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Effects of banana peel flour (*Musa paradisiaca* AAB (sub-group *Pisang Nangka*)) substitution on physicochemical and sensory properties of bun

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Abstract

This study focused on the utilisation of banana peel flour (BPF) as a potential substitute for wheat flour in buns, addressing both agriculture waste reduction and enhanced bun nutritional value. The widespread cultivation of bananas results in surplus by-products, particularly discarded peels, contributing to organic waste accumulation. Given the recognition of valuable compounds within banana peels and concerns surrounding wheat consumption, investigating BPF's feasibility as an alternative flour is paramount. The specific aims encompass assessing BPF's physicochemical attributes relative to wheat flour and evaluating sensory and physicochemical characteristics of BPF-incorporated buns compared to conventional wheat flour buns. Analysis of BPF revealed reduced moisture and water activity, and increased ash, minerals, crude fibre, and total soluble solids compared to wheat flour. The intensified red-yellow hues in BPF, attributed to the Maillard browning reaction, signify potential sensorial alterations. Upon substitution, bun hardness, gumminess, chewiness, mineral content, and crude fibre increased, while L* and b* values declined in both crumb and crust. The incorporation of 5% BPF had a milder impact on overall bun acceptance than a 10% substitution level. This gradual integration of BPF suggests a plausible way to replace wheat flour, effectively addressing waste reduction, enhancing environmental sustainability, and bolstering nutritional composition. Future research could delve into exploring the antioxidant and antimicrobial properties of BPF, unlocking innovative possibilities for utilising agricultural by-products, thereby advancing sustainable and nutritionally enriched food production.

1. Introduction

Bananas are from the Musaceae family, consisting of three genera in the same family: *Musa, Ensete* and *Musella* (Mohd Zaini *et al*., 2022). Bananas are grown in 130 countries across approximately 10 million hectares of land, with India, China, Indonesia, Brazil, and Ecuador being the leading producers. India produced 30.8 million tons of bananas in 2018, accounting for 26.83% of the global production. Mexico also contributes significantly with 2 million tons annually (Taib *et al*., 2021; Mohd Zaini *et al*., 2022; Segura-badilla *et al*., 2022; Deb *et al*., 2022). Malaysia was the 53rd largest banana exporter globally, producing 330,956 tons of bananas in 2018, covering 30,455 hectares. Banana plantation in Malaysia is expected to increase annually, and by 2030, Malaysia is expected to produce 450,000 tons of bananas (Taib *et al*., 2021). The consumption of bananas has surged due to their pleasant aroma, soft texture and high content of nutrients including carbohydrates, proteins, fibre, fat, vitamins A and C, minerals such as potassium, calcium, and magnesium, and antioxidants (Ashokkumar *et al*., 2018; Ranjha *et al*., 2022; Deb *et al*., 2022). The nutritional composition of bananas is influenced by factors such as geographical location, soil conditions, and the specific types of fertilisers employed during cultivation (Guimarães *et al*., 2020). Banana is a significant food crop, with an average consumption of 12 kg per capita (Zaini *et al*., 2020). The harvest season generates a significant amount of waste, including rotten fruit, peel, rachis, leaves, pseudo-stem, stalk, rhizome, and inflorescences (Zaini *et al*., 2020; Taib *et al*., 2021).

Banana peel accounts for 40% of the weight of fresh

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bananas, with an annual production of banana peel waste of over 40 million tons (Zaini *et al*., 2020; Mohd Dom *et al*., 2021). Banana peel waste leads to adverse environmental effects and economic losses (Zaini *et al*., 2020). Thus, the banana peel waste has been used as an alternative feed for sheep in Indonesia, as it contains organic biomass with protein, fibre, minerals, and other nutrients suitable for ruminants (Ramdani *et al*., 2019). However, a lack of banana peel waste utilisation in nutritional value-added food products can lead to nutrient losses due to its high content of protein, dietary fibre, potassium, polyunsaturated fatty acids, essential amino acids, and antioxidant compounds that play important roles in various functionalities including preventing cardiovascular disease, cancer, and other degenerative disease (Amini Khoozani *et al*., 2019; Muhammad Ansari *et al*., 2023). Banana peel is undeniably valuable in food industry applications such as baked products for their nutritional value and bioactive compounds (Muhammad Ansari *et al*., 2023). There is research trending to fortify buns with no-wheat material that contains dietary fibres and functional compounds (Mohd Dom *et al*., 2023) following food insecurity that impacted 155 million people in 10 nations, which calls for urgent efforts to lessen reliance on wheat flour given disruptions in wheat production resulted from the Russia -Ukraine conflict, while also noting wheat's product unsuitability for individuals with glucose and lipid metabolism syndrome due to its high glycaemic index (Mottaleb *et al*., 2022; Cao *et al*., 2023).

