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RESEARCH ARTICLE

Formulation and Quality Evaluation of Composite Biscuits Incorporated with Dried Blue Pea (*Clitoria ternatea*) Flower Powder

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ABSTRACT

The flowers of blue pea, a nutrient-rich yet underutilized crop in Sri Lanka, holds potential as a natural food colourant and health-enhancing ingredient. Therefore, Blue pea flower (BPF) provides an attractive natural blue colour to the biscuits and enhances their antioxidant and anti-inflammatory properties. Similarly, peanut butter enhances the biscuits' palatability and improves their nutritional value, including protein, healthy fats, essential vitamins, and minerals. This study aimed to develop healthy composite biscuits by incorporating dried BPF powder at varying levels (9, 10, 11, and 12%) along with peanut butter. A sensory evaluation with 30 semi-trained panellists using a 5-point hedonic scale identified the 9% dried BPF formulation as the most preferred. Proximate and physicochemical analyses confirmed that biscuits incorporated with 9% dried BPF powder exhibited superior nutritional properties, including 0.84% moisture, 7.27% crude protein, 1.9% crude fibre, and 17.67% fat, compared to the control biscuit. Incorporation of dried BPF powder enhanced the antioxidant properties of the composite biscuits, including total phenolic content (29.89%), flavonoid content (32.43%), and DPPH antioxidant capacity (69%). It also improved physicochemical characteristics such as a lower pH (7.30) and reduced water activity (0.51). After two months of storage, microbial analysis confirmed that the biscuits remained within safe limits, with a total plate count of 4×10^2 CFU/g and no detectable levels of yeast or mold. These findings suggest that the addition of dried BPF powder can significantly improve the nutritional, sensory, and functional qualities of biscuits, offering a healthier alternative to conventional options.

Keywords: *Antioxidant, Blue pea flower, Colourant, Composite biscuit, Microbial analysis*

INTRODUCTION

The blue pea (*Clitoria ternatea*) plant, known as Asian pigeon wings, thrives in tropical climates (Tuan Putra *et al.*, 2021). The blue pea flower (BPF), recognized for its vibrant blue colour and rich content of flavonoids, anthocyanins, and other polyphenols with antioxidant properties, has been widely used in traditional medicine to enhance cardiovascular health and reduce hypertension, pyrexia, and liver diseases, as well as in culinary applications. Recently, there has been growing interest in utilizing BPF as a functional ingredient in food products because of its potential health benefits and natural colouring properties (Amali *et al.*, 2021; Soedirga *et al.*, 2023).

Cream biscuits, a popular baked snack enjoyed globally, are known for their rich, creamy texture and sweet flavour. Typically, they are made from wheat flour, sugar, fat, leavening agents, and artificial colouring agents. However, regular consumption of such biscuits can contribute to various health issues, such as obesity, diabetes, and digestive problems, due to their high levels of sugar, gluten, and potentially harmful artificial colourants and sweeteners. In recent years, there has been growing interest in incorporating functional ingredients such as BPF powder into popular food products like biscuits. BPF, a natural plant-based colourant, is valued for its potential health benefits, including antioxidant and anti-inflammatory properties. Its inclusion in cream biscuits enhances visual appeal and enriches the nutritional profile, making it a more attractive option for health-conscious consumers seeking functional and aesthetically pleasing snacks (Saly *et al.*, 2018).

Peanut butter, a widely used ingredient in baked goods, is rich in protein and healthy fats, and also serves as an excellent source of essential nutrients such as magnesium, phosphorus, and zinc, which support bone health and immune function. It is also high in vitamins B3 and B6, which facilitate energy metabolism and brain function (Jeyaraj *et al.*, 2021). Additionally, peanut butter contains vitamin E, a powerful antioxidant that helps protect cells from oxidative stress (Saheedat, 2018). When combined with BPF powder in composite biscuits, it enhances both nutritional value and sensory appeal by introducing a unique flavour, colour, and health-promoting properties (Saheedat, 2018; Shibli *et al.*, 2019).

Considering these advantages, the incorporation of BPF powder into biscuit formulations presents a promising way to improve both nutritional value and functional properties. Its natural antioxidant potential and role as a plant-based colourant provide a healthier alternative to artificial additives. Similarly, peanut butter adds essential nutrients, including protein, healthy fats, and key micronutrients that support overall health. Therefore, this study aimed to develop healthy composite biscuits using dried BPF powder and peanut butter, and to evaluate their physicochemical properties, sensory attributes, and antioxidant potential. The findings are expected to demonstrate the potential of dried BPF powder as a functional ingredient, thereby promoting the development of nutrient-rich, health-enhancing food products.

