailed)

integrity, and stability, making them pivotal for food product development.

Water Solubility Index: WSI is one of the parameters used to evaluate the integrity of starch granules (Paramasivam *et al.,* 2021). The water solubility indexincreased with temperature, reflecting progressive leaching of soluble amylose as starch granules hydrated and lost structural integrity. PUBF showed a WSI of 9.78% at 70°C, while MUBF reached 12.7% at 90°C, likely due to differences in granule crystallinity and amylose–amylopectin distribution. For reference, WSI values of 5.58–6.71% have been reported for other banana varieties (Anajekwu*et al*., 2020).

Water Absorption Index:WAI is a parameter used to evaluate the water absorption capacity of flour. MUBF exhibited a linear increase in WAI from 50°C to 90°C, reaching 3.47 g/g at 90°C. In contrast, PUBF showed peak hydration and gelling capacities at 70°C. For comparison, Campuzano *et al*. (2018) reported WAI values of 3.39–3.52 g/g dry weight for green banana flour.

Water Holding Capacity:UBF exhibited good water-holding capacity, which increased with temperature from 50°C to 90°C, ranging from 4.00 to 4.31 g/g. Adequate WHC supports its application in moisture-retentive formulations such as baked goods and meat analogues.

Swelling volume: The swelling volume of PUBF was 3.49 ± 0.21 mL/g, whereas MUBF exhibited a higher value of 6.20 ± 0.87 mL/g. Elevated starch content, especially with a higher proportion of branched amylopectin, contributes to increased swelling capacity in flours and food products (Awuchi*et al*., 2019).

Least Gelation Concentration: Partial gelation of PUBF and MUBF was observed at 10% starch concentration, with complete gelation at 12%. The gelation capacity is affected by water competition between protein gelation and starch gelatinization. Thanyapanich *et al*. (2021) reported complete gelationat 10–14% w/v for banana starch. These findings indicate that UBF can form gels at moderate starch concentrations, supporting its potential application in structured foods such as puddings and gluten-free doughs.

Paste Clarity and Syneresis: Storing unripe banana flour at 4°C for 120 hours led to decreased light transmittance and increased syneresis (Table 2), with significant