Banana peel flour has high soluble fibre content, water holding, swelling capacity, and low oil-holding capabilities, making it suitable for food product applications (Mohd Dom *et al*., 2023). To utilise the banana peel as a wheat flour replacer in baked products, the peel needs to be processed first. The banana peel will be washed and cut, then immersed in 0.5% citric acid to retard enzymatic browning. The peels will be dried in an oven or cabinet dryer for 48 to 72 hrs at a temperature from 40 to 60°C, and the milled powder will be sieved for 126 to 250 µm sizes and then the flour will be stored in a zip lock bag for further processing (Zaini *et al*., 2020; Mohd Dom *et al*., 2023). Banana peel flour is suitable for wheat flour replacer in baked products such as bread, bun, waffles, cake, and biscuits due to its high-water holding capacity that helps to restore baked product moisture. In addition to the beneficial compounds in banana peel waste, they can be used to increase the bun's nutritional level and improve the development of low gluten bun (Mohd Dom *et al*., 2023). From previous studies, the percentage of banana peel flour (BPF) inclusion in baked products such as flat-bread was 5 to 10% (Zaini *et al*., 2020), biscuits (5 to 15%) and pasta (5 to 10%) (Segura-badilla *et al*., 2022). Segura-badilla *et al*. (2022) mentioned that 10% BPF inclusion can be a maximal substitution because it can make the dough dry and need more effort for the preparation such as kneading and limits the pasta formulation with 10% BPF substitution because the colour of the pasta was darkened if more BPF is added. So far, scarce data has been collected from research that has incorporated BPF in bun. This may be due to a lack of information about banana peel properties that have been studied. The potential benefits of banana peel flour rely on its chemical and physicochemical components before it can be implemented in the bun. Therefore, the objectives of this study were to determine the physicochemical attributes of BPF in relation to wheat flour; and subsequently, to determine the physicochemical and sensory characteristics of buns prepared with BPF substitution compared to buns made from wheat flour.

2. Materials and methods

2.1 Materials

The material utilized for this research consisted of second-stage ripe bananas, exhibiting a vibrant green hue with delicate yellow traces (*Musa* AAB Pisang Nangka). The banana was obtained from Kuala Pilah, Negeri Sembilan, Malaysia. The other materials used in this study were citric acid solution (0.5%), hydrochloric acid (20%), deionized water, distilled water, sulphuric acid (18 M), sodium hydroxide (1.25%) and sulphuric acid (1.25%). These chemicals were an analytical grade.

2.2 Preparation of banana peel flour

The preparation of banana peel flour (BPF) was performed according to Zaini *et al*. (2020) and Deb *et al*. (2022). The banana was washed using tap water, and the peel and pulp were separated. The banana peel was collected after being cut into pieces and dipped in 0.5% (w/v) citric acid solution for 10 mins to stop enzymatic browning (Deb *et al*., 2022). After that, the solution was drained and dried using a drying cabinet for 48 hrs at 40°C (Zaini *et al*., 2020). Next, the dried peel was ground into powder. Then the powder was sieved using 50 mesh screens that gave 250 µm in particle size. The BPF was stored in airtight plastic packs at 5±2°C for further analysis.

2.3 Physicochemical properties of banana peel flour and wheat flour

2.3.1 Moisture content and water activity

The moisture content of banana peel flour (BPF) was determined by using the standard AOAC protocol extracted from Qadir and Wani (2022). The moisture dishes were dried in a hot air oven (FSFCN-302, FINETECH) at 120°C and placed in a desiccator, followed by weighing the moisture dishes. About 5 g (W1) of the sample was added to the pre-weighed moisture dish and placed in an oven at 120°C for 2 hrs. After that, the moist dishes were taken out of the oven and cooled in a desiccator. The cooled moisture dishes were weighted (W2). The moisture content was calculated on a wet basis by using the equation below: The water activity of banana peel flour was measured by a water activity meter (Series 4TE, Aqua Lab) at 25°C (Padhi and Dwivedi, 2022).

$$\text{Moisture content (\%) (wet basis)} = \frac{W2 \times 100}{W1} \quad (1)$$

2.3.2 Ash

The ash content of banana peel flour was carried out by heating the porcelain crucible at 550°C in a muffle furnace (SEF-301, FINETECH), cooled in a desiccator and weighed after it reached room temperature. About 2 g of the sample was put in the pre-weighed crucible and charred using a Bunsen burner. After that, the charred sample was exposed to a high temperature of 550°C for six hrs and cooled in a desiccator. Lastly, the dishes were weighed once they reached room temperature (Qadir and Wani, 2022). The ash content was calculated using the formula:

$$\text{Ash content (\%)} = \frac{\text{Weight of ash} \times 100}{\text{Weight of sample}} \quad (2)$$

2.3.3 Colour

The flour preparation for colour measurement was carried out by following Al-Sahlany and Al-musafer's (2020) method which 30 g of flour was mixed with 50 mL of water. The colour analysis was carried out using a colourimeter (Chroma Meter CR 400, Konica Minolta) which expresses the colour scale in L*, a* and b* values (Salazar *et al*., 2021). The L*, a* and b* are lightness, red/green and yellow/blue, respectively. The L* value is related to the lightness, showing that 0 is for pitch black and 100 is for white. Next, a* positive for red and *a negative for green while b* positive for yellow and b* negative for blue colour.