MATERIALS AND METHODS

Preparation of dried BPF powder

Fresh BPF were sourced from locally cultivated home gardens in Jaffna and thoroughly washed to remove contaminants. The flowers were then dried in a cabinet dryer (Minimini II, Taiki Sangyo, Japan) at 48°C for 18 h under controlled humidity conditions. After dring, the blue petals were ground using a high-speed stainless-steel grinder (ABS-W, Osaka Chemical, Japan) and sieved through a 100 μm stainless-steel sieve to ensure uniform particle size. The resulting dried BPF powder was stored in sterilized, airtight glass bottles in a cool (20±1°C), dry environment to preserve its quality and bioactive properties.

Formulation of dried BPF powder incorporated composite biscuits

Control and dried BPF powder-incorporated composite biscuits were prepared using the creamery method for biscuit dough, following the procedure outlined by Naseeha *et al*. (2023). Peanut butter was prepared according to the method described by Shibli *et al*. (2019). The standard control biscuit formulation consisted of 48 g of wheat flour (base flour), 30 g of butter, 20 g of sugar, and 2 g of baking powder. Additionally, 2 g of peanut butter was added to enhance palatability and nutritional quality, making up the 100% composition of the dough mixture. Dried BPF powder was incorporated into the dough at specified percentages for treatment variations according to the experimental design. All ingredients were mixed thoroughly to form uniform dough mixtures.

Initially, the first trial was conducted with four different formulations containing 3% dried BPF powder and 97% dough mixture, 6% dried BPF powder and 94% dough mixture, 9% dried BPF powder and 91% dough mixture, and 12% dried BPF powder and 88% dough mixture, along with a control (0% dried BPF and 100% dough mixture). Based on the results of a preliminary sensory evaluation, biscuit formulations with 9 and 12% dried BPF powder were preferred over the other two formulations, leading to a second trial focusing on formulations within this range. The formulations of the second trial were as follows: T1 (9% dried BPF powder and 91% dough mixture), T2 (10% dried BPF powder and 90% dough mixture), T3 (11% dried BPF powder and 89% dough mixture), and T4 (12% dried BPF powder and 88% dough mixture). Different formulations of biscuits from the first and second trials were then rolled, cut, and baked in a baking oven (CBS1.0406, Aicohsha, Japan) at an optimal temperature of 180°C for 12 min.

Sensory evaluation

The composite biscuit samples collected from the first and second trials were subjected to sensory evaluation separately to determine consumer preference, using a 5-point hedonic scale with 35 semi-trained panellists. The samples were labelled with 3-digit random numbers and presented to the panellists for sensory evaluation, along with score sheets for each sensory attribute for the different treatments. Sensory attributes, namely appearance, texture, colour, flavour, taste, and overall acceptability, were evaluated using a scale where 1 signified "dislike very much" and 5 indicated "like very much."

Analysis of functional properties of dried BPF powder

The water and oil absorption capacity, swelling capacity, and bulk density of dried BPF powder were determined as described by Naseeha *et al*. (2023). For water and oil absorption capacity, 1 g of sample was mixed with 10 mL of distilled water or oil in a centrifuge tube, allowed to stand for 1 h, then centrifuged at 2,150 *g* for 30 min (LCX 100, Tomy Digital Biology, Japan). The results were then expressed as percent water/oil bound per gram of flour. Swelling capacity was determined by filling 1 g of sample up to the 10-mL mark in a 100 mL graduated cylinder and adding water to reach a total volume of 50 mL. The sealed cylinder was inverted twice, and then left undisturbed for 30 min. The volume occupied by the sample was recorded. For bulk density, 10 g of powder was transferred into a 100 mL measuring cylinder and tapped until a constant volume was reached. Bulk density (g/cm^3) was calculated as the weight of the sample divided by its final volume.

Analysis of physical properties

The diameter, thickness, and weight of control and composite biscuits were determined as explained by Naseeha *et al.* (2023), while the spread factor was calculated using the procedure described by Krystyjan *et al.* (2018). Bulk density was determined using the method outlined by Naseeha *et al.* (2023), and water activity and pH were measured using a water activity meter (EZ 200, Freund Sangyo, Japan) and pH meter (HM-30P, DKK-TOA, Japan), respectively.

Proximate analysis

Proximate components such as ash (dry ashing method), moisture (oven drying method), crude protein (Kjeldahl method), and crude fat (Soxhlet extraction method) of the samples were analysed according to the standard procedures described by the AOAC (2000). The crude fibre was analysed using a fiber analyser (A200, ANKOM Technology, USA). The carbohydrate percentage was determined by percentage differences (Godswill, 2019).

Estimation of reducing sugar and total sugar

To determine reducing sugars, 1 mL of the sample or standard glucose solution was taken in a test tube, and 1 mL of DNS reagent was added. The mixture was thoroughly mixed and then heated in a boiling water bath for 5 to 10 minutes to facilitate the reaction. After boiling, 1 mL of 40% sodium potassium tartrate solution was immediately added to stabilize the color. The mixture was then allowed to cool to room temperature, and the absorbance was measured at 540 nm using a UV-visible spectrophotometer (UH5300, Hitachi, Japan). The concentration of reducing sugars was determined using a standard glucose calibration curve.

