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PHYSICOCHEMICAL AND ORGANOLEPTIC PROPERTIES OF FLAKES MADE FROM HEAT MOISTURE TREATMENT (HMT)-MODIFIED PURPLE SWEET POTATO AND MUNG BEAN

Ghina Qanitah Valerie[1], Shanti Fitriani[1*], Emma Riftyan[1], Nizaha Juhaida Mohamad[2]

[1]Department of Agricultural Technology, Faculty of Agriculture, Universitas Riau, Pekanbaru, Indonesia
[2]Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, Terengganu, Malaysia
[*]Correspondence: shanti.fitriani@lecturer.unri.ac.id

ABSTRACT

This study aimed to determine the optimal ratio of heat moisture treatment (HMT)–modified purple sweet potato flour and mung bean flour for flakes production. Flakes are instant foods typically made from cereal-based ingredients through baking. Purple sweet potato flour is a promising local raw material but has limited physical properties, which can be improved through HMT modification. Mung bean flour was added to enhance protein content. A completely randomized design with four treatments and four replications was applied. The treatments were ratios of HMT-modified purple sweet potato flour to mung bean flour: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50). Data were analyzed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. Results showed that the flour ratio significantly affected moisture, ash, protein, fat, and carbohydrate contents, as well as crispness retention and sensory attributes (color, aroma, taste, and texture). The best formulation was UK4 (50:50), with moisture content of 3.18%, ash 2.11%, protein 13.81%, fat 2.82%, carbohydrate 78.08%, and crispness retention of 8.33 minutes. Sensory evaluation indicated a brownish-purple color, slight mung bean aroma, characteristic mung bean taste, and crispy texture, with overall acceptance rated as "liked."

Keywords: flakes, heat moisture treatment, mung bean, purple sweet potato

INTRODUCTION

Flakes are an instant breakfast cereal made from rice, wheat, corn, and tubers. They are typically consumed with milk, water, or yogurt (Putri et al., 2020). They have a crunchy texture, are flakes or flat round pieces, and range in color from yellow to brown, depending on the raw materials used. Commercial flakes typically consist of corn kernels and wheat flour. Corn is widely used in extruded food products, while wheat is difficult to grow in tropical climates like Indonesia, requiring imports from other countries. The use of local food sources is essential to replace corn and wheat.

Nutritious flakes require ingredients containing carbohydrates and protein. Purple sweet potato is a local food source, in addition to corn, that can be used to make flakes. Purple sweet potato can be processed into flour, simplifying the processing of flakes and extending their shelf life. 100 g of purple sweet potato flour contains 84.4 g of carbohydrates, 12.9 g of fiber, 9.4 g of water, 2.8 g of protein, and 0.6 g of fat (Mahmud et al., 2018).

The physical properties of natural purple sweet potato flour have a weakness, namely its resistance to high temperatures. Natural starches generally have several drawbacks, such as inconsistent gel formation and resistance to acidic conditions, which makes their use in food processing less than optimal (Miksusanti et al., 2019). Modifications are necessary to improve the natural properties of flour, one of which is physical modification.

One physical modification method that can be used is heat moisture treatment (HMT). Heat moisture treatment is a modification method carried out using heat and humidity. Flour is heated to a gelatinization temperature (80–120°C) with a limited moisture content of less than 35%. The controlled temperature and moisture content conditions in the HMT process can alter the structure of starch granules, resulting in changes in the properties and physical characteristics of the starch. This treatment can affect the crystalline and amorphous structure of starch and improve its thermal stability and functional properties (Lv et al., 2022).

The HMT method has been used in several studies, including one by Rahmah (2022), which found that the use of HMT-modified sword bean starch resulted in brighter biscuit colors, a decrease in moisture content from 5.02% (pre-HMT) to 4.53% (after HMT modification), and an increase in carbohydrate content. Lower moisture content in flour can result in crispier biscuits; the lower the moisture content, the crispier the product. The use of HMT-modified purple sweet potato flour is expected to produce crispy flakes.

