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Summary and Conclusion

The increasing popularity of ready-to-eat (RTE) and ready-to-cook (RTC) foods reflects a shift towards convenience-driven consumer behaviour. Today's consumers seek quick, high-quality food products that cater to diverse tastes and dietary preferences. This trend has spurred the emergence of start-ups and the development of innovative RTE/RTC products enriched with functional ingredients. These components, including dietary fibers, prebiotics, and antioxidants, enhance the nutritional profile and offer health benefits. Consequently, the RTE/RTC market is set for continued expansion, as health-conscious consumers gravitate towards convenient, nutritious options.

Banana is a nutrient-rich fruit and a key source of essential macronutrients, micronutrients, and phytonutrients. Unripe banana flour is recognized as a promising functional ingredient due to its rich resistant starch and dietary fiber content. Resistant starch is an indigestible carbohydrate that functions as a prebiotic, improving the proliferation of beneficial gut microbes and enhancing health. It contributes to blood sugar control by slowing glucose absorption, which can aid in managing diabetes. The dietary fiber in unripe banana flour also contributes to digestive health by enhancing bowel regularity and satiety, which can support weight management. These attributes make unripe banana flour attractive for developing health-focused ready-to-eat (RTE) and ready-to-cook (RTC) products.

Hence this research was undertaken to assess the potential of unripe banana flours of *Musa paradisiaca* cultivars Peyan (ABB) and Monthan (ABB) as adjuncts for RTE and RTC products and examining its nutritional, physicochemical, prebiotic, and antioxidant properties and assessing the nutrient composition, acceptability, prebiotic potential, and predicted glycemic index of the developed RTE and RTC products.

In phase 1, a baseline online survey was carried out to gather information on the knowledge, attitude, and practice (KAP) regarding RTE and RTC foods. Using a convenience sampling method, 500 respondents aged 20 to 50 years were selected. A structured questionnaire was developed using Google Forms and evaluated for its reliability through Cronbach's Alpha, yielding a score of 0.7, indicating acceptable internal consistency. A pilot test with 15 respondents was conducted to identify any ambiguities, and feedback from this test led to minor revisions for improved clarity and effectiveness. The KAP score was calculated according to the FAO's KAP Manual (2014).

In phase 2, *Musa paradisiaca* Peyan (ABB) and Monthan (ABB) were selected for the study and procured from the fruit market in Chennai and authenticated by the Siddha Central Research Institute, Chennai. The physical characteristics of the fruits were assessed by standard methods (Ravi and Mustaffa,2013), and their ripening stages were determined using the Von Loesecke scale (1950) with further validation through Brix value measurements (Campuzano et al.,2018). Unripe banana flour was prepared by the protocol of Kumar et al. (2019).

In phase 3, the starch morphology and characteristics of the unripe banana flours were analyzed using SEM, FTIR, and XRD techniques. The starch composition, including total starch, amylose, amylopectin, and resistant starch, was also determined. The physicochemical and functional properties, including flour hydration and gelling characteristics, were evaluated using standard protocols to understand the behaviour and potential applications of the flours.

In phase 4, the unripe banana flours were evaluated for their nutrient profile, including macro and selected micronutrients, using standard methods. Qualitative screening followed by quantification of total phenolic content, total tannins, flavonoids, and phytic acid was carried out. The flours were tested for inhibitory efficacy against *E. coli* and *S. aureus*, as well as their antioxidant potential using DPPH, ABTS, and FRAP assays. The prebiotic potential of unripe banana flours (PUBF and MUBF) was assessed. The study involved representative gut bacteria, including *Lactobacillus acidophilus* (ATCC 314), *Bifidobacterium longum* (ATCC BAA 999), and *Lactobacillus paracasei* (ATCC BAA 2839), to assess growth promotion by UBF. Changes in pH, optical density, and colony count were tracked over 24-96 hours, and the prebiotic index (PI) was assessed to determine the effectiveness of UBF as a prebiotic. The predicted GI of PUBF and MUBF was estimated by the Goni et al. (1997) method.