For total sugar determination, 1 mL of the sample was taken, and 1 mL of 1 N hydrochloric acid was added to a test tube. The mixture was heated in a boiling water bath for 10 minutes to hydrolyze non-reducing sugars into reducing sugars. After heating, the sample was cooled and neutralized by adding 1 N sodium hydroxide until a neutral pH was achieved. Then, 1 mL of DNS reagent was added to the hydrolyzed sample, the solution was mixed, and boiled again for 5 to 10 minutes. After boiling, 1 mL of 40% sodium potassium tartrate solution was added to stabilize the color, and the mixture was allowed to cool. Finally, the absorbance was measured at 540 nm, and the total sugar concentration was determined using the standard glucose curve (Saqib and Whitney, 2011).

Estimation of mineral content

About 1 g of sample was dry-ashed at 300–450°C for 2–3 h. The ash was treated with HCl, evaporated, re-dissolved, filtered, and diluted to 100 mL. For phosphorus estimation, a 5-mL aliquot was mixed with vanadomolybdate reagent, and absorbance was measured at 450 nm using a UV-visible spectrophotometer (UH5300, Hitachi, Japan); phosphorous content (%) was calculated from a standard curve. For potassium estimation, the ash was dissolved in 0.05 N HCl, diluted, and analysed using a flame photometer (PFP7, Jenway, UK) calibrated with 0–40 ppm potassium standards to calculate potassium content in % (Chikhale and Chikhale, 2017).

Estimation of antioxidant properties

The antioxidant properties of the samples were assessed by determining their total phenolic content, total flavonoid content, and antioxidant capacity. Total phenolic content was determined using the Folin-Ciocalteu method with gallic acid as the standard, while total flavonoid content was determined using the aluminium chloride colorimetric method with catechin as the standard (Naseeha *et al.*, 2023). The absorbance of total phenolic and total flavonoid contents in the samples was measured at 760 nm and 510 nm, respectively, using a UV-visible spectrophotometer (UH 5300, Hitachi, Japan). The antioxidant capacity of the extracts was determined using the DPPH free radical scavenging assay, as described by Phuyal *et al.* (2020), with slight modifications, and ascorbic acid was used as the standard. Here, the absorbance of the samples was measured at 517 nm using a UV-visible spectrophotometer (UH 5300, Hitachi, Japan).

Determination of colour and texture

The colour of the samples was measured using a colorimeter (NR20XE, Shenzhen Threenh Technology, China). The texture profile analysis of biscuit samples (hardness) was done using a texture analyser (FRTS-100N, IMADA, Japan).

Shelf-life study of samples

Freshly prepared control and selected composite biscuit samples were packed in moisture-proof metal tins and stored at an ambient temperature. The minimum recorded temperature for this shelf-life study period was 25°C, and the maximum was 33°C. Visual analysis and microbial evaluation, including total plate Count (TPC) and Yeast and Mold Count, were conducted at 30-day intervals for up to 60 days to assess the quality and safety of the biscuits (Naseeha *et al.*, 2023) using an incubator (TVA-660-DB, Advantec, Japan) and colony counter (Galaxy 330, Rocker, Taiwan).

Statistical analysis

Sensory data were analysed using the Friedman Nonparametric statistical method using SPSS Software with a 95% confidence interval. The study was designed as a Completely Randomized Design (CRD) to assess functional, physical, chemical, and antioxidant properties, with data analysis was conducted using one-way ANOVA via the SAS statistical package. The significant difference was compared using Duncan's Multiple Range Test (DMRT) at a $p<0.05$ significance level.

RESULTS AND DISCUSSION

Sensory result of prepared biscuits

The sensory analysis results are illustrated in Figure 1, indicating a statistically significant difference ($p<0.05$) in sensory attributes among the samples. T1 and T2 exhibited superior mean values for all sensory attributes. However, T1 consistently displayed the highest mean values across all attributes compared to other formulations. Consequently, T1 was selected for further analysis to compare the physical, physicochemical, nutritional, and shelf-life characteristics of biscuits with the control sample.

