



The Physicochemical and Sensory Properties of Gluten-Free Brownies Produced using Purple Yam Paste (*Dioscorea alata*) and Mocaf

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Abstract:

The development of gluten-free brownies with purple yam paste and mocaf is an alternative for individuals who avoid consuming gluten. This study aims to determine the effect of purple yam paste and mocaf ratio on the characteristics of a gluten-free brownies. A Randomized Block Design was used with six treatment levels of purple yam paste to mocaf ratios: 0:100, 15:85, 30:70, 45:55, 60:40, and 75:25. Each treatment was replicated three times. The data obtained were analyzed using Analysis of Variance and Duncan new Multiple Range Test (DnMRT) at the 5% level when necessary. The results showed that the ratio of purple yam paste to mocaf significantly affected the texture, color, and the hedonic of texture and color. The best treatment was the 75:25 ratio which resulted in a hardness of 105.5 N, water content of 20.16%, L* 37.1 a* 7.8 b* -2.9, ash content of 1.42%, protein content of 4.82%, fat content of 29.12%, and carbohydrate of 44.49%. Despite its high sensory scores in texture, color, taste, and overall acceptance, this chosen brownie's hardness and its overall acceptance were lower than commercial brownies.

Keywords: Gluten-Free Brownies, Mocaf, Purple Yam Paste

1. Introduction

Brownies are a popular bakery product, widely enjoyed for their rich chocolate flavor and commonly found in bakeries. They are favored by people from all walks of life due to their distinctive taste. Traditionally, brownies are made by baking a dough without any leavening agents, which is why they are often referred to as "bantat cake"—a type of dense, soft-textured cake with a rich chocolate flavor. Brownies are typically consumed as a dessert, with textures ranging from fudgy to cakey depending on personal preference (Selvakumaran et al., 2019).

Wheat flour is one of the main ingredients used in traditional brownie recipes. However, different types of flour can significantly affect the quality of the final product. According to Hariadi et al. (2023), variations in the type and ratio of flour—such as mocaf and black soybean flour—can influence the sensory properties of brownies, including flavor, aroma, and texture. Their study showed that wheat flour with higher protein content produced an aroma rated at an average of 4 (very strong), while lower-protein wheat flour scored an average of 1.6 (weaker). For texture, high-protein wheat flour yielded an average score of 4 (very dense), compared to 1.6 (not dense) for the low-protein variety. These results demonstrate the significant impact of gluten content on the sensory characteristics of brownies.

The popularity of brownies has continued to grow over time, alongside the increasing variety of cakes enjoyed by many people. However, in recent years, there has been a rising awareness of the importance of a healthy diet. One key aspect of this is avoiding gluten. Gluten, a protein found in wheat flour, can cause allergic reactions or intolerances in certain individuals, including those with conditions such as celiac disease or autism. This has driven demand for gluten-free products that maintain both good quality and taste.

To meet this demand, one alternative is the development of gluten-free brownies. A potential solution involves using gluten-free ingredients such as mocaf (modified cassava flour) and purple yam paste (*Dioscorea alata*) as substitutes for wheat flour. Purple yam was chosen as a substitute because its use in bakery products is still relatively uncommon, despite its high potential. It is rich in carbohydrates, low in sugar, and contains beneficial nutrients such as fiber, protein, phenolic compounds, and anthocyanins (Tamaroh et al., 2018). Notably, anthocyanins are bioactive compounds that act as natural antioxidants.

However, food processing methods such as heating, steaming, or baking—used in products like cakes, bread, noodles, cendol, pudding, and macaroni—typically reduce anthocyanin levels and antioxidant activity compared to fresh samples. For example, fresh purple yam contains 38.12 mg/100 g of anthocyanins, which decline to 2.99 mg/100 g after cake processing. Similarly, its antioxidant activity drops from 79.08% to 22.64% (Larief et al., 2018). In addition to anthocyanins, purple yam also contains 5.18 mg GA/100 g extract of total phenolic content (Tamaroh et al., 2018). The antioxidant activity of fresh purple yam reaches around 62.14%, but decreases to approximately 20.19% in its flour form (Satar & Emilia, 2023).

Research by Selvakumaran et al. (2019) showed that orange sweet potato purée can be used as a partial substitute for wheat flour in various ratios. The resulting brownies received positive feedback from panelists, indicating the acceptability of gluten-free products. Another study by Damat et al. (2023) on gluten-free biscuits made with purple yam flour reported a favorable moisture content of 5.05% and high antioxidant activity of 83.68%. Organoleptic scores for texture, taste, and aroma fell in the neutral to slightly liked category.