In phase 5, the development and evaluation of RTE and RTC products incorporating unripe banana flours was carried out. Two product categories, baked foods and extruded products, were selected for developing RTE and RTC foods. A total of five products, namely jeera (cumin) cookies, muffins, and baked choco cereals (RTE category), and noodles and pasta (RTC category). were chosen for the study. All five products were developed by replacing wheat flour with PUBF and MUBF in variations of 15%, 30%, and 50% levels, and the products were tried out and standardized. These products were treated as the test products. Control products were developed with 100% wheat flour alone for all five products for comparison purposes. Subsequent trials were conducted to standardize the formulations of the RTE and RTC products. Sensory evaluations were carried out to assess consumer acceptability. The physicochemical properties and nutrient composition of the products, particularly those with 30% unripe banana flours, were analyzed using standard protocols. A shelf-life analysis was performed by assessing Total Plate Count (TPC), peroxide value, and free fatty acid value.

In phase 6, the prebiotic potential of the developed RTE/RTC products containing 30% PUBF was evaluated by the growth promotion of selected probiotics and calculating the prebiotic index. Inhibition of pathogenic *E. coli* by the fermentation supernatant was evaluated. The predicted glycemic index (eGI) and consumer acceptance of the developed PUBF-based RTE and RTC products were assessed. The GI was calculated using the method based on the starch hydrolysis index. The consumer purchase intent was evaluated using a 5-point scale to ascertain the likelihood of respondents buying the PUBF cookies and Noodles.

The salient findings of the study are presented as follows.

Phase 1

- The study provided valuable information on the consumers' knowledge, attitudes, and consumption patterns of functional foods.
- Seventy-six percent of the participants were aware of functional foods/nutraceuticals. Among the respondents, 29 % considered raw banana and sweet potato as functional foods.
- The importance of incorporating functional ingredients and foods into their diet was expressed by 79% of the respondents. 45% of respondents expressed confidence in the safety of functional foods.
- Nearly 52% of respondents expressed a preference for incorporating functional ingredients in ready-to-eat and ready-to-cook foods.
- A willingness to pay a higher cost was indicated by 31% of respondents, while 67% expressed readiness to accommodate the taste of functional foods.

- The Chi-Square test revealed a significant correlation between respondents' academic qualification levels and their knowledge scores, whereas the Chi-Square test of association found no significant relationship between respondents' consumption scores and their age, educational qualification, or income.
- Spearman's Rank Correlation R value indicated a very weak association between the knowledge, attitude, and consumption trends of the participants.
- A positive response on reading health claims and nutritional labels was reported by 79% of respondents. Preference for functional foods was highest for dietary fiber-rich foods (52%), followed by omega-3 fatty acids (48%), low-calorie foods (42%), and low-salt or low-sodium foods (38%).

Phase 2

- The online survey revealed that 52% of respondents preferred RTE and RTC foods with enriched dietary fiber, prompting the identification of high-fiber functional ingredients. However, only 29% recognized unripe bananas, sweet potatoes, and yam as functional foods, highlighting the need to raise awareness of unripe banana health benefits. Given their high resistant starch and dietary fiber content, unripe bananas (*Musa paradisiaca*) were selected for incorporation due to their year-round availability, versatility, nutrient density, gut-friendly properties, and cost-effectiveness.
- The vast diversity of banana cultivars emphasizes the need for selective exploration. Thus, *Musa paradisiaca*, Peyan (ABB), and Monthan (ABB) were chosen for this study due to their indigenous presence in Southern India, widespread availability, underutilization, and limited research.
- *Musa paradisiaca* cultivar Peyan (regional name) with an ABB genome, grown in Tamil Nadu and Kerala, is known for its short, ridged fruits with a broad base and slightly tapered apex.
- The *Musa paradisiaca* cultivar Monthan (regional name), with an ABB genome, is a popular cooking banana in India and widely cultivated on a large commercial scale in the Cauvery delta region, Tamil Nadu, India.
- Fresh unripe bananas (*Musa paradisiaca* cv. Peyan and Monthan) had a moisture content of 69.56 ± 1.48% and 76.80 ± 2.49%, respectively.