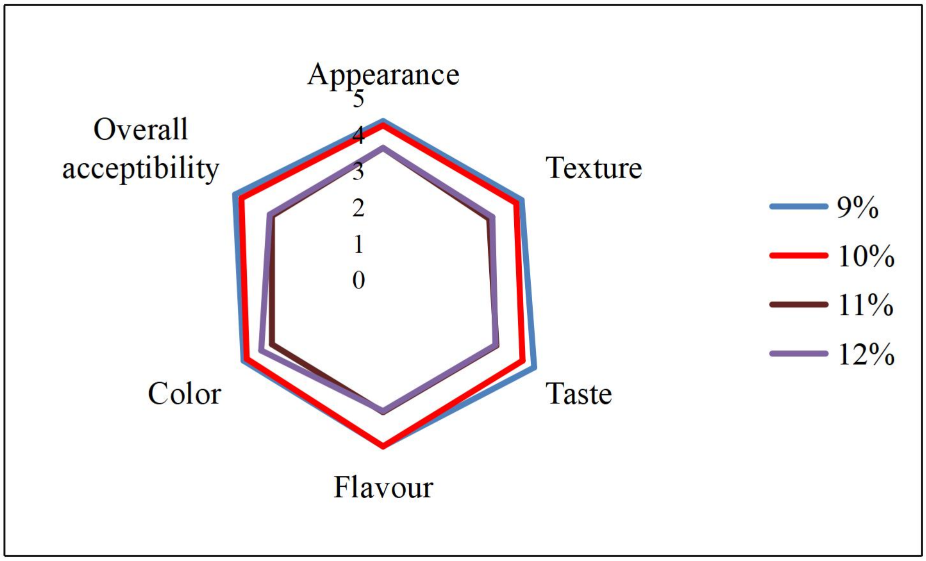

Figure 1: Results of sensory analysis

Functional properties of dried BPF powder

The functional properties of raw materials play a vital role in food manufacturing. Organoleptic and physical aspects of foods are frequently used to determine their functional characteristics. The structure, quality, texture, acceptability, and appearance of the food product define the functional properties of food items (Awuchi *et al.*, 2019). Table 1 shows the functional properties of dried BPF powder.

Table 1: Functional properties of dried BPF powder

Water absorption capacity (mL/g)	Oil absorption capacity (mL/g)	Swelling capacity (mL/g)	Bulk density (g/cm^3)
4.83±0.06	2.22±0.04	9.89±0.16	0.65±0.02

Values represent the mean±standard deviation of triplicate determinations

The bulk density is affected by particle size and initial moisture content. In this study, the bulk density of dried BPF powder was slightly lower than that of wheat flour, which had a reported bulk density of 0.76 g/cm^3 (Hasmadi *et al.*, 2020). A lower bulk density in dried BPF powder may influence biscuit production by affecting ingredient dispersion and dough handling properties. Specifically, a lower bulk density can contribute to a lighter texture in biscuits, which is often desirable for achieving a crisp and tender final product. However, it may also require adjustments in formulation to ensure proper binding and structural integrity during baking (Banusha and Vasantharuba, 2014).

However, the water absorption capacity (WAC) and oil absorption capacity (OAC) of dried BPF powder were higher than those of wheat flour, as reported by Alviola and Monterde (2018), who found the WAC and OAC of wheat flour to be 1.31 mL/g and 0.88 mL/g, respectively. Therefore, the higher WAC and OAC values of dried BPF powder are desirable characteristics that contribute to its high baking quality. A higher WAC contributes to improved dough hydration, leading to enhanced dough strength and texture. This positively impacts the final product by ensuring uniform moisture distribution, which is essential for consistent baking quality. Similarly, the higher OAC of dried BPF powder indicates a better ability to retain fats and oils, which can enhance the mouthfeel and flavour retention of biscuits. This property helps develop a more tender and flavourful product, as increased oil retention maintains a desirable crumb structure and prolongs freshness (Hasmadi *et al.*, 2020).

The swelling capacity of starch is a critical parameter that reflects its ability to absorb water and expand, indicating the strength of intermolecular forces within the granules. This characteristic is vital in bakery products and influences the final product's quality. Factors such as particle size, species variation, and processing techniques significantly affect the swelling capacity of flour (Awuchi *et al.*, 2019). In this study, the swelling capacity of dried BPF powder was 0.65±0.02 mL/g. This value is comparable to the swelling capacity of wheat flour, which is reported in previous research (Kumar *et al.*, 2017). The similar swelling capacity of BPF powder to wheat flour supports proper dough development, promoting volume expansion and a balanced biscuit texture for improved eating quality (Naseeha *et al.*, 2023).

Proximate composition of dried BPF powder

The proximate composition of dried BPF powder, as illustrated in Figure 2, provides valuable insights into its nutritional profile. Moisture content is a crucial parameter in food processing and analysis, often used interchangeably with water content to describe the amount of water present in a substance (Park, 2008). In this study, the moisture content of dried BPF powder was found to be 4.83±0.76%. In comparison, wheat flour was reported to have a higher moisture content of 10.20±0.42% in a study by Verem *et al*. (2021). The lower moisture content of dried BPF powder suggests enhanced microbial stability and a longer shelf life when compared to wheat flour, as lower moisture levels reduce water activity, thereby inhibiting microbial growth and spoilage (Pasqualone *et al.*, 2021).