2.3.4 Total soluble solid

The total soluble solids (TSS) were determined using a bench refractometer (REICHERT). About 10 g of flour sample was mixed with 100 mL distilled water. After that, four drops of sample mixture were placed on the refractometer plate. After reading the sample, the plate was rinsed with distilled water to remove any residue sample (Mutshinyani *et al*., 2020).

2.3.5 Mineral

According to Bhinder *et* al. (2021), 1 g of the sample was charred at 600°C in a muffle furnace (SEF-301, FINETECH) to obtain mineral-rich ash. After that, the ash was added with 2.5 mL of nitric acid (1 M) in the crucible to dissolve the ash, followed by the filtration and diluted with distilled water in a 100 mL volumetric flask. The minerals composition (Mg and Ca) was analysed using an Atomic Absorption Spectrophotometer (AAS) (Analyst 400, Perkin Elmer).

2.3.6 Crude fibre (insoluble dietary fibre)

The crude fibre content was determined using the method that has been carried out by Das *et al*. (2022). About 1 g of fat-free banana peel flour was boiled for 30 mins using 200 mL of 18 M sulphuric acid. After that, the mixture was passed through muslin cloth and washed with boiling water. Next, the sample was boiled with 200 mL of sodium hydroxide for 30 mins. The cleaning step was repeated with 50 mL sulphuric acid, 150 mL water and 25 mL ethanol. The residue was transferred to a pre-weighed crucible (W1), dried at 130°C for 2 hrs, and then cooled and weighed (W2). The residue was ignited at 600°C for 30 mins using a muffle furnace (SEF-301, FINETECH). Then, the crucible with ash was cooled and weighed (W3). The fibre content was calculated.

$$\text{Loss of weight on ignition (g)} = (W2 - W1) - (W3 - W1) \quad (3)$$

$$\text{Crude Fibre (g/kg)} = \frac{\text{Loss of weight on ignition} \times 100}{\text{weight of sample (g)}} \quad (4)$$

2.4 Substitution of banana peel flour in buns

Two types of buns were prepared: one using only wheat flour (control), and another with some of the wheat flour replaced by banana peel flour (BPF). So, three bun samples were made: the control, one with 5% BPF, and one with 10% BPF. These buns were prepared according to the recipe and method extracted from Segura-badilla *et al*. (2022).

The yeast and sugar were mixed with 50 mL of drinking water at 30°C for 15 mins. The dried ingredients (wheat flour, BPF and salt), and yeast-sugar mixture were mixed to form a dough. The dough was left to ferment at 38°C until doubling of its volume. The gas was kneaded out and divided the dough into 30 g each. The dough was left to ferment again for 20 mins. Baked at 180°C until completely cooked, approximately 30 mins. The bun was cooled to room temperature before being stored in hermetic plastic bags at room temperature for further analysis.

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2.5 Physicochemical properties of banana peel flour bun

2.5.1 Colour

The colour analysis was carried out on the bun crumbs and crust, where the bun was cut into 2 × 2 × 2 cm cubes. After that, the cut bun was placed in a digital colourimeter (Chroma Meter CR 400, Konica Minolta). The colour analysis was expressed in the value of L*, a* and b* (Nasir *et al*., 2020).

2.5.2 Texture profile analysis

Crumb texture was determined using a two-bite test to obtain hardness, cohesiveness, chewiness, gumminess, springiness and resilience of the bun by using a texture analyzer (TA-XT plus Texture Analyser) with the standard cylinder probe diameter of 36 mm, equipped with a 5-kg load cell and 50 mm compression plate (P50). Uniaxial compression with 100 mm min-1 crosshead speed was applied to a 5 × 5 × 5 cm sample with crumb hardness corresponding to the force N required for a 40% compression (Corrado *et al*., 2023).

2.5.3 Mineral

Mineral analysis of bun used the same method as flour. Firstly, 1 g of the sample was charred at 600°C in a muffle furnace (SEF-301, FINETECH) to obtain mineral -rich ash. After that, the sample was added with 2.5 mL of nitric acid (1 M) to the crucible to dissolve the ash, followed by the filtration and diluted with distilled water in a 100 mL volumetric flask. The minerals composition (Mg and Ca) was analysed using an Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer Model analyst 400) (Bhinder *et al*., 2021).

