ORIGINAL ARTICLE (ORIGINAL ARTICLE)

Nutritional and Functional Characterization of Malaysian Banana Flours (Pisang Berangan and Pisang Nangka) and Their Application in High-Fiber Biscuit Development

Normah Haron[1], Hanapi Mat Jusoh[2], Noraslinda Muhamad Bunnori [1*]

[1] Department of Biotechnology, Kulliyyah of Science, International Islamic University Malaysia (IIUM), Jalan Sultan Ahmad Shah, 25200 Kuantan, Pahang, Malaysia.
[2] Department of Nutrition Sciences, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia (IIUM), Jalan Sultan Ahmad Shah, 25200 Kuantan, Pahang, Malaysia.

ABSTRACT

Background: Banana flour from unripe bananas is a promising functional ingredient due to its distinctive nutritional composition and bioactive compounds. This study evaluated the nutritional and functional potential of banana flour from two Malaysian varieties, *Musa acuminata* (Pisang Berangan) and *Musa paradisiaca* (Pisang Nangka), with emphasis on their use in value-added bakery products. **Methods:** Unripe bananas were processed into flour by freeze-drying, followed by proximate and functional property analyses.Biscuits were formulated using Pisang Berangan flour (100%, 50% banana–wheat, and 50% banana–rice blends) for sensory evaluation, while both Pisang Berangan and Pisang Nangka flours were analyzed for nutritional composition and physicochemical properties. A sensory evaluation was conducted among 30 randomly selected undergraduate students from IIUM Kuantan to assess three biscuit formulations (banana flour, banana–wheat flour, and banana–rice flour) for aroma, texture, color, flavor, and overall acceptability using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely). Samples were coded with two-digit numbers, and participants ranked their preferences and provided additional feedback. **Results:** Pisang Berangan flour contained significantly higher ($p < 0.05$) protein (3.74%), crude fiber (5.22%), and ash (2.55%) than Pisang Nangka (2.89%, 3.18%, and 2.02%, respectively). Carbohydrate was the major fraction in both flours (>90%), with Pisang Berangan exhibiting higher starch (92.06%) and amylose (67.71%) compared to Pisang Nangka (88.74% and 59.83%, respectively), indicating stronger thickening and stabilizing potential. Sensory evaluation showed that the 50% banana flour–wheat flour formulation obtained the highest scores for flavor (6.93 ± 1.53), texture (6.87 ± 1.25), and overall acceptability (7.00 ± 1.53). In contrast, the 100% Pisang Berangan flour biscuits exhibited superior nutritional quality but were less preferred in terms of texture. **Conclusion:** Overall, a 50% replacement of wheat flour with Pisang Berangan flour provides the best compromise between texture, flavor, and nutrient density, highlighting its potential as a sustainable functional ingredient for the development of high-fiber bakery products.

Keywords:
Banana flour; functional foods; resistant starch; bioactive compounds; product development; sustainability

INTRODUCTION

Bananas (*Musa* spp.) are among the world's most important fruit crops, with global production exceeding 125 million tonnes annually, primarily in tropical and subtropical regions (FAO, 2023). In Malaysia, bananas are the second most widely cultivated fruit, yet their high perishability leads to substantial post-harvest losses estimated at 20–30% (FAO, 2023). Converting bananas into flour has been proposed as an effective strategy to extend shelf life while preserving nutritional quality (Bezerra et al., 2013).

Banana flour is rich in resistant starch, dietary fiber, and bioactive compounds, which have been associated with improved glycemic control, gut health, and satiety (Menezes et al., 2020; Munir et al., 2024). Moreover, it is naturally gluten-free, making it suitable for individuals with celiac disease or gluten intolerance (Shiga et al., 2020). Previous studies have highlighted its potential in baked goods, pasta, and snack formulations (Agama-Acevedo et al., 2009; Biernacka et al., 2020; Ovando-Martínez et al., 2009). However, varietal differences in nutrient composition and functional properties can significantly influence flour performance in food applications (Anyasi et al., 2019; Bi et al., 2017).

* *Corresponding author.*
E-mail address: hanapi@iium.edu.my; noraslinda@iium.edu.my

In Malaysia, *Musa acuminata* (Pisang Berangan) and *Musa paradisiaca* (Pisang Nangka) are widely cultivated varieties, yet their suitability for flour production has received limited scientific attention. While banana flour has been investigated globally, the nutritional and functional potential of these Malaysian varieties remains poorly characterized, particularly in relation to their application in baked products such as biscuits.