Flakes require raw materials with a sufficiently high protein content to enhance their nutritional value. Mung bean flour is a potential source of vegetable protein for use in flake production due to its relatively high protein content, around 22–24%. The addition of mung bean flour to flake products can increase protein content and affect the product's physical and sensory characteristics, such as texture and consumer acceptance (Insania et al., 2024). In addition, mung beans contain major secondary metabolites including phenolic compounds, flavonoids, saponins, phytosterols, and alkaloids in small amounts that are beneficial for health (Hou et al., 2019). Khairunnisa et al. (2018) have used mung bean flour in the manufacture of taro flour-based flakes. The best treatment of the ratio of taro flour and mung bean flour in the study was a 50:50 ratio which produced flakes with a moisture content of 2.44%, a protein content of 9.33%, slightly yellow in color, mung bean flavor, and a crunchy texture. This study aims to determine the effect of the ratio of HMT-modified purple sweet potato flour and mung bean flour on the physicochemical properties of flakes, determine the organoleptic characteristics of color, aroma, taste, and crispiness of flakes, and determine the ratio of selected flakes.

METHODS

Material and Tools

The materials used in this study were fresh purple sweet potatoes and green beans. Other additional ingredients were refined sugar (Merbabu), refined salt (Dolpin), margarine (Blue Band Cake & Cookies), and water. The materials for analysis were distilled water, selenium reagent, n-hexane, PP indicator, methyl red indicator, methyl blue indicator, 0.1N HCl, concentrated H_2SO_4, 40% NaOH, and 2% H_3BO_3, and 95% alcohol. The tools used were aluminum foil, plastic gloves, plastic wrap, basins, baking pans, ampia, cutting boards, spray bottles, digital scales spoons, blenders, 80 mesh sieves, 1 cm diameter molding tools (round plunger cutters), and ovens. The tools used for the analysis are analytical scales, stopwatches, porcelain cups, analysis ovens, furnaces, tongs, filter paper, desiccators, Kjeldahl flasks, distillation flasks, measuring cups, volumetric flasks, funnels, Erlenmeyer flasks, Soxhlet flasks, dropper pipettes, spatulas, burettes, water baths, rubber gloves, and sensory testing tools such as organoleptic test containers, organoleptic booths, label paper, stationery, and documentation tools (cameras).

Methods

The study was conducted experimentally, using a completely randomized design (CRD) with four treatments and four replications, resulting in 16 experimental units. The treatment used in this study was the ratio of HMT purple sweet potato flour to mung bean flour, referring to a modified version of Rani et al. (2021). The treatment ratios for HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50).

Production Purple Sweet Potato Flour HMT7

The process of making HMT-modified purple sweet potato flour refers to Agustiani & Maharani (2020). The baking pan is lined with aluminum foil, then purple sweet potato flour is added and water is evenly added by spraying until the moisture content reaches 28%. The flour is wrapped in aluminum foil and plastic wrap and then stored for 24 hours in a refrigerator at a temperature of 4–5°C so that the moisture content is even. Next, the plastic wrap is opened and placed in an oven wrapped in aluminum foil and heated at a temperature of 80°C for 5 hours and then dried in an oven at a temperature of 50°C for 4 hours. The dried flour is then ground and sieved using an 80-mesh sieve to obtain HMT-modified purple sweet potato flour.

Production of Flakes with HMT-modified Purple Sweet Potato Flour and Mung Bean Flour

The process of making purple sweet potato flour refers to Purnamasari & Putri (2015) which has been modified. HMT modified purple sweet potato flour and mung bean flour are weighed according to the treatment ratio, then added supporting ingredients namely fine sugar, salt, and margarine then dissolved with water. The mixture of dough is stirred until smooth by hand. Next, the dough is flattened using an *ampi* with knob number 3, the dough is rectangular and then molded into circles with a diameter of 1 cm. Next, the molded dough is arranged in a baking pan to continue the baking process using an oven at a temperature of 120°C for 20 minutes to produce flakes.

Physicochemical Analysis

Analysis in this study included tests of moisture content, ash content, protein content, fat content, carbohydrate content (AOAC, 2016), crispiness resistance (Papunas et al., 2013), descriptive and hedonic organoleptic assessments, and overall assessment of flakes (Lawless & Heymann, 2019).

Data Analysis

The data obtained were analyzed statistically using the analysis of variance (ANOVA) test. If the data from the analysis results F count ≥ F table, then it will be continued with the Duncan multiple range test (DMRT) at the 5% level.