Selvakumaran et al. (2019) also found that a 50:50 ratio of orange sweet potato purée to wheat flour produced the best results, yielding brownies with 25.88% moisture, 6.22% protein, and 27.75% fat content. Organoleptic evaluations of appearance, color, texture, flavor, and overall acceptability showed that this formulation was preferred by the panelists.

Based on the growing development of gluten-free brownies and findings from previous related studies, the present research aims to explore the appropriate ratio of purple yam paste and mocaf to produce gluten-free brownies with optimal physicochemical and sensory characteristics. The purpose of this study is to evaluate the effect of varying ratios of purple yam paste and mocaf on the physical, chemical, and sensory properties of gluten-free brownies, and to determine the best formulation as preferred by panelists.

2. Research Method

Materials

This study used purple yam, mocaf, tapioca, eggs, granulated sugar, water, vanilla, butter, white chocolate, parchment paper, and tissue. The chemical used for analysis were KCl, sodium acetate, HCl, Na₂SO₄, HgO, H₂SO₄, NaOH, Na₂S₂O₃, and PP indicator. The equipment needed for analysis was a texture analyzer, color reader, and spectrophotometer.

Methods

This study used a Randomized Block Design (RBD) with a ratio of purple yam paste to Mocaf. The ratio treatment was obtained based on preliminary research. Each treatment was repeated three times, resulting in 18 experimental units. The following is the ratio treatment:

P0 = Purple yam paste: Mocaf = 0 : 100

P1 = Purple yam paste: Mocaf = 15 : 85

P2 = Purple yam paste: Mocaf = 30 : 70

P3 = Purple yam paste: Mocaf = 45 : 55

P4 = Purple yam paste: Mocaf = 60 : 40

P5 = Purple yam paste: Mocaf = 75 : 25

The Preparation of Purple Yam Paste (Pushpakumara et al., 2024; Ulyarti et al., 2024)

Purple yam was first peeled and rinsed two to three times to remove dirt and latex. This washing and cleaning process is a standard preliminary step in tuber processing to ensure the hygiene of raw materials prior to further handling (Pushpakumara et al., 2024; Ulyarti et al., 2024). The yam was then sliced into small pieces (approximately 3 cm) to facilitate faster cooking and ensure uniform doneness (Pushpakumara et al., 2024).

The sliced yam pieces were steamed at approximately 100 °C for 45 minutes until a soft texture was achieved. Steaming is a commonly used method to soften tubers before processing them into paste or other food products. After steaming, the yam was drained and allowed to cool to room temperature before homogenization. The softened yam was then mashed or milled to form a smooth paste. This purple yam paste serves as a potential raw material for various food applications (Ulyarti et al., 2024).

Gluten-Free Brownies Preparation (Moreira et al., 2023 with Modification)

The preparation of gluten-free brownies is based on the procedure carried out by Moreira (Moreira et al., 2023) which has been modified, with the ingredient formulation as presented in Table 1.

Table 1. Formulation of Gluten-Free Brownies Preparation

Ingredient (g)	Ratio of Purple Yam Paste and Mocaf					
	0:100	15:85	30:70	45:55	60:40	75:25
Purple Yam Paste	0	12	24	36	48	60
Mocaf	80	68	56	44	32	20
Tapioca	20	20	20	20	20	20
Egg (piece)	2	2	2	2	2	2
Sugar	40	40	40	40	40	40
Butter	70	70	70	70	70	70
White chocolate	100	100	100	100	100	100
Salt	1	1	1	1	1	1
Total	313	313	313	313	313	313

The preparation of gluten-free brownies begins by weighing all ingredients according to the specified formulation. The eggs, sugar, and salt are then mixed until thickened, for approximately 2 minutes. Melted white chocolate and butter are added to the mixture and stirred until homogeneous. Next, the tapioca flour, purple yam paste, and mocaf are added to the batter according to the treatment variations, and the mixture is stirred again until smooth and lump-free. The resulting batter is poured into a baking pan lined with baking paper to prevent sticking. The brownies are baked in a preheated oven at 150 °C for 40 minutes.

Color (Lazaro et al., 2019)

Color measurement in food products such as brownies is generally carried out objectively using instruments such as a colorimeter or color reader, which provide L, a, and b* values in the CIELab color system. The L* value indicates the level of lightness, a* represents the degree of redness-greenness, and b* denotes the degree of yellowness-blueness. The color description based on L*, a*, and b* can be seen in Table 2.