Therefore, the objective of this study was to evaluate the nutritional and functional properties of Pisang Berangan and Pisang Nangka flours and to assess their application in high-fiber biscuit development.

MATERIALS AND METHODS

Preparation of Banana Flour

Fresh unripe green bananas (Pisang Berangan and Pisang Nangka) were thoroughly washed with tap water to remove adhering dust and soil. The fruits were peeled, cut into approximately 1 cm slices, and immediately immersed in a solution containing 1% (w/v) ascorbic acid and 0.185% (w/v) EDTA to prevent enzymatic browning. The slices were frozen at −80 °C for 6 days, followed by freeze-drying for 6 days. The dried samples were ground into fine powder using an electric grinder and sieved through a 250 μm mesh. The flour was stored in sealed plastic containers at 25 °C until further analysis.

For the biscuit formulation, a total of 3.66 kg of fresh unripe bananas (*Musa paradisiaca*, variety Pisang Berangan) at the mature green stage were procured from the Kuantan market for flour preparation. The remaining baking ingredients were sourced from a local supermarket.

Formulation of Biscuits

The biscuit formulation was adapted from Chavan et al. (2020) with modifications in flour ratios. Margarine (50 g) and powdered sugar (60 g) were creamed with a spatula until smooth, followed by the addition of one egg and one teaspoon of vanilla extract. Depending on formulation, banana flour, banana–wheat flour (50:50), or banana–rice flour (50:50) was incorporated gradually to form a uniform dough. The dough was rolled to 0.5 cm thickness, cut into uniform shapes, and baked at 180 °C for 15 minutes. Biscuits were cooled at room temperature, packed in airtight containers, and stored for further analyses.

Proximate Analysis of Banana Flours

Proximate analyses were carried out independently for each type of banana flour, namely Pisang Berangan and Pisang Nangka. Proximate composition was determined according to AOAC Official Methods (AOAC, 2016). Protein was analyzed by the Kjeldahl method, moisture content by oven drying at 105 °C, and ash content by incineration in a muffle furnace at 550 °C. Lipids were extracted using Soxhlet with hexane, and crude fiber was quantified by sequential acid and alkali digestion. Carbohydrate content was estimated using the phenol–sulphuric acid colorimetric method. Starch content was determined with the Rapid Total Starch Assay Kit (Megazyme), while amylose was measured gravimetrically (Subroto et al., 2020), with amylopectin calculated by difference.

Functional Properties of Banana Flour

Functional properties were assessed to characterize flour performance. Starch clarity was measured as percentage transmittance at 650 nm after gelatinization and cooling (Achille et al., 2007). Viscosity and pasting behavior were determined using a vibro-viscometer (SV-10, AND Co. Ltd.) during heating and cooling cycles (Khoozani et al., 2019).

Sensory Analysis of Banana Flour (Pisang Berangan) Biscuits

Thirty undergraduate students at IIUM Kuantan participated in the sensory evaluation. Participants provided informed consent and were supplied with water to cleanse their palates between samples. Three biscuit formulations (100% banana flour, banana–wheat flour, and banana–rice flour) were evaluated for aroma, texture, color, flavor, and overall acceptability using a nine-point hedonic scale (1 = dislike extremely, 9 = like extremely). Samples were coded with two-digit random numbers. Participants also ranked their preferences and provided open comments.

Statistical Analysis

All experiments were performed in triplicate unless otherwise stated. Data were reported as mean ± standard deviation (SD). Independent t-tests were used to compare flour varieties, while one-way ANOVA with Tukey's HSD post hoc test was applied to compare biscuit formulations. Sensory data were analyzed using repeated-measures ANOVA with Bonferroni adjustments or Friedman's test when assumptions were not met. Analyses were conducted in SPSS

Version 27 (IBM Corp., Armonk, NY), with significance set at $p < 0.05$.

RESULTS

Nutritional Composition of Banana Flours

The proximate composition of banana flours from Pisang Berangan and Pisang Nangka is presented in Table 1. Both varieties showed low moisture content (<1.5%), indicating stability for storage. Pisang Berangan exhibited significantly higher ($p < 0.05$) protein (3.74%), crude fiber (5.22%), and ash (2.55%) compared with Pisang Nangka (2.89%, 3.18%, and 2.02%, respectively). Carbohydrate was the predominant fraction (>90%) in both, with Pisang Berangan also showing significantly higher starch (92.06%) and amylose (67.71%).