RESULTS AND DISCUSSION

Moisture Content

Moisture content testing indicates the amount of water contained in a food ingredient. Table 1 shows that the resulting flakes' moisture content ranged from 3.18 to 4.26%. The highest flake moisture content was found in treatment UK1, which was not significantly different from treatments UK2 and UK3 but significantly different from treatments UK4. Flake moisture content increased with increasing use of HMT purple sweet potato flour and decreasing use of mung bean flour. This is due to differences in the ratio and moisture content of the ingredients used. HMT purple sweet potato flour in this study had a higher moisture content than mung bean flour, at 10.13%, while mung bean flour had a higher moisture content than mung bean flour, at 9.73%. Furthermore, the starch content in the raw materials HMT purple sweet potato flour and mung bean flour also influenced moisture content because it is closely related to water absorption.

Starch has the ability to absorb water because its molecular structure is rich in hydrophilic hydroxyl (–OH) groups. This group allows hydrogen bonds to form with water molecules, giving starch a high water-binding and absorption capacity (Koshenaj & Ferrari, 2024). Starch is the main component of sweet potatoes and is composed of two main fractions: amylose and amylopectin. The amylose content in sweet potato starch generally ranges from 20–25%, with the remainder being amylopectin, which is more predominant (Kim et al., 2020). Meanwhile, according to Ramadhan et al. (2024), the starch content in mung bean flour is 30.9%, with amylose content at 33% and amylopectin at 67%. Amylose is composed of simple, straight chains that readily absorb and release water, while amylopectin has branched chains that inhibit water absorption. However, once absorbed, water becomes trapped and difficult to escape (Edelweiss, 2024).

Yuliansar et al. (2020), confirmed that high amylopectin levels in a material result in higher water absorption rates. According to Sun et al. (2023), HMT treatment causes starch chain reorganization and changes in the amylopectin structure, resulting in surface modifications to starch granules and increased swelling capacity. These changes allow greater water penetration into the starch granules, thereby increasing water absorption and swelling properties. In this study, the higher ratio of HMT purple sweet potato flour used resulted in an increase in the moisture content of the resulting flakes due to the amylopectin contained in HMT purple sweet potato flour compared to mung bean flour. The moisture content of the flakes obtained in this study met the SNI 4270-2021 cereal moisture content quality standard, which is a maximum of 8%.

Ash Content

Ash content is the inorganic residue remaining after the water and organic components are removed through a heating or ashing process, so it can be used as an indicator of the total mineral content in food ingredients (Cortés-Herrera et al., 2023). Table 1 shows that the ash content of the flakes obtained ranges from 1.95–2.11%.

The highest ash content of the flakes was found in the UK4 treatment, which was not significantly different from the UK3 treatment, but significantly different from the UK1 and UK2 treatments. The ash content of the flakes decreased with increasing ratios of HMT purple sweet potato flour to mung bean flour. This is because HMT purple sweet potato flour has a lower ash content than mung bean flour. Utami et al. (2018) stated that every 100 g of purple sweet potato flour contains 1.10% ash, while mung bean flour has an ash content of around 3–4% (Yen et al., 2023).

The HMT purple sweet potato flour and mung bean flour used contain several minerals that can affect the total ash content, such as calcium, phosphorus, and iron. According to Sudhakaran et al. (2024), 100 g of raw green beans contains 16.6–34.1 mg calcium, 271.7–447.3 mg phosphorus and 4.0–34.9 mg iron.

Table 1. Chemical analysis of flakes with HMT-modified purple sweet potato flour and mung bean flour

Treatment	Moisture content (%) ± SD	Ash Content (%) ± SD	Protein Content (%) ± SD	Lipid Content (%) ± SD	Carbohydrate Content (%) ± SD
UK1	4.62^{a}±0.53	1.95^{a}±0.05	8.74^{a}±1.28	2.60^{a}±0.04	51.48^{c}±6.15
UK2	3.91^{ab}±0.41	2.02^{a}±0.06	10.78^{b}±0.44	2.67^{ab}±0.11	38.89^{b}±10.23
UK3	3.52^{ab}±0.54	2.10^{b}±0.05	11.86^{b}±0.78	2.73^{bc}±0.07	30.19^{ab}±5.01
UK4	3.18^{b}±0.47	2.11^{b}±0.03	13.81^{c} ±0.99	2.82^{c}±0.02	22.71^{a}±1.20

Numbers followed by different lowercase letters indicate significant differences ($p<0.05$), n=4.
The treatment ratios of HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50).