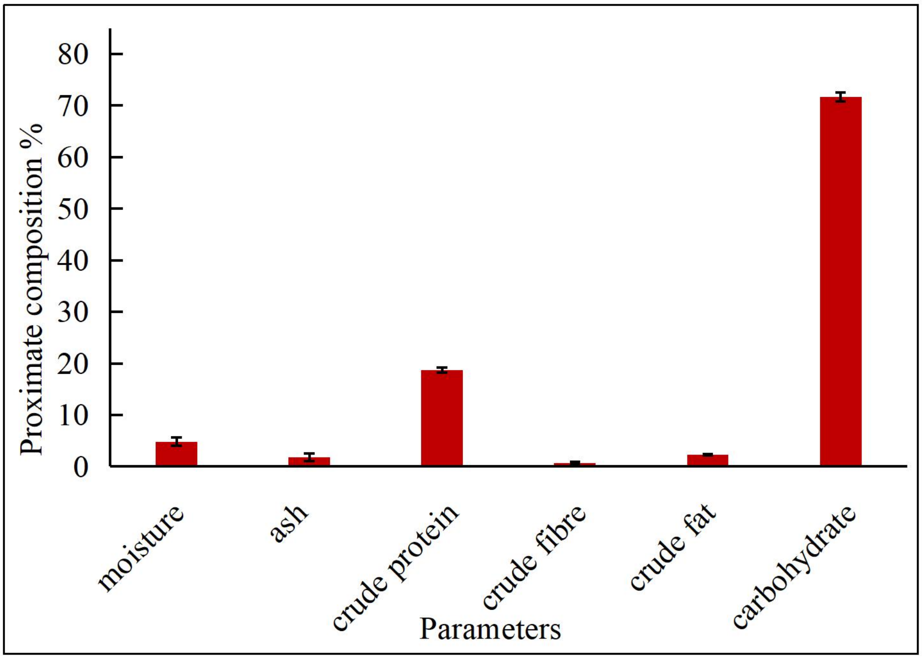

Figure 2: Proximate composition of BPF powder

The dried BPF powder exhibited higher levels of crude protein (20.02±0.49%), crude fat (2.24±0.12%), and crude fibre (0.70±0.20%) compared to wheat flour, which contained 10.23% crude protein, 1.33% crude fat, and 0.51% crude fibre according to a previous study (David *et al.*, 2015). These differences have important nutritional implications. The higher protein content in BPF powder supports muscle maintenance and overall dietary protein intake, making it a beneficial ingredient for protein-enriched baked goods. Additionally, its increased fibre content promotes digestive health, aids in bowel regularity, and may help reduce the risk of chronic diseases such as diabetes and heart disease. The higher fat content also enhances flavour and improves the mouthfeel of baked products (Madukokila *et al.*, 2021).

Wheat flour from the same study had a higher carbohydrate content (83.60%) than BPF powder, which suggests that incorporating BPF powder into baked goods could reduce overall carbohydrate intake, potentially making products more suitable for individuals managing blood sugar levels (Madukokila *et al.*, 2021). Additionally, the ash content of BPF powder (1.83±0.7%) was similar to that of wheat flour (1.00%), indicating comparable mineral content. Since ash content represents the total mineral content in food, this similarity suggests that BPF powder may provide essential minerals such as calcium, magnesium, and potassium, contributing to overall dietary mineral intake (Shamnad, 2020).

Physicochemical properties of dried BPF powder

The physicochemical composition of the dried BPF powder is detailed in Table 2. The pH of a food product plays a significant role in microbial growth, with acidic foods being less prone to spoilage than those with neutral pH (Robert and William, 2016). The dried BPF powder had a pH of 5.5, indicating its slightly acidic nature, whereas wheat flour has a pH of approximately 6.5, according to a previous study (Carter *et al.*, 2015). The slightly acidic pH of BPF powder can inhibit the growth of spoilage microorganisms and foodborne pathogens, thereby contributing to extended shelf life and improved microbial stability when used as a substitute for wheat flour (Preetha *et al.*, 2020)

Water activity is a critical factor in controlling the shelf life and safety of food products, influencing chemical reaction rates by acting as a solvent, or reactant, or altering the mobility of reactants through viscosity (Pushparaja *et al.*, 2023). The water activity of dried BPF powder (0.48) was lower than that of wheat flour (0.66) reported in another study by Carter *et al.* (2015), suggesting that microbial and enzymatic reactions may be less prevalent in dried BPF powder, reducing the risk of spoilage and extending storage stability. Foods with lower water activity are less susceptible to mold growth and bacterial contamination, making dried BPF powder a potentially more shelf-stable ingredient in food formulations (Sandulachi, 2012).