- TSS of the fruits ranged from 1.13 ± 0.11 to 1.20 ± 0.20° Brix, which is low due to the bananas being in the first stage of ripening.
- Monthan exhibited significantly greater fruit length and circumference, measuring 18.75 ± 0.45 cm and 15.98 ± 0.73 cm, respectively, while Peyan recorded a length of 12.16 ± 1.01 cm and a circumference of 12.68 ± 0.62 cm.
- The average fruit weight was 74.42 ±4.15 g for Peyan and 192.71±4.81g for Monthan.
- Peyan exhibited a thicker peel and comparatively a lower pulp-to-peel ratio of 1.70±0.24. The pulp/ peel ratio of Monthan was 2.10 ±0.19.
- Unripe Banana flour (UBF) prepared by the method outlined by Kumar et al. (2019) had a creamy, pale-yellow hue. The flour recovery was 30.45 % for Peyan flour (PUBF) and 23.25 % for Monthan flour (MUBF).

Phase 3

- Starch morphology analyzed by SEM revealed that *Musa paradisiaca* Peyan flour (PUBF) exhibited a combination of irregularly shaped round, oval, spherical, and occasionally flattened or elongated granules. In contrast, *Musa paradisiaca* Monthan flour (MUBF) predominantly showed elongated, oval-shaped granules with a few spheroid forms. The starch granules appeared intact, without any fractures.
- XRD analysis indicated that *Musa paradisiaca* PUBF had a relative crystallinity percentage of 8.91%, while Monthan exhibited a relative crystallinity percentage of 13.06%.
- The band observed at 3300 cm^{-1} in the infrared spectrum of unripe banana flours indicates the stretching vibrations of O–H bonds, signifying the presence of hydroxyl groups. This characteristic suggests that unripe banana flour can effectively retain moisture, enhancing its texture and functionality in various food applications, such as baked goods and sauces. The band at 1627-1635 cm^{-1} signifies C=C stretching. Both cultivars displayed a peak at 1002 cm^{-1}, attributed to the stretching of carbonyl bonds, which contribute to the characteristic flavor and aroma of bananas.
- The total starch content of PUBFs was 82.94 %, and MUBF had 86.47%. Both cultivars exhibited an amylose content of 23%, with PUBF showing a higher amylopectin content of 61.49 ± 2.37 g/100 g dry weight.
- Both PUBF and MUBF exhibited 44% resistant starch content and 43% digestible starch

- The gelatinization temperature of banana flours ranged from 85.6 to 88.37 °C. MUBF exhibited a higher gelatinization temperature of 88.37 °C, accompanied by an enthalpy of gelatinization of 253.5 J/g. Conversely, PUBF displayed a lower ΔH value of 210.8 J/g.
- The bulk density of UBFs was recorded as 0.68 - 0.69 g/ cm3. 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. Based on the compressibility index and Hausner Ratio, PUBF and MUBF fall under the "excellent" or "very free-flowing" category.
- The foaming capacity of the flours was observed to be 0.73% for PUBF to 0.67% for MUBF. PUBF and MUBF exhibited emulsion activity of 6.45 ± 0.97% and 8.15 ± 1.35%, respectively. The emulsion stability test resulted in a negative result. Oil absorption capacity in UBFs was found to be 1.71 - 1.75 g/g.
- Water holding capacity of unripe banana flours increased with increasing temperature from 50 ºC to 90 ºC and ranged from 4 to 4.31 g/g. A linear increasing trend in water absorption index (WAI) was observed from 50ºC to 90ºC for MUBF, and at 90ºC, MUBF had a WAI of 3.47 g/g. PUBF had the peak hydration and gelling capacities at 70ºC.
- The swelling power of PUBF ranged from 1.58% to 3.63% for the temperature range of 50-90ºC, while MUBF had a swelling power of 2.96-3.47%. The swelling power of PUBF was maximum (4.21%) at 70ºC, while MUBF recorded a swelling power of 3.98% at 90ºC.
- For the unripe banana flours, partial gelation was observed at a starch concentration of 10%, while complete gelation occurred at a concentration of 12%. Storing unripe banana flour samples at 4 ºC for up to 120 hours resulted in a decreasing trend in light transmittance and increased syneresis.