Table 2. Color Description

Color Value	Description
L*	Score 0 (black) until 100 (white)
+ a*	Score 0-80 (red)
- a*	Score 0-(-80) (green)
+ b*	Score 0-70 (yellow)
- b*	Score 0-(-70) (blue)

Hardness (Guiné, 2022; Paredes et al., 2022)

Instrumental texture analysis is commonly performed using a texture analyzer with a compression test setup and a cylindrical probe. Samples are placed on the platform, where the probe compresses them at a

defined speed (e.g., 100 mm/min) before returning to its initial position. The resulting data, including maximum force and force–time curves, are recorded and applied to determine hardness.

Sensory properties (Sinay & Karuwal, 2023)

Sensory test was conducted by 25 semi-trained panelists. The test consisted of a sensory quality test with two parameters: texture and color, a hedonic test with two parameters: taste and overall acceptance, and a multiple comparison test with two parameters: texture and overall acceptance. These sensory testing were conducted by assigning scores to the products, as shown in Table 3.

Table 3. Sensory score of gluten-free brownies

Score	Texture	Color	Hedonic	Multiple Comparison
5	Very Soft	Very purple	Like very much	Much better than R
4	Soft	Purple	Like	Better than R
3	Semi-soft	Slightly purple	Quite Like	Same as R
2	Hard	Not purple	Dislike	Less good than R
1	Very Hard	Very Not purple	Dislike very much	Very bad from R

Proximate analysis

The chemical composition of the best quality of gluten-free brownies is determined using a proximate content test. The proximate content test includes water content, fat content, protein content, ash content, and carbohydrate content, conducted using the AOAC method (2005).

Data Analysis

Analysis of Variance (ANOVA) at the 1% and 5% levels was used, followed by Duncan new Multiple Range Test (DnMRT) when applicable.

3. Results and Discussion

Hardness

Gluten-free brownies with purple yam paste and mocaf showed similar texture and appearance to commercial brownies made of wheat flour (Figure 1). Gluten-free brownies is relatively soft in all ratios applied in this experiment. Brownie’s texture is determined by several factors, particularly flour particle size and the mixing process. Finer flour particles contribute to a softer, smoother texture and influence sensory attributes, including pore density and tenderness (Richardson et al., 2021). Figure 1 shows significant differences in the brownie’s crumb morphology among the treatments. As the purple yam paste concentration increases, the brownie pore structure decreases (pores become smaller). In the 0:100, 15:85, 30:70, and 60:40 treatments, the pores are not uniform due to incomplete gas trapping, resulting in uneven pores in the brownies. Furthermore, another factor influencing crumb structure is the mixing process. Yunieta & Sutrisno (2018) reported that the mixing process can aid in cake crumb formation. Pores in cakes are formed by the foam produced by eggs, sugar, and cake emulsifier, thus creating a monomolecular layer that traps gas.





Figure 1. Brownies processed using several ratios of purple yam paste and mocaf

Table 4. Average values of hardness, water content, and color of brownies with different ratios of purple yam paste and mocaf

Purple Yam : Mocaf Ratio	Hardness (N)	Moisture Content (%)	Color		
			L*	a*	b*
0:100	119.3 ^c ±4.11	18.49±1.10	66.1 ^c ±1.47	1.5 ^a ±0.67	20.2 ^d ±0.75
15:85	114.9 ^b ±1.51	18.92±0.66	65.1 ^c ±3.68	2.0 ^a ±0.47	19.0 ^d ±1.15
30:70	106.1 ^a ±1.28	18.93±1.93	61.0 ^e ±2.29	3.4 ^b ±0.29	14.1 ^c ±0.64
45:55	107.2 ^a ±1.40	19.09±1.23	55.2 ^b ±3.72	4.4 ^c ±0.51	10.4 ^c ±4.78
60:40	106.9 ^a ±2.05	18.06±0.98	53.3 ^b ±0.35	6.4 ^d ±0.32	5.9 ^b ±1.25
75:25	105.5 ^a ±1.83	20.16±0.53	37.1 ^a ±3.35	7.8 ^e ±0.74	-2.9 ^a ±1.83

Numbers followed by different superscript in the same column are significantly different at the 5% level according to the DnMRT test.

Hardness is defined as the peak force required to push or crush a product and is expressed in Newtons (N). The average hardness corresponds to this peak value, indicating the maximum force needed to break the product's structure. A higher peak force signifies a firmer or harder texture (Satar & Emilia, 2023). The ratio of purple yam paste to mocaf significantly influenced the hardness of the brownies (Table 4). In general, hardness tended to decrease as the proportion of purple yam paste increased. This reduction in hardness may be attributed to the lower starch content associated with higher levels of purple yam paste.