Table 2: Physicochemical properties of dried BPF powder

Parameters	Value
pH	5.50±0.18
Water activity	0.48±0.02
Reducing sugar (g/100g)	0.20±0.03
Total sugar (g/100g)	1.00±0.09
Potassium (mg/100g)	111.19±1.05
Phosphorus (mg/100g)	20.78±0.96

Value represents mean ± standard deviation of triplicate determination

The reducing sugar and total sugar contents of dried BPF powder were approximately similar to wheat flour, with values of 0.49 g/100 g and 1.10 g/100 g, respectively (El-Hady and El-Galeel, 2012). However, the potassium content of dried BPF powder was higher than that of wheat flour (12.50±0.03

mg/100 g), while the phosphorus content was slightly similar to wheat flour (25.00±0.02 mg/100 g; Atikur Rahman *et al.*, 2015). The higher potassium content in dried BPF powder supports muscle function, cardiovascular health, and fluid balance in the body (Rini *et al.*, 2025). These findings suggested that dried BPF powder could be a beneficial ingredient in food products due to its lower pH, water activity, and potentially higher mineral content when compared to wheat flour, which could contribute to improved shelf life and microbial stability.

Physical properties of control and selected composite biscuit

Colour parameters of biscuit samples

The colour parameters of the products are summarized in Table 3. The addition of dried BPF powder resulted in a noticeable change in the colour of the biscuit, with the control biscuit being notably lighter than the selected composite biscuit. This change is primarily due to browning reactions, such as the Maillard reaction and sugar caramelization, which generate brown pigments during baking. These reactions are influenced by several factors, including water activity, pH, temperature, sugar concentration, and the ratio of amino compounds, all of which contribute to the final colour development (Saeed *et al.*, 2020).

The L*, a*, b*, and c* values were highest for the control biscuit compared to the composite biscuit samples. A positive b* value indicates yellowness, while a negative value indicates blueness. The h* value, representing the colour intensity, was higher for the composite biscuit than the control biscuit, showing a more intense colour in the composite biscuit. Except for the a* value, all other values showed a significant difference between the control and composite samples.

Table 3: Colour parameters of control and selected composite biscuit samples

Samples	L*	a*	b*	c*	h*
Control biscuit	54.48 ± 0.17^{b}	6.29 ± 0.06	23.16 ± 0.12^{b}	24.00 ± 0.21^{b}	74.82 ± 0.34^{a}
Composite biscuit (T1)	20.29 ± 0.07^{a}	4.48 ± 0.06	-2.26 ± 0.02^{a}	5.34 ± 0.02^{a}	320.27 ± 0.86^{b}

Values represent mean±standard deviation of triplicate determination. Means values in each column with different superscript letters (a, b) are significantly different ($p<0.05$)

Other physical properties of biscuit samples

Other physical properties of the control and selected biscuits are given in Table 4. No significant differences were observed for bulk density, diameter, thickness, and spread ratio of the biscuits between the samples. However, a significant difference was observed in the weight and hardness of the biscuits due to the addition of dried and powdered flowers. The different functional properties of wheat flour and dried BPF powder likely contributed to these changes in physical parameters for both control and selected biscuits, ultimately impacting their baking quality. These physical parameters closely align with those reported in another study on biscuit-making (Latif and Pik Wan, 2023).

Moreover, the control biscuit had higher values for all physical parameters except spread ratio and hardness. The composite biscuit, formulated with dried BPF powder, had a higher spread ratio, which is desirable in biscuit-making as it contributes to improved texture and crispiness. A higher spread ratio is typically associated with better dough flow and expansion during baking, leading to a lighter, crispier biscuit (Jayalath *et al.*, 2024). Flour composition directly influences this change, as BPF powder affects the dough's water absorption and fat-binding properties, altering its spreadability (Meenakumari *et al.*, 2023).

Hardness is the main parameter in determining biscuit quality, influencing texture and consumer preference. The hardness of the control biscuit was 47.2 N with a displacement of 2.04 mm, whereas the selected composite biscuit had a hardness of 40.0 N with a displacement of 2.98 mm. The partial substitution of wheat flour with dried BPF powder decreases hardness, making the biscuit softer and improving its mouthfeel. The decrease in hardness may be attributed to the higher water absorption capacity of dried BPF powder, which influences gluten network formation and leads to a more tender texture (Blahovec, 2007).

Table 4: Other physical properties of control and selected composite biscuit samples

Physical properties	Control biscuit	Composite biscuit (T1)
Weight (g)	5.42 ± 0.04^{b}	5.22 ± 0.03^{a}
Bulk density (g/cm^3)	0.66 ± 0.08	0.65 ± 0.02
Diameter (cm)	3.86 ± 0.08	3.82 ± 0.02
Thickness (cm)	0.64 ± 0.02	0.63 ± 0.03
Spread ratio	6.03 ± 0.06	6.06 ± 0.17
Hardness (N)	47.2 ± 0.06^{a}	40.0 ± 0.06^{b}

Values represent mean±standard deviation of triplicate determination. Mean values in the same row with different superscript letters (a,b) are significantly different ($p<0.05$)

Proximate composition of control and selected composite biscuits

The proximate composition of the control and selected composite biscuits is illustrated in Figure 3. The results indicated that the moisture and carbohydrate contents of the control biscuit were higher than those of the composite biscuit. Specifically, the moisture content of the control biscuit was 5.98±0.14%, and the carbohydrate content was 66.53±1.22%, while for the composite biscuit, the values were 5.72±0.36% and 59.62±1.35%, respectively. On the other hand, the ash, crude protein, crude fibre, and crude fat contents were higher in the composite biscuit, with values ranging from 0.57 to 0.84%, 5.21 to 7.26%, 0.80 to 1.90%, and 15.07 to 17.67%, respectively.