Phase 4

- The moisture content was 3.95 ± 0.75% for PUBF and 8.67 ± 0.67% for MUBF. The pH levels of unripe banana flours varied between 4.54 ± 0.02 for PUBF and 6.4 ± 0.11 for MUBF, with a titratable acidity ranging from 0.22 to 0.43 g of citric acid per 100 g dry weight. The TSS of PUBF was 2.86 ±0.11% and for MUBF it was 1.97±0.05%.
- The ash content was estimated to be 3.89% - 4.51%. Protein content was 4.89±0.18 g/100g in PUBF and 6.15±0.52 g/100g in MUBF. The fat content of PUBF and MUBF

was 1.36 – 1.96 g/100g. Their carbohydrates were 87 to 88 %, while total starch content varied between 82% and 84%.

- The chosen cultivars of *Musa paradisiaca* displayed a noteworthy dietary fiber content of 13%. PUBF contained 1.17 ± 0.51 g/100g of crude fiber and 2.12 ± 0.05 g/100g of cellulose, while MUBF had 1.52 ± 0.28 g/100g of crude fiber and 3.11 ± 0.39 g/100g of cellulose. The pectin content was 0.144% to 0.176%.
- *Musa paradisiaca* flours showed the following nutrient profiles: Vitamin C was 35.55±0.77 mg/100g in PUBF and 37.8±0.28 mg/100g in MUBF. Calcium content was 30.9±0.11 mg/100g in PUBF and 35±0.94 mg/100g in MUBF. Phosphorus levels were 85.44±2.53 mg/100g for PUBF and 92.89±4.06 mg/100g for MUBF. Iron content was 2.98±0.32 mg/100g in PUBF and 4.81±0.54 mg/100g in MUBF. Potassium levels were 1390±2.82 mg/100g in PUBF and 1403.8±1.42 mg/100g in MUBF.
- PUBF had a total phenolic content of 119 mg GAE/100g, significantly higher compared to MUBF (87 mg GAE/100g). The tannin content of the unripe banana flours was estimated as 612mg TAE/100g for PUBF and 461 mg TAE/100g for MUBF. The phytic acid content of Peyan flour and Monthan flour was 0.598 g/100g and 0.129 g/ 100g, respectively. Higher flavonoids were quantified in MUBF (179 mg QE/100g) compared to PUBF (113 mg QE/100g)
- The statistical analysis revealed a significant variation in the phytonutrient content of PUBF and MUBF. PUBF has a pronounced quantity of polyphenols, tannins, and phytic acid, whereas the MUBF showed a significantly higher flavonoid content.
- Unripe banana flour of Peyan and Monthan demonstrates anti-bacterial properties against *E. coli.* PUBF and MUBF showed a 13mm and 11 mm zone of inhibition, respectively.
- The IC_{50} values for the UBF extracts were calculated as 5-7 mg/mL for DPPH radicals.
- The antioxidant capacity of unripe banana flour, as determined by FRAP assay, was 16.75 ± 0.48 mg AAE/g for the PUBF and 13.64 ± 0.64 mg AAE/g for the MUBF.
- The ABTS assay results showed that the PUBF and MUBF extracts (1.5 mg/mL), had IC_{50} values of 14.21 mg/mL and 15.33 mg/mL, respectively.
- The Pearson correlation coefficient indicated a strong positive correlation linking the FRAP assay with phytonutrients (total polyphenol and total tannin content) as well as with other antioxidant assays, including DPPH and ABTS. The ABTS assay showed a strong positive correlation with the DPPH assay (r = 0.8214) and a moderate positive

correlation with total polyphenol content. These results indicate that both PUBF and MUBF exhibit robust antioxidant potential across different mechanisms, suggesting a more consistent antioxidant response.