2.5.4 Crude fibre (Insoluble dietary fibre)

The sample was homogenised and oven-dried to a constant temperature of 100°C. The sample was extracted with hexane in the Soxhlet apparatus (RIO 65S, Behr) to remove the fat. After that, the dried and defatted samples were boiled for 30 mins with 1.25% H_2SO_4 followed by 1.25% NaOH solution. Finally, the sample was ignited at 600°C for 8 hrs in a muffle furnace (SEF-301, FINETECH) (Tanweer and Imran, 2018). The crude fibre was calculated using the following formula:

$$\% \, Crude\ Fibre = \frac{(Weight\ of\ crucible\ with\ defatted - weight\ of\ crucible\ with\ ash) \times 100}{Weight\ of\ sample} \quad (5)$$

2.6 Sensory evaluation

For sensory evaluation, small pieces (30 g) of the bun were prepared at room temperature (García-Gómez *et al*., 2022) and presented as a whole bun on a disposable plate without any additional ingredients to taste (jam, butter, etc). A total of thirty untrained panellists from Universiti Teknologi MARA (UiTM) Campus Kuala Pilah, Negeri Sembilan, Malaysia of food technology's bachelor degree students were involved to determine the degree of acceptance through the 5-point Hedonic scale: 1 = I don't like it very much; 2 = I moderately dislike it; 3 = I don't like or dislike it; 4 = I moderately like it; and 5 = I like it very much. All the panellists needed to evaluate the texture, appearance, colour, taste and overall acceptance of the bun.

2.7 Statistical analysis

For the analyses of banana peel flour (BPF) and wheat flour (as control), the Independent Sample T-test was used to analyse the data and determine the significant difference between BPF and the control. One-way analysis of variance (ANOVA) with Turkey's test (α=0.05) was used to analyse the data and the differences in the means between samples for the physicochemical and sensorial properties of the bun. The results were expressed as mean ±standard deviation (SD). The significant difference was accepted if $p<0.05$. Statistical analysis was performed using SPSS Version 28.

3. Results and discussion

3.1 Physicochemical properties of banana peel flour

3.1.1 Moisture content and water activity

Moisture content in food plays a crucial role in affecting attributes like density, viscosity, and shelf life, as well as maintaining taste, texture, and appearance, and preventing microbial growth. It extends product shelf life and stability, particularly in items like flour, by hindering enzymatic activity and microbial development. Alam *et al*. (2020) mentioned that keeping flour moisture below 14% is capable of curbing microbial growth. In Table 1, the moisture content in banana peel flour (BPF) was slightly lower compared to wheat flour (control), though this difference was not significant ($p>0.05$). A study by Mohd Dom *et al*. (2021) reported slightly higher BPF moisture content (in the 9.18 to 9.2% range), likely due to using a different banana cultivar (*Musa paradisiaca*

Table 1. Physical analysis of banana peel flour and wheat flour

Parameter	Banana peel flour (BPF)	Wheat flour (WF)
Moisture (% wb)	6.55±1.17^a	9.28±1.70^a
Water activity (%)	0.27±0.01^b	0.44±0.02^a
Ash (% wb)	8.37±0.27^a	2.41±0.53^b
L*	49.07±0.04^b	92.17±0.08^a
a*	2.44±0.03^a	-0.57±0.01^b
b*	15.01±0.09^a	9.7±0.06^b
Total soluble solid (°Brix)	3.20±0.20^a	0.17±0.06^b

Values are mean±SD (n = 3). Values with different superscripts within the same row are statistically significantly different ($p<0.05$).

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ABB cv. Pisang Saba). The change in the texture of the banana peel bun was noticeable due to lower moisture in BPF. Furthermore, the lower moisture content in flour led to higher dry solids content, including protein, starch, fat, sugars, and ash. This indicates stable flour quality during storage, as BPF had moisture content below 14%.

Water activity (aw) is the equilibrium relative humidity of the air surrounding the food system at the same temperature (Mohd Dom *et al*., 2021). According to Mohd Dom *et al*. (2021), pathogenic bacteria's minimum growth aw is 0.83, yet some can persist in low-aw foods for years, raising safety concerns for the food industry. Factors like pH, salt, antimicrobial agents, heat, and storage temperature can alter aw limits. In Table 1, banana peel flour's (BPF) aw was significantly lower ($p<0.05$) than wheat flour, categorizing both as low aw or dry foods. Reduced water content improves stability and shelf life by curbing microbial growth and enhancing resistance against physical and chemical reactions (Khoozani *et al*., 2019). The drying process of banana peel for BPF production removed water, thus reducing water activity.

3.1.2 Ash

The ash content of flour refers to its mineral composition after high-temperature combustion. Flour with higher ash content is less refined and contains more bran particles, serving as an indicator of purity and milling efficiency. This ash measure also reflects the presence of germ, bran, and endosperm (Czaja *et al*., 2020). In Table 1, banana peel flour has significantly higher ash content ($p < 0.05$) compared to wheat flour. A prior study by Alam *et a*l. (2021) reported similar findings, with banana peel flour's ash content (7.66%) surpassing that of banana pulp (1.27%) and wheat flour (0.44%). This confirms that banana peel flour contains more minerals than wheat flour.