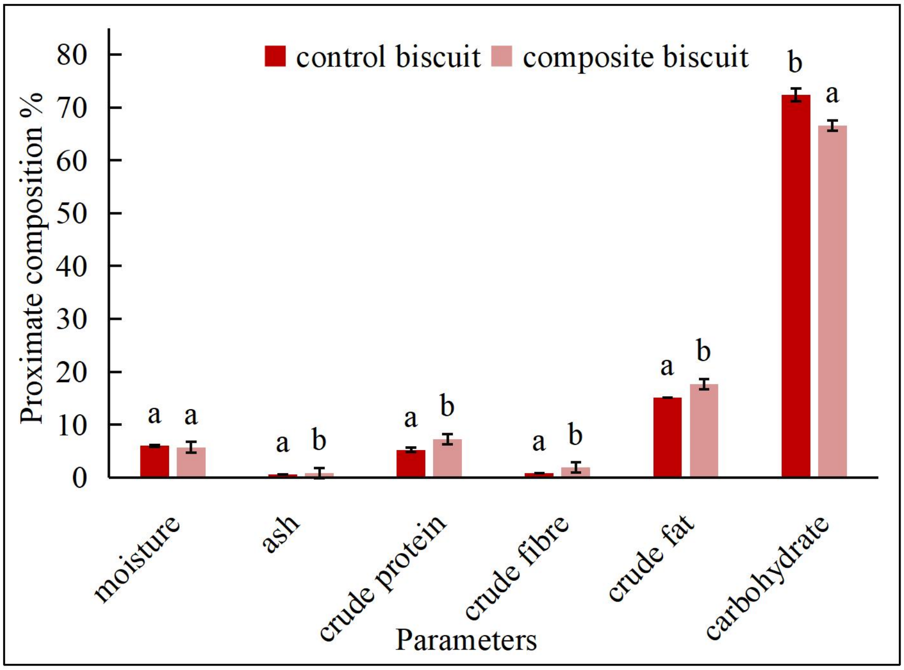

Figure 3: Proximate composition of control and selected composite biscuit samples
Bars with different letters (a-b) are significantly different (p<0.05)

Therefore, the composite biscuit can be considered more nutritious than the control biscuit. Additionally, microbial activity may be lower in the composite biscuit due to its comparatively lower moisture content (Pasqualone *et al.*, 2021). The proximate composition values of the control biscuit are slightly different from those of another wheat flour biscuit studied by Naseeha *et al.* (2023). All the tested parameters showed a significant difference between the control and composite samples except for moisture content (p<0.05).

Physicochemical properties of control and selected composite biscuits

The physicochemical properties of the biscuit samples are presented in Table 5. All parameters except phosphorus content reported significant differences (p<0.05) between the control and composite biscuits. The pH and water activity were slightly higher for the control biscuit than for the composite biscuit, which can be attributed to the partial addition of dried BPF powder, which affected and lowered the pH of the product. The pH and water activity of the wheat flour biscuit reported in a previous study were comparable to those of the control biscuit in the present study (Laganà *et al.*, 2022).

Furthermore, the reducing sugar, total sugar, potassium, and phosphorus contents were higher in the composite biscuit than in the control biscuit. This suggests that the partial addition of dried BPF powder instead of wheat flour increased the nutritional value of the biscuit. The nutrient value was comparatively higher in the dried BPF powder-incorporated biscuit.

Table 5: Physicochemical properties of control and selected composite biscuits samples

Parameters	Control biscuit	Composite biscuit (T1)
pH	7.88±0.02[b]	7.30±0.12[a]
Water activity	0.57±0.03[b]	0.51±0.01[a]
Reducing sugar (g/100 g)	0.07±0.02[a]	1.02±0.02[b]
Total sugar (g/100 g)	9.21±0.22[a]	10.45±0.58[b]
Potassium (mg/100 g)	52.78±1.07[a]	77.10±0.94[b]
Phosphorus (mg/100 g)	17.73±0.65	18.41±1.02

Values represent mean±standard deviation of triplicate determination. Mean values in the same row with different superscript letters (a,b) are significantly different (p<0.05)

Antioxidant properties of samples

The antioxidant properties of the samples are detailed in Table 6. A notable difference was observed between the control and composite biscuit samples for total phenolic content, flavonoid content, and antioxidant capacity, with the composite biscuits exhibiting higher values. Specifically, the control biscuits in this study had a total phenolic content of 11.32±0.91 mg GAE/g, flavonoid content of 10.34±1.56 mg CAE/g, and antioxidant capacity of 51.77±2.33%, all of which were slightly higher than the values reported for wheat flour biscuits in a previous study by Starowicz *et al.* (2019); 9.32±0.91 mg GAE/g, 10.04±1.56 mg CAE/g, and 50.77±2.33%, respectively. The changes in antioxidant properties are attributed to the baking temperature and duration. Temperature is a significant variable influencing antioxidant activity, with heating typically accelerating the start processes, thus lowering the activity of added or existing antioxidants (Réblová, 2012).