Protein Content

Protein content testing was conducted to determine the amount of protein contained in the flakes. Table 1 shows that the protein content of the resulting flakes ranged from 8.74 to 13.81%. The highest protein moisture content was found in the UK4 treatment, which was significantly different from all other treatments. The protein content of the flakes increased with increasing use of mung bean flour and decreasing with decreasing use of HMT purple sweet potato flour. This is because the mung bean flour used in this study has a higher protein content than HMT purple sweet potato flour, at 26.53%, while HMT purple sweet potato flour contains 3.29%.

Utami et al. (2018) stated that 100 g of purple sweet potato flour contains 5.44% protein, while Mahmud et al. (2018) stated that the protein content of mung bean flour is 22.92%, almost four times higher than purple sweet potato flour. The protein found in mung beans is composed of various essential amino acids, such as isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine (Hariadi, 2017).

The higher the ratio of purple sweet potato flour used, the lower the protein content of the resulting flakes. This is consistent with the opinion of Rahmalia et al. (2024), who stated that the higher the use of purple sweet potato flour in the flake processing process, the lower the protein content. The protein content of the flakes in this study met the minimum protein quality standard for cereals, SNI 4270-2021, which is 4%.

Lipid Content

Fat content is one of the nutrients that plays a role in determining the quality of a product. Table 1 shows that the fat content of the resulting flakes ranges from 2.60–2.82%. The highest flake fat content was found in the UK4 treatment, which was not significantly different from UK3, but significantly different from UK1 and UK2. The flake fat content increased with the lower use of HMT purple sweet potato flour and the increased use of mung bean flour. This is because HMT purple sweet potato flour has a lower fat content compared to mung bean flour. According to Mahmud et al. (2018), the fat content of purple sweet potato flour is 0.6 g, while the mung bean flour in the study by Skylas et al. (2018) was 1.90 g. Mung bean flour contains fat that is mostly composed of unsaturated fatty acids such as 20.8% oleic, 16.3% linoleic, and 37.5% linolenic (Roifah et al., 2019). Therefore, the higher the ratio of mung bean flour used, the higher the fat content of the flakes.

The fat content obtained in this study was lower than the results of a study conducted by Khairunnisa et al. (2018) on the production of flakes using taro flour and mung bean flour. The fat content obtained in that study ranged from 0.5–1.02%, while in this study it ranged from 2.60–2.82%. This is due to the differences in the raw material content used in the study. Taro flour had a fat content of 0.66% and mung bean flour 1.67%. The higher the use of HMT purple sweet potato flour in this study, the lower the fat content of the resulting flakes. The addition of margarine also increased the total fat content of the flakes. Margarine has a fat content of 81%. The amount of fat in a food product can affect the taste, texture, aroma, and color of the resulting product (Mahmud et al., 2018).

Carbohydrates Content

Carbohydrates in food products function as fillers, stabilizers, thickeners, paste-forming agents, sweeteners, textures, and energy sources (Estiasih et al., 2018). Table 1 shows that the carbohydrate content of the resulting flakes ranged from 78.08 to 82.45%. The highest carbohydrate content of the flakes was found in the UK1 treatment, which was significantly different from all other treatments. The carbohydrate content of the flakes decreased with decreasing mung bean flour use and increasing HMT purple sweet potato flour use. This is because the carbohydrate content of HMT purple sweet potato flour in this study was higher than that of mung bean flour, at 85.41 g, while mung bean flour had a lower carbohydrate content, at 58.57 g per 100 g of material. This is consistent with Khairunnisa (2018), who stated that the less mung bean flour used, the higher the carbohydrate content of the resulting flakes.

The increase in carbohydrate content in this study aligns with the research of Yolanda et al. (2018) in the manufacture of wet noodles from purple sweet potato flour and wheat produced carbohydrate content ranging from 72.94–81.99%, indicating that the more purple sweet potato flour used in making dry noodles, the higher the carbohydrate content. The higher the ratio of HMT purple sweet potato flour used in this study, the higher the carbohydrate content obtained. The carbohydrate content produced in this study has met the SNI 4270-2021 cereal quality standard, which is a minimum of 60%.