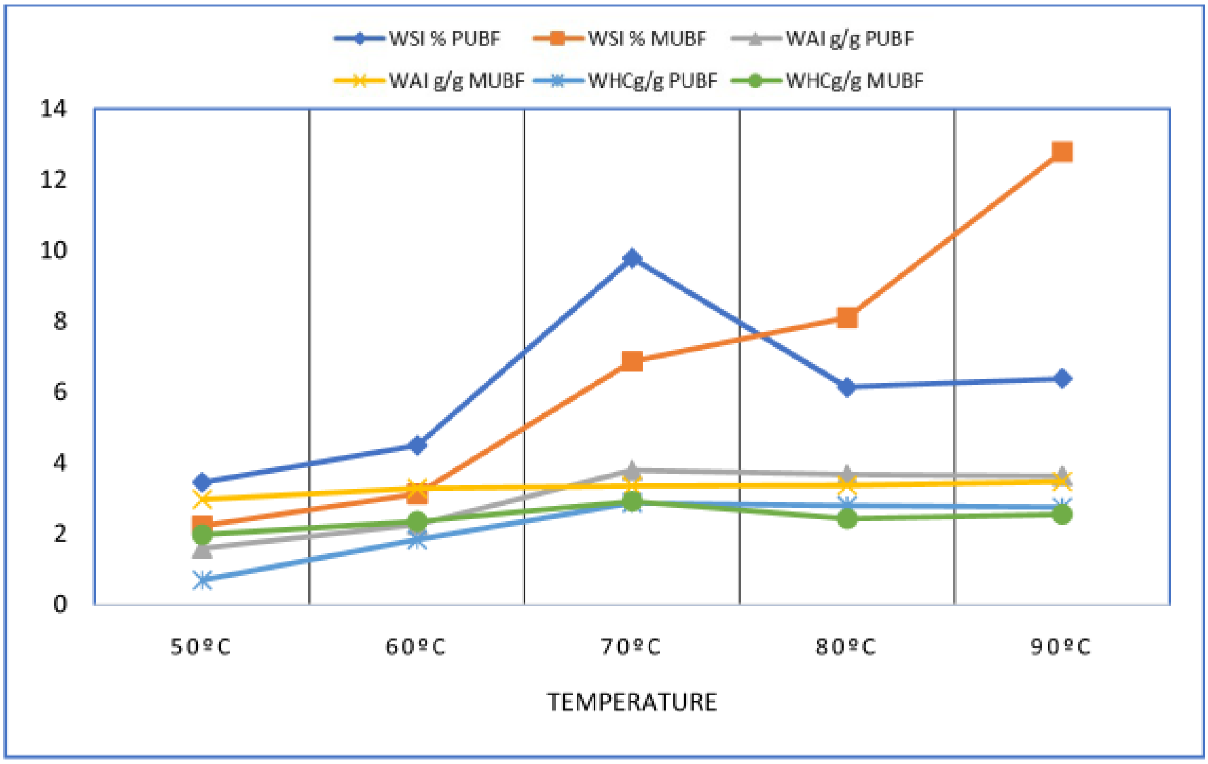

Fig. 1. Flour Hydration Properties of UBFs

differences between Peyan and Monthan flours. The reduced clarity is attributed to starch retrogradation and amylopectin recrystallization. Monthan and Saba (ABB) starches have shown syneresis of 70–77%, which increased to 80–85% after 5 days of storage (Paramasivam *et al*., 2021).High syneresis restricts use in refrigerated gels but indicates potential suitability in freeze-thaw-stable applications where controlled retrogradation is desirable.

CONCLUSION

This study investigated the functional properties of unripe banana flours from Musa cv. Peyan and Monthan to emphasize their potential as valuable additives in various food products. Based on the compressibility index and Hausner Ratio, both PUBF and MUBF were classified as excellent or very free-flowing, indicating their suitability for efficient industrial handling, blending, and packaging. The water-holding capacity of the flours increased with temperature (4–4.31 g/g between 50ºC and 90ºC), supporting their use in moisture retention and texture improvement in baked goods, meat analogues, and ready-to-cook products. Peyan and Monthan flours showed notable water solubility, enhancing their applicability in beverages, soups, sauces, and instant mixes. Their hydration and gelling abilities further position them as effective natural thickeners, stabilizers, and binding agents for gluten-free foods, extruded snacks, confectionery, and dairy/plant-based formulations. Refrigerated storage (4ºC for 120 hours) resulted in decreased light transmittance and increased syneresis, reflecting typical retrogradation behaviour of high-amylose flours. The functional attributes of Peyan and Monthan unripe banana flour demonstrate strong potential for product development, particularly in ready-to-eat and ready-to-cook foods.

Table 2. Light Transmittance and Syneresis of Unripe Banana Flour

Storage in hours	Peyan (PUBF)	Monthan (MUBF)	*p value*
Light Transmittance			
24	3.25 ± 0.02	1.49 ±0.05*	.000555
48	3.01 ± 0.33	1.38 ±0.04*	.0206
72	2.55 ±0.34	1.27 ±0.07*	.035842
96	1.83 ±0.25	1.04 ±0.08^{NS}	.053128
120	1.61 ± 0.01	0.76 ±0.22*	.033312
Syneresis			
24	71.68± 2.23	65.56±2.87^{NS}	.140525
48	83.66± 1.47	70.23±1.78*	.00973
72	85.76 ±0.734	74.36± 2.77*	.030152
96	87.94±2.35	75.99±1.65*	.027714
120	89.23 ±0.69	84.14±2.09^{NS}	.082604

Values are mean ± standard deviation (n = 3), *p-value* <0.05, significant independent t-test (two-tailed)

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