3.1.3 Colour

Flour colour was reported in terms of 3-dimensional colour values, which are L*, a* and b* values. The L* value indicates the lightness of the flour colour when the value is closest to 100 and vice versa. In Table 1, the banana peel flour (BPF) is significantly darker ($p<0.05$) in colour compared to wheat flour, as can be seen from L values. The a* value is green (-) or red (+) chromaticity. The result obtained on a* coordinates showed that BPF tends to be significantly redder ($p<0.05$) than wheat flour. Besides, the b* value refers to blue (-) or yellow (+) chromaticity showing that the BPF is significantly yellower ($p<0.05$) than wheat flour. These results show that the BPF from the banana cultivar in this study tends to be red-yellow in colour. Previous research done by Türker *et al*. (2016) reported brighter colour of green bananas (Musa Cavendishii) peel flour for L*, a* and b* values were 65.16±0.13, -1.72±0.01 and 22.49±0.02, respectively. The difference in colour observations was due to the different banana species and the geographical location of the banana obtained. The dark colour of banana peel flour is caused by enzymatic browning due to the polyphenol oxidase enzyme in banana peel (Umairah and Hasmadi, 2023).

3.1.4 Total soluble solid

Total soluble solids (TSS) represent dissolved solids in a sample, often associated with sugar (Doreen *et al*., 2021). Measuring TSS by using a refractometer, which gauges the way light changes speed in various mediums, reflecting the solution's density or soluble solids concentration. The refractive index determines TSS content in a solution, measured in °Brix, by comparing angles of light incidence and refraction during the transition from a vacuum to the medium. In Table 1, the TSS of banana peel flour (BPF) is significantly higher ($p<0.05$) than wheat flour. Silva *et al*. (2020), measured TSS of 3.10±0.00 for the variety "Prata" (*Musa sapientum* AAB). The TSS in BPF was detected due to the presence of three types of soluble sugar such as sucrose, glucose and fructose in banana peel (Reginio *et al*., 2020). Thus, this result shows that BPF contains higher total sugar than wheat flour which would affect the final product's colour and aroma through the Maillard reaction and caramelisation as sugar is the requirement in both reactions. The TSS also signifies the product's humectant quality, allowing it to effectively manage water absorption and retention due to sugar's binding capacity with water.

3.1.5 Mineral

Table 2 compares mineral content in banana peel flour (BPF) and wheat flour through ash analysis. Ash analysis involves high-temperature combustion that still retains minerals like iron, zinc, calcium, magnesium, phosphorus, and potassium. A previous study by Farouk *et al.* (2022) has recorded calcium (24.85 mg/100 g) and magnesium (10.35 mg/100 g) content in wheat flour, while Alshehry (2022) found 80.27±10.16 mg/100 g and 5.29±0.15 mg/100 g of calcium and magnesium, respectively in banana peel (*Musa sapientum*) flour. Table 2 shows significantly higher mineral content in BPF than wheat flour ($p<0.05$). Differences in wheat grain geography and banana cultivar (*Musa sapientum vs. Musa paradisiaca*) may explain variations in mineral results.

3.1.6 Crude fibre (insoluble dietary fibre)

Crude fibre is the residue of plant materials after the food is treated with acid and alkali during digestion, such as cellulose and lignin. The treatment with sulfuric acid is for extracting sugar and carbohydrates while alkali digestion uses a sodium hydroxide solution that removes proteins and some hemicellulose and lignin. A high-fibre diet benefits adults by aiding digestion, promoting intestinal movement, and preventing constipation. Crude fibre absorbs water, thus supporting digestion and preventing constipation. From the result obtained in Table 2, the crude fibre of banana peel flour (BPF) was 9.36±0.9297%, while there is no reading for crude fibre in wheat flour. This is because no residue is left for the wheat flour after the digestion with sodium hydroxide. Whole wheat is high in fibre, but refined wheat contains little dietary fibre due to the removal of the bran layer during the milling process (Ma *et al*., 2022). The study conducted by Alam *et al*. (2021) also found that the crude fibre content in banana peel flour (8.82%) is significantly higher than banana pulp (1.34%) and wheat flour (0.34%). Hence, this indicates that banana peel flour contains a greater amount of crude fibre than wheat flour. Incorporating BPF into baked goods raises their crude fibre levels due to BPF's crude fibre content. Eshak (2016) mentioned that crude fibre in flour can result in a denser crumb structure in baked items by thickening the dough around air bubbles.

Table 2. Chemical analysis of banana peel flour and wheat flour

Parameter	Banana peel flour (BPF)	Wheat flour (WF)
Calcium (mg/100 g)	$101.5±0.82^a$	$41±0.89^b$
Magnesium (mg/100 g)	$114.92±0.83^a$	$25.58±1.89^b$
Crude fibre (%)	9.36±0.93	-

Values are mean±SD (n = 3). Values with different superscripts within the same row are statistically significantly different ($p<0.05$).
-: not detected.