- The fermentation of unripe banana flour by the selected probiotics (*Lactobacillus acidophilus, Bifidobacterium longum, and Lactobacillus paracasei*) showed a decrease in the pH of the growth medium and an increase in optical density. In the case of *Lactobacillus acidophilus* incorporated with PUBF, a decrease in pH from 6 to 4 was observed during the fermentation period. The optical density of PUBF incorporated media with *Lactobacillus paracasei* increased from 0.117 to 1.918 from 24 hours to 92 hours.
- The pour plate method revealed that UBF markedly enhances the proliferation of the selected probiotic strains as indicated by the colony-forming units. The CFU count of *L. acidophilus* progressed from 69 x 10^5 to 50 x 10^7 and from 66 x 10^5 to 43 x 10^7 in PUBF media and MUBF media, respectively, in 24 hours to 72 hours.
- The prebiotic index (PI) data were analyzed for *Lactobacillus acidophilus, Bifidobacterium longum, and Lactobacillus paracasei* over a 72-hour fermentation period using PUBF, MUBF, and inulin as substrates. The prebiotic index (Ipreb / PI) values across 96 hours demonstrate a positive effect of all tested carbohydrates on probiotic growth, as all values exceeded 1. For *Lactobacillus acidophilus,* the mean PI over the fermentation period was highest with Peyan (PI=1.40).
- Throughout the fermentation, inulin consistently showed a higher mean PI of 1.44 for *Bifidobacterium longum* while PUBF and MUBF had PI values of 1.10 and 1.02, respectively.
- *L. paracasei* can utilize various substrates for growth, with a marginal preference for PUBF with a mean PI of 1.13 over MUBF and inulin, both at 1.08.
- The fermentation supernatant of PUBF inoculated with *L. acidophilus* exhibited a 13 mm zone of inhibition, indicating effective antibacterial properties, while MUBF and inulin showed an 11 mm inhibition zone.
- PUBF had an eGI of 54.39 ± 0.41, classifying it as a low-GI food, while MUBF had an eGI of 57.60 ± 0.21, placing it in the medium-GI category.

Phase 5

- Cookies were formulated with 15%, 30%, and 50% PUBF and MUBF incorporation. Cookies containing 15% and 30% PUBF/ MUBF incorporation demonstrated higher acceptability scores compared to those with 50% incorporation.
- One-way ANOVA analysis indicated a significant difference among the cookies in all assessed attributes. The post hoc DMRT indicated a significant difference between control cookies and those with 50% UBF incorporation. PUBF/ MUBF 15% and 30% incorporations were comparable to the control, indicating the experimental cookies' acceptance.
- 30% PUBF and 30% MUBF cookies with 100% wheat cookies as control were taken further for physicochemical parameters, nutritional analysis, and shelf- life study based on sensory results.
- The weight of the cookies was around 16g for all the variations. The spread ratio of the control cookies was 6.48, and that of the UBF cookies was 7.35-7.37. The cookies had a bulk density of 0.6 g/cm^3.
- PUBF and MUBF cookies moisture content was 3.25 and 4.04 %, respectively. The total fat content of the cookies ranged from 23-24% without any significant difference among them. The total dietary fiber content in the control (100% wheat flour) cookies was 8.54 g/100g, while it ranged significantly higher in the PUBF (11.11g/100g) and MUBF (10.23g/100g) cookies.
- The resistant starch content of the control cookies was 1.41 %, whereas the UBF incorporated cookies recorded a significant increase in the RS content. The UBF incorporated cookies had an appreciable amount of RS in the range of 10- 12%.
- The cookies prepared in this study had good microbiological quality (1-2 x 10^2 cfu/g) during the shelf-life period, and the microbial load was at acceptable levels (<10^5 cfu/g). Peroxide values increased from 0.2 to 0.5 meq/kg during storage 0- 5 days, within accepted standards of less than 10 meq/kg. The free fatty acid values of all products remained below the acceptable threshold of 0.5%.
- Muffins were formulated with 15, 20, and 50% unripe banana flour replacing the wheat flour. One-way ANOVA showed significant differences across all attributes, and the DMRT test confirmed a significant distinction between control muffins and those with 50% UBFs. 15% and 30% UBFs had similar overall acceptability compared to the control, indicating that these levels of UBFs were well accepted. 30%

PUBF and 30% MUBF muffins with control were taken further for physicochemical parameters, nutritional analysis, and shelf- life study based on sensory results.