The Durability of The Crispy Flakes in Milk Immersion

Flake crispness is a physical test that affects texture and is used to determine the flakes' ability to maintain a crispy texture after being poured with milk for a certain period of time. Table 2 shows that the flake crispness ranged from 8.33 to 10.51 minutes. The highest crispness was found in treatment UK1, which was not significantly different from treatment UK2, but significantly different from treatment UK3 and UK4. The crispness duration in this study increased with the higher use of HMT purple sweet potato flour and decreased with the use of mung bean flour. This is related to the high carbohydrate content of the raw materials used.

According to Papunas et al. (2013), carbohydrate content, consisting of starch, namely amylose and amylopectin, plays a role in determining the crispness of flakes. The high carbohydrate content in the flake raw materials significantly contributes to the crispness of flakes when mixed with milk. Carbohydrates, particularly starch, are water-resistant, extending the time flakes remain crispy in wet conditions such as milk. Starch with a relatively high amylose content tends to have good water absorption but is also resistant to softening, so the flakes don't crumble quickly. The size and structure of the starch granules after HMT treatment also affect this crispness, with larger, more homogeneous starch granules providing better crispness for the flakes.

Flakes retain their crispiness longer in milk immersion with increasing use of HMT purple sweet potato flour and decreasing use of mung bean flour. In the flour modification process with HMT, heating at a limited moisture content can cause changes in the structure of starch granules, including disruption of hydrogen bonds and reorganization of amylose and amylopectin chains. Prolonged heating can increase the level of damage to the starch crystalline structure and cause changes in the interactions of starch molecules within the granules (Milkias et al., 2025). These structural changes can limit the ability of starch granules to expand and absorb water due to restructuring and increased interactions between starch chains. Therefore, the higher the HMT purple sweet potato flour content, the longer the flakes retain their crispiness in milk immersion.

Moisture content is also a factor influencing the crispiness of flakes. Flakes with a higher moisture content tend to have a denser and stronger structure, with low porosity, or layers with more closed pores, which slows milk penetration and prevents immediate liquid absorption, preventing the flakes from becoming soft.

Flakes with a lower moisture content tend to have a more fragile and porous structure, making them more likely to absorb liquid upon contact with milk, causing the texture to soften quickly. Conversely, products with a higher moisture content can form a denser matrix structure, resulting in a slower rate of liquid penetration. The pore structure and moisture content of cereal products are known to influence the water absorption mechanism and texture changes during hydration (Takahashi & Fujii, 2025). As an instant breakfast product, flakes are expected to maintain their crispiness for more than 3 minutes. This is because instant products typically require less than 3 minutes to prepare.

Table 2. The durability of flakes with HMT-modified purple sweet potato flour and mung bean flour

Treatment	The Durability of The Crispy Flakes (%) ± SD
UK1	$10.51^{c}\pm0.39$
UK2	$10.24^{c}\pm0.03$
UK3	$9.29^{b}\pm0.14$
UK4	$8.33^{a}\pm0.06$

Numbers followed by different lowercase letters indicate significant differences ($p<0.05$), n=4.
The treatment ratios of HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50).

Sensory Evaluation

Color

Color is a crucial parameter influencing consumer acceptance of food products. Based on Table 3, the descriptive color assessment scores for flakes ranged from 1.73 to 3.97, ranging from dark brown to purple-brown. This color change was influenced by the ratio of HMT-modified purple sweet potato flour to mung bean flour. The higher the proportion of HMT-modified purple sweet potato flour used, the more likely the flakes were to exhibit a purple-brown hue, while the higher the proportion of mung bean flour used, the more dominant the brown color. The purplish color of the flakes stems from the anthocyanin pigment found in purple sweet potatoes. Anthocyanins are flavonoid compounds distributed from the skin to the flesh of the tuber and act as natural red to purple pigments (Santoso & Estiasih, 2014). These pigments continue to contribute color to the product even when heated during processing.

Table 3. Average color assessment of flakes with HMT-modified purple sweet potato flour and mung bean flour

Treatment	Color ± SD	
	Descriptive	**Hedonic**
UK1	$1.73^{a}\pm0.45$	$2.29^{a}\pm0.58$
UK2	$1.90^{a}\pm0.31$	$3.31^{b}\pm0.61$
UK3	$3.13^{b}\pm0.35$	$3.99^{c}\pm0.41$
UK4	$3.97^{c}\pm0.18$	$4.10^{c}\pm0.50$

Numbers followed by different letters in the same column indicate a statistically significant difference ($P<0.05$), n=4. The treatment ratios of HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50).