3.2 Physicochemical properties of banana peel flour bun

3.2.1 Colour

Table 3 shows the result of colour in terms of L* (lightness), a* (red/green) and b* (yellow/blue) for bun crumb and crust by using colourimeter (Chroma Meter CR 400, Konica Minolta). Colour is one of the most essential factors in food products that are appetising and influence market acceptance. The colour analysis of the bun was reported in terms of 3-dimensional colour values, which are L*, a* and b* values in lightness, red/green and yellow/blue, respectively. From the result, the control bun's crumb and crust have significantly higher L* values than the bun with 5% and 10% banana peel flour (BPF). This showed that the control has a lighter colour than other formulations, and each formulation was significantly different ($p<0.05$) from the other as can be seen in Figure 1. The L* values of crumb and crust decreased proportionally with the increasing addition of BPF. The drying process in flour production caused the brown colour occurrence due to the ruptured chlorophyll in the peel of the banana, and the resulting browning colour is due to a Maillard reaction in bread production that used heat treatment (Salazar *et al*., 2021). Besides the Maillard reaction, the caramelisation of sugar also produced brown pigments during baking (Ayoub *et al*., 2022). Due to this browning phenomenon, it has been shown that the L* value of baked products decreased when the substitution of banana peel flour in bun production increased.

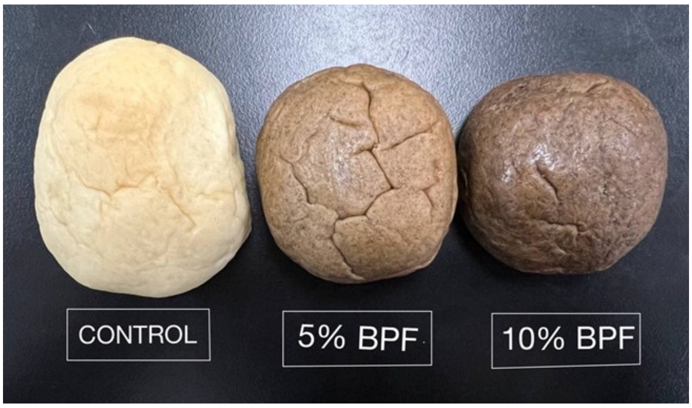

Figure 1. Control and bun substituted with banana peel flour

The a* values for crumb and crust ranged from 0.33 to 3.53 and 4.45 to 6.58, respectively. However, there was no significant difference ($p>0.05$) in a* values for bun crumb and crust between 5% and 10% bun substituted with BPF. The result also shows that the control sample tended to skew towards the yellow side due to the significantly higher ($p<0.05$) b* values for crumb and crust. There was a significant difference ($p<0.05$) for each formulation on crumb and crust for b* values. The combination of the BPF bun's L* a* and b* values was associated with the enzymatic browning initiated by the presence of polyphenol oxidase enzyme in banana peel that could enhance the browning colour of

Table 3. Colour analysis of bun.

Sample	Control (100% wheat flour)	Formulation 1 (5% banana peel flour)	Formulation 2 (10% banana peel flour)
Crumb			
L*	$64.25±0.90^a$	$27.63±1.40^b$	$23.02±1.22^c$
a*	$0.33±0.32^b$	$3.53±0.07^a$	$3.23±0.10^a$
b*	$23.23±1.12^a$	$12.23±0.83^b$	$9.08±0.61^c$
Crust			
L*	$74.94±1.25^a$	$44.48±0.75^b$	$35.27±0.37^c$
a*	$4.45±1.42^a$	$6.58±0.19^a$	$6.13±0.52^a$
b*	$35.04±1.59^a$	$22.15±0.74^b$	$15.81±0.33^c$

Values are mean±SD (n = 3). Values with different superscripts within the same row are statistically significantly different ($p<0.05$).

the flour (Shafi *et al*., 2022; Alshehry, 2022).

3.2.2 Texture profile analysis

The texture quality of the bun is essential for consumers' acceptance. The texture profile analysis was conducted for attributes such as hardness, springiness, cohesiveness, gumminess, chewiness and resilience of the bun. Formulations 1 and 2 of the banana peel flour (BPF) bun were evaluated against 100% wheat flour bun (control). Referring to the result in Table 4, the hardness of the bun increased proportionally with the increasing amount of BPF added to the bun due to the fibre content in BPF (Alkurd *et al*, 2020). The hardness value was higher in the bun substituted with 10% BPF (Formulation 3, F3), while the lowest value was found in the control bun. The hardness result is related to the toughness and structural features of the bun which are affected by the fibre content in BPF. According to Coutinho *et al*. (2023), the substitution of flour that contains high fibre content can cause an increase in the firmness of the bun due to the least formation of the starch-gluten matrix that restricts the retention of gas in the gluten network and affects the specific volume of the bun. This will cause the bun denser than the control as wheat flour has higher protein gluten that binds gliadin and glutenin during dough formation. Other than that, the presence of fibre with high water binding capacity also limited the absorption of water by wheat flour in baked products that use BPF from developing gluten complex (Aydogdu *et al*., 2018).