- The muffins had an average weight of 25 g, and bulk density values were recorded between 0.47 and 0.56 g/cm^3. Muffins with UBF incorporation exhibited a slightly lower height compared to the control, while the diameter ranged from 53 to 54 mm. However, there was no significant variation in the physical attributes with the control (100% wheat flour), which authenticates the comparable UBF muffin product attributes.
- Moisture in UBF muffins was lower compared to the wheat flour muffins. Protein levels ranged from 5.87±0.13 g/ 100g in PUBF muffins to 6.07±0.12 g/100 g in MUBF, while the control contained 6.33 g/100 g. The fat content remained consistent across all samples, 26-29 g/100g.
- Total carbohydrates were 43.89 ±0.58 g/100 g in the control muffin, whereas the UBF muffins exhibited carbohydrate levels between 47.58 ±1.16 and 49.64 ±1.74 g/100 g.
- Dietary fiber in the PUBF and MUBF muffins was approximately 4 g/100 g, significantly higher than the control wheat muffin.
- There was a significant increase in the RS content of muffins, UBF muffins featuring 4g/ 100g.
- The prepared muffin had a good shelf life of 5 days with microbiological quality standards determined by TPC. On day 5, the TPC ranged from 5 x 10^2 cfu/g for PUBF and 7 x 10^2 cfu/g for MUBF. The peroxide value and free fatty acid values were within the standard limits at the end of the shelf-life period.
- Baked choco cereal was developed using whole wheat flour, with unripe banana flours- PUBF and MUBF incorporated at levels of 15%, 30%, and 50% to create a product rich in dietary fiber, resistant starch, and bioactives.
- The baked choco cereal incorporating 15% UBF achieved higher acceptability scores, comparable to those of control wheat flour cereals. The cereals with 30% PUBF and MUBF incorporation received acceptable scores of 7 and above. One-way ANOVA revealed significant differences across all evaluated attributes, and DMRT Post Hoc test confirmed a notable distinction between the control baked choco cereal and those containing 50% PUBF/ MUBF. Baked choco cereals with 30% PUBF, 30% MUBF,

and the control were selected for physicochemical analysis, nutritional evaluation, and shelf-life study based on sensory results.

- The baked choco cereal with 30% PUBF and MUBF and the control exhibited a moisture content of 3%. Breakfast cereals presented a protein content of 5.5% to 6.8%, with no significant differences observed in mineral content.
- The total carbohydrate content was between 73% and 75%, while total sugars ranged from 10% to 11%. Dietary fiber levels were also comparable, falling within the range of 8% to 9%. PUBF cereals had the highest fiber content of 9.85±0.35 g/100g.
- The incorporation of UBF resulted in a notable rise in resistant starch compared to the control. 30% PUBF and MUBF choco cereals presented an appreciable RS content of 6.27±0.53 g/100g and 5.17±0.42 g/ 100g, respectively.
- The shelf life of baked choco cereal, as determined by microbiological standards, was found to be 90 days. The TPC was found to be 3.7×10^{2} cfu/g for PUBF cereals and 4.1×10^{2} cfu/g for MUBF cereals at the end of the 90th day. The peroxide value rose from 0.2–0.3 to 3.7–4.1 meq / kg over 90 days in the baked choco cereal. The free fatty acid value increased from 0.03-0.05 % to 0.36-0.42 % during the study period, but they were within the standard thresholds.
- Wheat flour with UBF incorporated in varying proportions (15, 30, and 50%) was extruded into noodles. The highest overall acceptability was recorded for control (8.47±0.49), followed by 15 and 30% UBF samples, with no significant difference among them by DMRT post hoc test. However, 50% variation had a significantly lower preference
- Use of UBF in noodle preparation at 30% shows promise in delivering a nutritious, functional food product with satisfactory sensory characteristics and was taken for further analysis. The cooking time for the control noodles was 10 minutes, and the addition of UBF caused a decrease of one minute in the cooking time.
- The moisture levels across the noodles were relatively consistent, 4.01±0.12% to 4.40±0.31%. The highest protein content was observed in the control sample at 6.25±0.18%, while and UBF samples had lower values of 4.94±0.45% and 5.34±0.14%.