Descriptive scores: 1. Very dark brown, 2. Dark brown, 3. Brown, 4. Purple brown. **Hedonic scores:** 1. Dislike very much, 2. Dislike, 3. Somewhat like, 4. Like, 5. Like very much.

Furthermore, the formation of the brown color is also influenced by the non-enzymatic Maillard reaction, a reaction between the carbonyl group of reducing sugars and the free amino group of proteins or amino acids during the heating process. This reaction proceeds through several stages and produces intermediate compounds such as 3-deoxyglucosone, hydroxymethylfurfural (HMF), and furfural, which then polymerize to form complex brown pigments known as melanoidins. In flakes, the Maillard reaction is triggered by the presence of proteins from mung bean flour and reducing sugars derived from raw materials and additives.

Reducing sugars in the system originate from multiple sources, such as the intrinsic simple sugars in mung bean flour (e.g., glucose and maltose), the hydrolysis of sweet potato starch during thermal processing, and the inversion of added sucrose. These reducing sugars participate in the Maillard reaction, forming melanoidins. Consequently, the final brown to purple-brown color of the flakes results from the synergy between Maillard-induced browning and the presence of anthocyanin pigments from the purple sweet potato.

Based on Table 3, it can be seen that the average hedonic color assessment score ranges from 2.29–4.10 (dislike, to like). The lower the ratio of HMT modified purple sweet potato flour used, namely in treatments UK3 and UK4, the higher the panelists' preference for the color of the flakes. This is because the intensity of the brown color in the resulting flakes decreases and the purple color in the flakes begins to appear along with the higher ratio of mung bean flour used. Color is a sensory attribute that greatly influences consumer acceptance of food products. The brown color of the flakes that changes to a more purple or dark color can reduce the panelists' preference for the flakes. The distinctive brown color of flakes is generally assumed to indicate a product with poor quality (burnt/overcooked), so it is considered less attractive to the panelists.

Aroma

Aroma is one of the parameters that determines consumer acceptance of food products. Based on Table 4, the descriptive aroma color assessment scores for flakes ranged from 1.93 to 2.97, ranging from slightly purple sweet potato to slightly mung bean. As the ratio of HMT purple sweet potato flour to mung bean flour decreased, the resulting flakes became more slightly mung bean-flavored.

Commercially available flakes generally lack a distinctive aroma, while the flakes in this study had a distinctive mung bean aroma. This distinctive mung bean aroma comes from ethyl laurate, a carboxylic acid, a type of fatty acid found in mung beans. This distinctive aroma is known as a nutty aroma due to the saturated fatty acid content in mung beans (Astarini et al., 2014). Khairunnisa et al. (2018) stated that adding 50% mung bean flour will produce flakes with a distinctive mung bean aroma.

Table 4. Average aroma assessment of flakes with HMT-modified purple sweet potato flour and mung bean flour

Treatment	Aroma ± SD	
	Descriptive	**Hedonic**
UK1	$1,93^{a}\pm0,25$	$3,18^{a}\pm0,50$
UK2	$2,00^{a}\pm0,00$	$3,53^{b}\pm0,55$
UK3	$2,77^{b}\pm0,43$	$4,09^{c}\pm0,28$
UK4	$2,97^{c}\pm0,18$	$4,18^{c}\pm0,55$

Numbers followed by different letters in the same column indicate a statistically significant difference (P<0.05), n=4. The treatment ratios of HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50).

Descriptive scores: 1. Purple sweet potato flavor, 2. Somewhat purple sweet potato flavor, 3. Somewhat green bean flavor, 4. Green bean flavor. **Hedonic scores:** 1. Very dislike, 2. Dislike, 3. Somewhat like, 4. Like, 5. Very like.

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Based on Table 4, the hedonic aroma assessment score for flakes ranged from 3.18 to 4.18 (moderately liked to liked). The higher the ratio of mung bean flour used, the higher the panelists' preference for the aroma of flakes. Panelists preferred the aroma of mung beans, so the strong aroma of mung beans could mask the aroma of HMT purple sweet potato flour. This was caused by the unpleasant aroma produced by the HMT process in purple sweet potatoes, making it less preferred by the panelists. Purple sweet potatoes contain anthocyanins and phenolic compounds which during processing into flour can degrade and react to form volatile compounds that cause an earthy aroma. Salma et al. (2018) stated that the aroma that appears in purple sweet potato flour is due to the degradation of anthocyanin pigments during drying.