However, the springiness values decreased proportionally with the increasing amount of BPF added to bun production. According to Tóth *et al*. (2022), springiness is correlated with bread freshness. The product with low values of springiness will show crumb brittleness. On the other hand, the springiness of a breadcrumb is a measurement of how much it recovers after being pressed once, which is also a crucial factor in determining the staling degree of bread (Moawad *et al*., 2019). In Table 4, the decreasing value of springiness was related to the higher amount of fibre included which caused partial dehydration and dilution of gluten followed by insufficient starch swelling and gelatinization of the bun during baking (Azadfar *et al*., 2023). In addition, the interaction of water, gluten and starch gives bun its elasticity related to springiness. The lower elasticity is due to the increasing fibre content that causes a reduction in proteins and gluten which affects the dough's ability to absorb water and prevents the development of the gluten network.

Next, the gumminess and chewiness of the bun with 5% and 10% BPF were significantly different ($p<0.05$) than the control sample. The gumminess and chewiness were increased proportionally with the increased substitution of BPF in the bun. The chewiness value was proportional to the bun's hardness, where higher energy was needed to chew the bun with the higher hardness value. It is also related to the fibre content in BPF that absorbed water during dough formation. This absorbed water surrounding the protein structure caused the difficulty of gliadin and glutenin to bond (Agnieszka *et al*., 2023). Thus, this caused increasing in the hardness and chewiness of the bun and a decreased in springiness and resilience. On the other hand, the resilience and cohesiveness of all the formulations were not significantly different ($p>0.05$) from each other. The data obtained showed that the increasing substitution of banana peel flour in bun production increased the hardness, gumminess and chewiness while the decreased value of springiness, cohesiveness and resilience of the bun.

3.2.3 Mineral

Table 5 indicates the calcium and magnesium content of the control, 5% BPF (F1) and 10% BPF (F2) substitution bun. The result showed that the calcium and magnesium content in the control formulation was significantly lower ($p<0.05$) than F1 and F2 bun. The calcium content was increased significantly ($p<0.05$) when substituted with 5% and 10% BPF, respectively. Meanwhile, the magnesium content in control, F1 and F2 bun was also increased gradually with the increment of BPF especially for F1 and F2. However, there was no significant difference ($p>0.05$) in magnesium content

Table 4. Texture profile analysis of bun

Sample	Control (100% wheat flour)	Formulation 1 (5% banana peel flour)	Formulation 2 (10% banana peel flour)
Hardness (g)	378.39±43.40^{b}	883.95±31.83^{a}	1127.30±345.66^{a}
Springiness (mm)	0.95±0.01^{a}	0.90±0.03^{ab}	0.88±0.03^{b}
Cohesiveness	0.77±0.02^{a}	0.78±0.06^{a}	0.73±0.06^{a}
Gumminess (mm)	292.03±39.84^{b}	686.28±79.52^{a}	814.95±97.72^{a}
Chewiness (N)	278.42±39.07^{b}	619.58±87.06^{a}	714.96±73.47^{a}
Resilience	0.36±0.01^{a}	0.37±0.03^{a}	0.34±0.02^{a}

Values are mean±SD (n = 3). Values with different superscripts within the same row are statistically significantly different ($p<0.05$).

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Table 5. Chemical analysis of bun

Sample	Control	Formulation 1	Formulation 2
	(100% wheat flour)	(5% banana peel flour)	(10% banana peel flour)
Calcium (mg/100 g)	24.5±0.50[c]	27.25±0.90[b]	31.5±1.25[a]
Magnesium (mg/100 g)	30.33±1.28[b]	34.08±2.96[b]	38.83±0.38[a]
Crude fibre (%)	-	1.51±0.15[a]	2.29±0.65[a]

Values are mean±SD (n = 3). Values with different superscripts within the same row are statistically significantly different ($p<0.05$).
-: not detected.

between the control and F1 bun. Both had significant differences ($p<0.05$) with F1 bun. It can be concluded that the mineral content in BPF substituted bun was higher than wheat flour bun and may be related to the greater mineral content of BPF compared to wheat flour as can be seen in Table 2.