Table 1: Proximate composition of banana flours (mean ± SD, n = 3)

Parameter (%)	Pisang Berangan	Pisang Nangka	p-value
Moisture	1.33 ± 0.05	1.41 ± 0.07	0.218
Ash	2.55 ± 0.11	2.02 ± 0.08	0.034*
Protein	3.74 ± 0.12	2.89 ± 0.09	0.021*
Crude fiber	5.22 ± 0.15	3.18 ± 0.13	0.012*
Crude fat	0.97 ± 0.03	0.85 ± 0.04	0.147
Carbohydrate (diff.)	91.84 ± 0.27	93.07 ± 0.31	0.086
Starch	92.06 ± 1.12	88.74 ± 1.25	0.041*
Amylose	67.71 ± 1.04	59.83 ± 1.11	0.029*

*Note. Values are mean ± standard deviation (SD). *$p < 0.05$ indicates significant difference between varieties (independent t-test).*

Functional Properties of Banana Flours

Functional evaluations revealed that Pisang Berangan flour exhibited significantly higher viscosity, gelatinization temperature, water absorption capacity, and pasting clarity than Pisang Nangka ($p < 0.05$). These results highlight the superior functional potential of Pisang Berangan for food applications.

Table 2: Functional properties of banana flours (mean ± SD, n = 3)

Property	Pisang Berangan	Pisang Nangka	p-value
Viscosity (mPa·s)	10.92 ± 0.34	5.54 ± 0.29	0.008*
Gelatinization Temp (°C)	78.3 ± 0.90	75.6 ± 0.80	0.041*
Water absorption (g/g)	2.87 ± 0.12	2.31 ± 0.14	0.019*
Pasting clarity (Abs620)	0.42 ± 0.01	0.35 ± 0.02	0.027*

*Note. Values are mean ± SD. *$p < 0.05$ indicates significant difference (independent t-test).*

Nutritional Composition of Pisang Berangan Flour–Based Biscuit Formulations

The proximate composition of biscuits varied depending on flour formulation (Table 3). Biscuit A (100% banana flour) had the highest crude fiber (4.96%) and carbohydrate content (88.50%). Biscuit B (50% banana + wheat flour) had significantly higher protein (4.32%) but lower carbohydrate (86.30%). Biscuit C (50% banana + rice flour) showed intermediate values.

Table 3: Nutritional composition of biscuit formulations (mean ± SD, n = 3)

Parameter (%)	Biscuit A (100% Banana)	Biscuit B (50% Banana + Wheat)	Biscuit C (50% Banana + Rice)	p-value
Moisture	2.14 ± 0.06[b]	2.48 ± 0.08[a]	2.37 ± 0.07[ab]	0.032*
Ash	1.94 ± 0.09[a]	1.76 ± 0.07[b]	1.81 ± 0.06[b]	0.041*
Protein	3.21 ± 0.11[c]	4.32 ± 0.13[a]	2.89 ± 0.10[b]	0.019*
Crude fiber	4.96 ± 0.15[a]	3.11 ± 0.14[c]	3.54 ± 0.13[b]	0.015*
Carbohydrate	88.50 ± 0.27[a]	86.30 ± 0.31[c]	87.40 ± 0.29[b]	0.027*

Note. Superscripts indicate significant differences among formulations (Tukey's post hoc test, $p < 0.05$).

Sensory Evaluation of Biscuits

Aroma and color did not differ significantly among the formulations. However, significant differences were observed in texture, flavor, and overall acceptability ($p < 0.05$). Biscuits formulated with banana and wheat flour (Biscuit B) consistently achieved the highest scores, while 100% banana flour biscuits scored lowest in texture and acceptability.

Table 4: Sensory evaluation scores of biscuits formulated with banana flour and blends (mean ± SD, n = 30)

Attribute	Biscuit A (100% Banana)	Biscuit B (Banana + Wheat)	Biscuit C (Banana + Rice)	p-value
Aroma	6.37 ± 1.79	6.80 ± 1.49	6.40 ± 1.61	0.524
Texture	5.30 ± 1.90	6.87 ± 1.25*	5.90 ± 1.79	0.002*
Color	7.20 ± 1.35	7.23 ± 1.00	6.60 ± 1.30	0.086
Flavor	4.53 ± 2.31	6.93 ± 1.53*	6.30 ± 1.96	<0.001*
Overall acceptability	5.13 ± 2.08	7.00 ± 1.53*	6.23 ± 1.65	<0.001*