The earthy aroma of purple sweet potatoes is produced by volatile compounds such as 2,4-nonadienal, 2,4-decadienal, and 3-octen-2-one (Feng & Wu, 2016). These compounds are formed naturally through lipid degradation reactions and thermal heating during processing. The aroma produced by purple sweet potatoes is often interpreted as a natural and distinctive taste, the addition of mung bean flour in higher amounts also contributes to the distinctive aroma of beans. The characteristic aroma of mung beans is quite strong, but still well received by the panelists, indicating that the aroma produced by mung beans is not disturbing and is still acceptable to them. The combination of the aroma of purple sweet potatoes and mung beans produces a final product flakes that the panelists like. The more mung bean flour used, the more the panelists like the aroma of the resulting flakes.

Flavor

Flavor, the tongue's response to a stimulus provided by a food ingredient, is an important factor that can influence consumer evaluation of a food product. Table 5 shows that the descriptive taste assessment scores for flakes range from 1.00 to 3.70, ranging from purple sweet potato to mung bean flavors. The higher the ratio of HMT purple sweet potato flour to mung bean flour used, the more the resulting flakes taste more like purple sweet potato.

HMT purple sweet potato flour has a naturally sweet and slightly earthy flavor. This sweetness results from the high carbohydrate content in purple sweet potato flour (Salma et al., 2018). The phenolic and anthocyanin compounds found in purple sweet potatoes impart a slightly astringent, bitter, and earthy flavor, especially if not properly processed. Meanwhile, mung bean flour has a distinctive savory flavor known as beany, peas-like, and nutty. The savory flavor of mung bean flour comes from its fat content, particularly saturated fatty acids.

Table 5 shows the average hedonic taste rating of the flakes ranging from 3.36–4.03 (somewhat liking to liking). The panelists increasingly preferred the taste of the flakes as the use of mung bean flour increased. This is because mung beans contain amino acids such as lysine, leucine, and arginine, which play a role in enhancing the taste and aroma of the flakes. Therefore, the higher the ratio of mung bean flour added, the higher the panelists' assessment score for liking the taste of the flakes. This is in accordance with research by Safira et al. (2022) which stated that the level of panelists' preference for the taste of cookies substituted with mung bean flour and soybean flour increased with the addition of the proportion of mung bean flour. Prasetyo et al. (2018) added that the use of 40% mung bean flour produced a savory, sweet, and distinctive mung bean flavor in the flakes and was favored by panelists.

Table 5. Average flavor assessment of flakes with HMT-modified purple sweet potato flour and mung bean flour

Treatment	**Flavor ± SD**	
	Descriptive	**Hedonic**
UK1	1.00^{a}±0.00	3.36^{a}±0.90
UK2	1.10^{a}±0.31	3.90^{b}±0.34
UK3	2.43^{b}±0.57	4.08^{b}±0.27
UK4	3.70^{c}±0.47	4.03^{b}±0.39

Numbers followed by different letters in the same column indicate a statistically significant difference (P<0.05), n=4. The treatment ratios of HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50).

Descriptive scores: 1. Tastes like purple sweet potato, 2. Somewhat tastes like purple sweet potato, 3. Somewhat tastes like green beans, 4. Tastes like green beans. **Hedonic scores:** 1. Dislike very much, 2. Dislike, 3. Somewhat like, 4. Like, 5. Like very much.

Crispness

Crispness is one of the determining factors in flake quality, related to consumer acceptance. Based on Table 6, the descriptive crispness assessment score for flakes ranges from 1.23 to 2.23, representing crispy to slightly crispy. The higher the ratio of HMT purple sweet potato flour to mung bean flour used, the less crispy the resulting flakes. This is due to the high moisture content in the UK1 treatment; the more HMT purple sweet potato flour used, the lower the crispness of the flakes.

Table 6. Average texture assessment of flakes with HMT-modified purple sweet potato flour and mung bean flour

Treatment	Texture ± SD	
	Descriptive	Hedonic
UK1	3.83^{d}±0.37	4.58^{d}±0.48
UK2	3.40^{c}±0.49	4.12^{c}±0.48
UK3	2.80^{b}±0.40	3.61^{b}±0.49
UK4	1.96^{a}±0.41	3.08^{a}±0.45

Numbers followed by different letters in the same column indicate a statistically significant difference (P<0.05), n=4. The treatment ratios of HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50).