3.2.4 Crude fibre (insoluble dietary fibre)

The result of crude fibre in different bun formulations is recorded in Table 5. The crude fibre in control cannot be detected due to the removal of fibre-rich bran and phytonutrient-rich germ layer during the milling process of flour (Harris *et al*., 2022) that resulted in the endosperm (consists of carbohydrate and protein) as the main ingredient in the baked product. The treatment with acid and the base solution will remove all the carbohydrates and proteins in wheat flour which results in no residue. The study conducted by Aly *et al*. (2021) found that crude fibre in wheat flour was 0.09±0.02%, while Ijarotimi *et al*. (2022) found the crude fibre in wheat flour was 0.89±0.02%, where both results showed small amount of crude fibre in wheat flour. In Table 5, the crude fibre content increased insignificantly ($p>0.05$) with increasing substitution of BPF in bun. The high crude fibre in BPF (Table 2) affected the crude fibre content in BPF substituted bun as shown in Table 5. Alshehry (2022) reported the crude fibre in a biscuit that has been substituted with 5% and 10% BPF (*Musa sapientum*) was 3.28±0.12% and 4.47±0.14%, respectively. Segura-badilla *et al*. (2022) found that the crude fibre in bread with 10% BPF (Musa Cavendish) was 2.7±0.23%. This is to show that the amount of crude fibre obtained in this study is almost similar to those studies.

Eshak (2016) reported the crude fibre in flatbread with 5% and 10% BPF was 1.97% and 2.18%, respectively. The increasing result is due to the greater crude fibre in BPF. This study's crude fibre content aligns with WHO and FAO recommendations of not more than 5 g per 100 g dry matter in daily intake, while various sources suggest different daily fibre intake levels ranging from 8 to 38 g per 1,000 calories (Madhu *et al*., 2017; Alam *et a*l., 2021; Ioniță-Mîndrican *et al*., 2022).

3.3 Sensory properties of banana peel flour bun

Table 6 shows the result of sensory evaluation of the bun made using wheat flour, and substitution with 5% (Formulation 1) and 10% (Formulation 2) banana peel flour (BPF) by using a 5-point Hedonic scale. Thirty (30) untrained panellists from Universiti Teknologi Mara (UiTM) students were involved in this sensory evaluation. Five sensory attributes were evaluated including texture, appearance, colour, taste and overall acceptance. According to the result in Table 6, there was no significant difference ($p>0.05$) in the texture attribute between F1 and the control bun. The F2 bun was denser than the control and F1 bun, making it the least preferred texture for the panellist. There was no significant difference ($p>0.05$) in colour attribute between F1 and F2 bun. This is because BPF is darker than wheat flour (Table 1) and affects the entire colour of the bun (Table 3), even with a little substitution with BPF. Apart from that, there were significant differences ($p<0.05$) among all the formulations in terms of their appearance, taste, and overall acceptance. The taste score for the F2 bun was the lowest due to the bitter leafy green aftertaste. Thus, it can be concluded that bun substitution with 5% BPF is the best formulation since the bun texture is nearly similar to the control bun. The colour of the F2

Table 6. Sensory analysis of bun

Sample	Control	Formulation 1	Formulation 2
	(100% wheat flour)	(5% banana peel flour)	(10% banana peel flour)
Texture	4.37±0.809[a]	3.83±0.747[a]	2.67±1.06[b]
Appearance	4.43±0.679[a]	3.37±0.850[b]	2.57±0.858[c]
Colour	4.27±0.868[a]	2.90±0.712[b]	2.53±0.937[b]
Taste	4.20±0.718[a]	3.50±1.14[b]	2.60±1.00[c]
Overall acceptance	4.37±0.718[a]	3.53±0.819[b]	2.53±0.937[c]

Values are mean±SD (n = 3). Values with different superscripts within the same row are statistically significantly different ($p<0.05$).

bun was darkened as the chemical reaction of the Maillard browning reaction that occurred during baking advanced (Salazar *et al*., 2021). The significant difference ($p<0.05$) in the overall acceptance attribute may be related to the unfamiliar taste of the BPF that gives an aftertaste during the sensory evaluation.

4. Conclusion

This study investigated the attributes of banana peel flour and its utilization as a wheat flour substitute in the bun. Comparing the two flours, banana peel flour exhibited lower moisture and water activity, but higher ash, minerals, crude fibre, and total soluble solids than wheat flour. Notably, the banana peel flour possessed a darker hue with intensified red-yellow tones, attributed to the Maillard browning reaction. When replacing bun flour with 5% and 10% banana peel flour, mineral content and crude fibre content in the buns increased proportionally. This resulted in a denser texture due to the elevated crude fibre content in the banana peel flour buns compared to the control. The bun also displayed discernible distinctions in colour and texture due to the incorporation of banana peel flour. On the other hand, substituting 5% banana peel flour in buns had a less adverse impact on overall bun acceptance in comparison to the 10% substitution level. This implies that a gradual integration of banana peel flour in baking could mitigate potential negative effects on bun appeal. Consequently, by progressively integrating banana peel flour, the feasibility of gradually replacing wheat flour becomes plausible. This approach not only curbs waste but also contributes to environmental betterment and boosts the nutritional profile of the buns. Future research could delve into exploring the antioxidant and antimicrobial qualities of banana peel flour, thus paving the way for innovative possibilities of utilizing agricultural byproducts.

Conflict of interest

The authors declare no conflict of interest.

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