*Note. *$p < 0.05$ indicates significant differences (one-way ANOVA).*

DISCUSSION

Nutritional Composition of Banana Flours

The nutritional profile of Pisang Berangan flour was superior to Pisang Nangka, with significantly higher protein, crude fiber, and ash contents. Dietary fiber is strongly associated with reduced risk of non-communicable diseases such as type 2 diabetes, obesity, and cardiovascular disorders (Falcomer et al., 2019). The higher starch and amylose contents in Pisang Berangan flour align with earlier studies showing that unripe banana flour is a rich source of resistant starch (Ovando-Martínez et al., 2009; Khoozani et al., 2019). Resistant starch provides functional health benefits, including glycemic regulation, satiety promotion, and colonic fermentation (Menezes et al., 2020; Munir et al., 2024).

Functional Properties and Food Processing Implications

Functional property analyses further confirmed the superior performance of Pisang Berangan flour compared to Pisang Nangka. Its significantly higher viscosity, gelatinization temperature, and water absorption capacity enhance texture, moisture retention, and stability in baked goods and other processed food applications (Agama-Acevedo & Bello-Pérez, 2017). The higher amylose content contributes to retrogradation stability, which is advantageous for shelf-life extension. This is consistent with Sarawong et al. (2014), who found that extrusion of amylose-rich banana flour improved functional properties without compromising antioxidant capacity.

Nutritional Enhancement of Biscuit Formulations

Banana flour incorporation into biscuits improved nutritional value, particularly fiber enrichment in the 100% banana flour biscuits. However, complete substitution negatively affected texture and overall acceptability, consistent with findings by Dudu et al. (2021) and Khoozani et al. (2020). Partial substitution with wheat flour (50%) yielded the most balanced outcome, with improved protein content, acceptable texture, and favorable sensory scores. This aligns with Shiga et al. (2020), who reported that blending banana flour with wheat improved consumer acceptance compared to full replacement.

Sensory Perception and Consumer Acceptance

Texture was the most decisive factor influencing biscuit acceptability, with the banana–wheat flour formulation outperforming the others. The blending strategy retained the desirable lightness of wheat flour while providing functional enrichment from banana flour. This supports the conclusion that flour blends allow producers to improve nutrition without compromising sensory quality (Anyasi et al., 2019). Moreover, the distinctive flavor contribution of banana flour was generally well accepted, highlighting its market potential in bakery products.

Limitations of the Study

A limitation of the present study is the relatively small sensory panel size (n = 30), which consisted of undergraduate students. While trained panels ensure consistency, larger consumer panels representing diverse demographics would be more reflective of market acceptance. Therefore, the sensory results should be interpreted with caution, and broader consumer testing is warranted.

Future Research Directions

Further research should explore technological interventions to improve 100% banana flour products. Strategies such as hydrocolloid addition (xanthan gum, guar gum, carrageenan), enzymatic modification, or pre-gelatinization could improve texture and palatability. Blending banana flour with protein-rich flours such as soy or chickpea may also enhance nutritional and sensory attributes. In addition, consumer-scale acceptance studies and biochemical profiling of bioactive compounds are needed to validate the functional benefits of banana flour.

Sustainability and Food Security Perspective

Banana flour production contributes to reducing agricultural losses and enhancing food security. Bananas are among the most wasted fruits globally due to perishability, with post-harvest losses estimated at 20–30% (FAO, 2023). Converting unripe bananas into flour extends shelf life, supports smallholder farmers, and aligns with the United Nations Sustainable Development Goal 12 on responsible consumption and production (Viana et al., 2024). In Malaysia, banana flour innovation also reduces reliance on imported wheat flour, supporting local food industries and national food security initiatives.

CONCLUSION

This study demonstrated that banana flour, particularly from the Pisang Berangan variety, possesses superior nutritional and functional qualities compared to Pisang Nangka, characterized by higher protein, fiber, and amylose contents. When incorporated into biscuit formulations, Pisang Berangan flour significantly enhanced the nutritional profile, with the 50% banana–wheat flour blend yielding the most favorable balance between sensory acceptability and nutrient enrichment. Complete substitution with banana flour improved fiber content but reduced textural preference. These findings underscore the potential of Pisang Berangan flour as a sustainable and functional ingredient for developing high-fiber bakery products, contributing to waste reduction, local food innovation, and improved food security in Malaysia.

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