- The total carbohydrate content increased with the inclusion of UBF, and dietary fiber content was notably higher in noodles with UBF, with 30% PUBF showing the highest level (7.1±0.12 g), followed by the control (6.25±0.43 g).
- RS in uncooked control dry noodles was 12.28 g/ 100g, and on cooking, the RS content was found to be 2.1g/ 100g. In UBFs, dry noodles' RS content was significantly high (36 g/ 100 g), and on cooking, the RS content reduced to 11-12 g/ 100g.
- Noodles are shelf-stable foods as they are low in moisture, and the microbial load was within the safe limits. The microbial quality of the control and UBF noodles was 2-3 x 10^2 cfu/g. The peroxide value and free fatty acid showed an increasing trend, and at the end of 3 months, the peroxides were 1.10-1.8 meq O_2/kg, and the free fatty acid value was 0.3 %.
- Pasta with 15% incorporation of unripe banana flour was most preferred by the panellists. Since products with 30% incorporation received acceptable scores above 7, they were chosen for further study due to their enhanced nutritional and bioactive content. The score for the appearance of the 50% incorporation was below acceptability.
- On cooking, a more pronounced darkening of the pasta was observed, making the product less acceptable. The cooking yield of the PUBF and MUBF pasta was 22-24g per 10g, while the control had a yield of 27 g/100g. The cooking time was 14-15 minutes.
- The moisture content of the pasta was between 3.74% and 5.41%. The control pasta had 5.2% protein, while the UBF pasta had 4%. The UBF pasta showed a significantly higher total carbohydrate content compared to the wheat pasta. All samples, made with whole wheat flour, had a notable fiber content of 5-6%.
- The dry UBF pasta had 36-37% RS, which is significantly higher than the control pasta. The cooking process led to disintegration and a decrease in RS content to 11-12 % in UBF pasta and 3% in the control. Incorporating UBF increased RS content.
- The microbial load, as determined by TPC, remained within the standard acceptable value 2 x 10^2 cfu/g, which is within the standard limits (< 10^4 cfu/g). The peroxide value was 1.7- 1.9 meq /kg, and free fatty acid values were less than 0.5 % over the shelf-life period of 3 months and were within acceptable standards.

Phase 6

- Jeera cookies (RTE) and noodles (RTC) with 30% PUBF were shortlisted based on selection criteria, including no added sugar and favorable sensory scores, high resistant starch and dietary fiber content. These products with their control were evaluated for prebiotic potential, predicted glycemic index, and consumer purchase intent.
- 30% PUBF cookies and PUBF noodles on fermentation with selected probiotics (*Lactobacillus acidophilus, Bifidobacterium longum, and Lactobacillus paracasei*) reached a final pH of 4 after 72 hours; they effectively create an environment that inhibits the growth of harmful pathogens. The optical density for PUBF cookies increased from 0.127 to 1.818 over 96 hours, while the control cookies recorded an increase from 0.119 to 1.719.
- The colony counts to enumerate the growth of probiotic strain- *L. acidophilus* in PUBF cookies and noodles recorded the highest and increasing trend from 68×10^5 to 31×10^7 and 66×10^5 to 33×10^7 at 24- 96 hours, respectively. *Bifidobacterium* and *L. paracasei* also recorded an increase in the colony count.
- The PUBF cookies showed a higher prebiotic index compared to the control throughout the fermentation period, with the highest PI observed at 48 hours (1.45). This suggests that the unripe banana flour in PUBF cookies promoted the growth of *L. acidophilus*, particularly during prolonged fermentation.
- PUBF cookies maintained a relatively consistent PI, with a peak value at 48 hours (1.31). This stability indicates the potential of unripe banana flour to support the growth of *B. longum* under fermentation conditions.
- The prebiotic index of PUBF cookies for *L. paracasei* remained stable across the fermentation period, with values around 1.00-1.09.
- PUBF noodles displayed higher PI values compared to the control, peaking at 72 hours (1.50), which was the highest recorded PI across all samples. This indicates strong support for *L. acidophilus* proliferation.
- The PI of PUBF noodles for *B. longum* varied slightly, with the highest recorded at 48 hours (1.31). The PI for PUBF noodles concerning *L. paracasei* showed moderate stability, with a slight increase at 72 hours (1.06).