Table 6: Antioxidant properties of dried BPF powder, control, and selected composite biscuits samples

Samples	Total phenolic content (mg GAE/g)	Flavonoid content (mg CAE/g)	Antioxidant capacity (%)
Control biscuit	11.32±0.91[a]	10.34±1.56[a]	51.77±2.33[a]
Composite biscuit (T1)	29.89±2.22[b]	32.43±2.21[b]	69.00±2.87[b]
Dried BPF powder	52.75±1.21	47.23±2.12	78.56±2.87

Values represent mean±standard deviation of triplicate determination. Means in the same column with different superscript letters (a,b) are significantly different (p<0.05)

The total phenolic content of dried BPF powder in this study was 52.75±1.21 mg GAE/g, which was lower than 75 mg GAE/g reported under steeping conditions (25°C) in a previous study (Soedirga *et al.*, 2023). This difference is likely due to the higher drying temperature (48°C) applied during powder preparation, which could lead to the loss of some phenolic compounds (Réblová, 2012). The flavonoid content of dried BPF powder in this study was recorded as 47.23±2.12 mg CAE/g, which is higher than the 35.7 mg QE/g reported for the ethanolic extract of blue pea flower reported by Tuan Putra *et al*. (2021), likely due to methodological differences in determining flavonoid content.

The composite biscuits consistently showed a significantly higher antioxidant capacity when compared to the control, with the dried BPF powder scoring 78.56%. The higher antioxidant values in composite biscuits are due to the addition of dried BPF powder, which is rich in anthocyanins like "ternatin." These compounds are known for their antioxidant properties and may help reduce oxidative stress, potentially mitigating the risk of chronic diseases like cardiovascular disease and cancer (Chandimali *et al.*, 2025). Moreover, Gaytos and Lumagbas (2019) noted that the addition of BPF powder to biscuits is expected to reduce the formation of free radicals in consumers. Therefore, incorporating dried BPF powder into biscuits enhances their antioxidant properties, offering potential health benefits to consumers.

Shelf-life study of control and selected composite biscuits

The total plate count and yeast and mold counts of the control biscuit and selected composite biscuit are reported in Table 7. A crucial aspect of assessing the shelf life of food products is the microbial test, as most foods adhere to microbial count limits to ensure they are safe for consumption. Proper storage of the product in packaging materials that protect against contamination and the subsequent spread of spoiling microorganisms is essential after processing (Nilugin *et al.*, 2015).

Bacterial or fungal colonies were not observed in either the control or selected composite fresh biscuit samples. During storage for up to 60 d, the total plate count increased in both biscuit types but remained below acceptable safe limits. Yeast and mold growth were not observed throughout the two-month storage period. The biscuits were packed using moisture-proof polythene bags and stored at room temperature (25–33°C) in a controlled environment with appropriate humidity levels (61–73%), which helped inhibit microbial growth, explaining the initial absence of bacterial or fungal colonies. Additionally, the microbial count of the biscuits in this study was lower than the values reported in a previous study by Latif and Pik Wan (2023), and both the control and composite biscuits remained within the safe bacterial count limit of 1×10^4 CFU/g (Banusha and Vasantharuba, 2014).

Table 7: Total plate count and yeast and mold count of control and selected composite biscuits samples

Samples	Storage period [after manufacture] (d)	Total plate count (CFU/g)	Yeast and mold (CFU/g)
Control	0	_	_
biscuit	30	3×10^2	_
	60	7×10^2	_
Composite	0	_	_
biscuit (T1)	30	2×10^2	_
	60	4×10^2	_

CONCLUSION

This study concludes that incorporating 9% dried BPF powder into biscuits resulted in a highly preferred product by sensory panellists and exhibited superior nutritional content and health-promoting properties compared to the control biscuit. The composite biscuits showed enhanced antioxidant properties, higher protein, fibre, and mineral content, and improved physicochemical properties such as lower pH, moisture content, and water activity. These characteristics contribute not only to a healthier product but also to extended shelf life by reducing microbial growth. Microbial counts remained within acceptable limits for a two-month storage period, aligning with relevant quality standards. Therefore, dried BPF powder-incorporated biscuits offer a nutritious, appealing, and microbiologically safe alternative to traditional biscuits. Future studies could explore the application of dried BPF powder in other food products to leverage its health and nutritional benefits. Additionally, further studies are needs to be conducted for selected biscuits by adding different levels of ingredients to enhance product quality and consumer acceptance.

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