Descriptive scores: 1. Crispy, 2. Somewhat crunchy, 3. Not crunchy, 4. Not very crunchy. **Hedonic scores:** 1. Dislike very much, 2. Dislike, 3. Like somewhat, 4. Like, 5. Like very much.

Flakes crispness is also influenced by protein content. Flake crispness is a textural characteristic that is significantly influenced by the ingredient composition, including the protein content. Protein plays a crucial role in shaping the product's structure and texture during the baking or heating process. High protein content in the raw material helps form a firm yet brittle network when bitten, resulting in a crispy sensation in the resulting flakes.

Mung beans, one of the main ingredients used, contain high levels of protein. Heating mung bean flour causes the protein to denature and interact with other components such as starch and water, forming a rigid yet easily broken structure with small pores. This structure then gives the flakes their crunchy texture. Raw materials with a high protein content will produce flakes that tend to be lighter, drier, and crunchier. High protein content can coat the starch particles, thus inhibiting water absorption. This inhibited water absorption by the starch results in a crunchy product (Astuti et al., 2019).

Table 6 shows the average hedonic assessment of flake crispness. Flake crispness scores ranged from 3.78 to 4.60 (like to very much). Panelists tended to prefer the crunchy texture of flakes when tasted. Khairunnisa (2018) stated that flakes with a ratio of taro flour and mung bean flour (50:50) had a crunchy texture that panelists preferred with a score of 3.73 (like).

Overall assessment

The overall assessment is the accumulation of preferences from the assessment parameters including taste, color, aroma, texture and crispness of the flakes. Based on Table 7, the overall hedonic assessment score of the flakes ranges from 3.79 to 4.55 (like to very like). Flakes with the UK4 treatment obtained the highest overall assessment score, namely 4.55, which indicates that the product is most preferred by the panelists. The most preferred overall assessment score for the flakes is found in the UK4 treatment which is significantly different from all treatments. The high preference score for the flakes in the UK4 treatment is thought to be closely related to the composition of the raw materials used, especially the higher ratio of mung bean flour compared to HMT purple sweet potato flour. Increasing the ratio of mung bean flour in the flakes formulation has a positive effect on the overall sensory quality of the product, it can also be concluded that the higher the proportion of mung bean flour in the flakes, the greater the likelihood that the resulting flakes will be preferred by the panelists. Flakes in the UK4 treatment have a distinctive color characteristic, namely purple-brown with a fairly pronounced aroma and taste of mung beans.

The crunchy texture of the flakes is an important aspect and provides a unique attraction for panelists during the organoleptic test. The resulting crispness of the flakes also increases the level of panelist acceptance of the flakes. The overall assessment of the flakes resulted in a flakes product that was favored by the panelists. Differences in the preference scores given indicate variations in individual preferences, considering that assessments of taste, aroma, and texture of a food product are subjective and can differ between people, depending on the background experience, consumption habits, and tastes of each panelist.

Table 7. Average overall assessment of flakes with HMT-modified purple sweet potato flour and mung bean flour

Treatment	Overall ± SD
	Hedonic
UK1	3.79^{a}±0.41
UK2	4.04^{b}±0.25
UK3	4.33^{c}±0.47
UK4	4.55^{d}±0.50

Numbers followed by different letters in the same column indicate a statistically significant difference (P<0.05), n=4. The treatment ratios of HMT purple sweet potato flour and mung bean flour were: UK1 (80:20), UK2 (70:30), UK3 (60:40), and UK4 (50:50). **Hedonic scores:** 1. Dislike very much, 2. Dislike, 3. Like somewhat, 4. Like, 5. Like very much.

CONCLUSION

This study demonstrates that the ratio of HMT-modified purple sweet potato flour to mung bean flour significantly affects the chemical properties (moisture, ash, fat, protein, and carbohydrate content), physical characteristics (crispiness resistance), and sensory attributes of the flakes. The optimal formulation was found in treatment UK4 (50:50 ratio), which yielded a moisture content of 3.18%, ash content of 2.11%, protein content of 13.81%, fat content of 2.82%, and carbohydrate content of 78.08%. This treatment also exhibited a crispiness resistance of 8.33 minutes and was highly preferred by panelists for its brownish-purple color, distinct mung bean flavor/aroma, and crispy texture.

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