- The study demonstrates that both PUBF cookies and noodles incorporating unripe banana flour exhibit significant prebiotic potential compared to their control counterparts.
- The results of the correlation between the prebiotic index and dietary carbohydrate components further illustrate the complex interactions between dietary components and microbial activity. The prebiotic index positively correlated with dietary fiber (r=0.7), suggesting that dietary fiber supports the growth of beneficial microbes contributing to prebiotic effects. A strong positive correlation of PI with RS (r=0.8) reinforces the role of resistant starch in enhancing prebiotic potential.
- The PUBF cookies exhibited an eGI of 62.85, indicating a moderate glycemic impact, while the control cookies had a higher eGI of 72.67.
- Noodles made with 30% PUBF had an eGI of 63.28, compared to the control noodles, which had a markedly higher eGI of 77.56.
- The lower eGI of the PUBF cookies and noodles indicates that adding UBF not only enhances the overall nutritional profile but also significantly reduces the glycemic response.
- RS shows a strong negative correlation with GI (r = -0.8148), reinforcing its known role in lowering the glycemic response. TDF has an even stronger negative correlation (-0.8629) with GI, which aligns with expectations since fiber slows glucose absorption.
- The positive correlation (r=0.5972) between RS and TDF may be attributed to RS being one of the various components that constitute dietary fiber, and resistant starches exhibit functions similar to dietary fiber in the large.
- Based on a consumer acceptability survey of 50 participants, products containing 30% PUBF received favorable responses. For PUBF cookies, 76% of the participants gave a score of 4 ("probably would purchase") and 22% provided a score of 5 ("definitely would purchase"). These scores are comparable to control cookies.
- PUBF noodles scored 84% as" probably would purchase" and 6% as "definitely would purchase," slightly lower than control noodles, yet still indicating good acceptance.
- These results emphasize the potential of unripe banana flour as a functional ingredient in cookies and noodles, suggesting satisfactory sensory attributes of PUBF products.

The preference ratings indicate successful integration of functional ingredients without compromising consumer acceptability.

Conclusion

This study highlights the potential of unripe banana flour from *Musa paradisiaca* cultivars Peyan (ABB) and Monthan (ABB) as a functional ingredient in ready-to-eat (RTE) and ready-to-cook (RTC) foods. Unripe banana flour exhibits favorable physicochemical properties, hydration, gelling, and structural characteristics, enhancing its suitability for food applications. Its substantial resistant starch and dietary fiber content further contributes to gut health and glycemic regulation in formulated foods. Consumer acceptability assessments indicate a preference for functional ingredients, reinforcing the potential of unripe banana flour in RTE and RTC formulations. Its compositional attributes support diverse applications in bakery products, noodles, and convenience foods without compromising sensory appeal.

Utilization of unripe banana flour promotes sustainability by minimizing post-harvest losses, converting surplus unripe bananas into value-added ingredients, and benefiting farmers and food processors. As a natural source of resistant starch, phytonutrients, and antioxidants, unripe banana flour from *Musa paradisiaca* Peyan and Monthan aligns with the growing demand for functional foods that support health and well-being. This study demonstrates the viability of *Musa paradisiaca* Peyan and Monthan flour in food product development, contributing to sustainable and nutritious formulations. Aligning with global functional food trends, it offers both convenience and health benefits with viable properties and will be a healthy adjunct in modern food innovations and applications.

Recommendations

1. Further exploration of indigenous and native banana cultivars is encouraged.
2. Conduct in vivo studies to investigate the prebiotic potential.

Limitations

1. Due to COVID-19 restrictions during the study period, only an online baseline survey was conducted, limiting participant diversity and response rates.
2. The pandemic extended the timeline for laboratory analyses, resulting in a delay that prevented the execution of in vivo studies for glycemic index.