Moisture content

Moisture content is a critical parameter in the food industry, as it influences both product quality and susceptibility to spoilage. Higher moisture levels increase the risk of spoilage due to biological activity (e.g., enzymatic reactions) and microbial growth (Awulachew, 2021). Analysis of variance (ANOVA) on the moisture content of the brownies revealed no significant effect from the treatment. The average moisture content ranged from 18.06% to 20.16%. These findings are consistent with the results of Bolang et al. (2022), who reported that cookies formulated with porang flour, moringa leaves, and tempeh exhibited moisture contents within acceptable standards, although their study did not specifically evaluate the impact of tempeh flour substitution on moisture levels. Lower moisture content is generally associated with extended shelf life (Awulachew, 2021). The results of this study indicate that the moisture content of the purple yam brownies complies with the standard set by SNI 8372-2018 for sweet bread, which allows a maximum moisture content of 40% (Badan Standarisasi Nasional, 2018).

Color

The average color measurements for purple yam brownies are presented in Table 4. The results indicate that the ratio of purple yam paste to mocaf significantly influenced the color characteristics of the brownies. In colorimetric terms, the L* value represents lightness, a* indicates redness, and b* denotes yellowness. As shown in Table 4, increasing the proportion of purple yam paste resulted in a decrease in both L* and b* values, while the a* value increased. These findings align with the study by Lubis et al. (2021), which reported that substituting purple sweet potato paste significantly affected the color attributes of brownies. Similarly, Ulyarti et al. (2023) found that increasing the proportion of purple yam flour in crackers led to reduced L*

values, indicating that higher levels of purple yam produced darker-colored products. The rise in a* values with increased purple yam paste can be attributed to its high anthocyanin content, a group of natural pigments responsible for red to purple coloration in food products (Wu et al., 2015; Cakrawati et al., 2021). Anthocyanins are the primary pigments in purple yam (*Dioscorea alata*) and play a crucial role in enhancing the redness of the final product. This is further supported by findings from Khoo et al. (2017), who demonstrated that anthocyanin-rich extracts, including those from purple yam and *Clitoria ternatea* flowers, intensify red-to-blue hues depending on pH levels and the molecular structure of the anthocyanins.

Sensory Properties

Texture

Texture is an important aspect in evaluating food products. Texture refers to “the mechanical, geometric, surface, and internal properties of a product that can be detected through touch, movement, and, when relevant, sight and sound from the first bite until swallowing.” It is a key factor in the overall sensory experience and consumer satisfaction, as qualities like firmness, softness, chewiness, and creaminess shape how food is experienced (Rune et al., 2025). Based on the analysis of variance (ANOVA), texture was significantly influenced by the ratio of purple yam paste to mocaf. Table 5 shows that the highest average for brownie texture was shown by the 30:70 treatment, at 3.52 (slightly soft), and the lowest average value was shown by the 60:40 treatment, at 2.96 (not soft).

Color

Color is one of the key factors consumers use to assess product quality. Recent studies emphasize the psychological influence of food color on flavor perception, noting that deeper, more intense colors are often associated with richer taste and higher nutrient content (Kardas et al., 2024). According to the analysis of variance, the ratio of purple yam paste to mocaf significantly influences the color of brownies. As shown in Table 5, the brownies become more purple as the proportion of purple yam paste increases. Research by Lubis et al. (2021) also found that the color of baked brownies becomes slightly more purple with increasing substitution of purple sweet potato paste. Similarly, Larief et al. (2018) reported comparable results when using purple yam flour in *cukke*.

Table 5. Sensory properties of gluten-free brownies

Purple Yam and Mocaf Ratio (%)	Texture*	Color**	Taste#	Overall Acceptance#	Texture##	Overall Acceptance##
0:100	3.00 ^a ±0.50	1.44 ^a ±0.51	3.56±0.71	3.60±0.76	2.16±0.69	2.48±0.71
15:85	3.24 ^{ab} ±0.66	1.48 ^a ±0.51	3.72±0.79	3.72±0.79	2.32±0.56	2.52±0.65
30:70	3.52 ^b ±0.59	1.92 ^b ±0.64	3.76±0.66	3.92±0.70	2.44±0.65	2.64±0.64
45:55	3.00 ^a ±0.50	2.12 ^b ±0.60	3.68±0.56	3.68±0.48	2.24±0.66	2.52±0.71
60:40	2.96 ^a ±0.68	3.08 ^c ±0.40	3.60±0.71	3.72±0.79	2.28±0.68	2.48±0.65
75:25	3.48 ^b ±0.71	4.40 ^d ±0.58	4.00±0.76	4.04±0.79	2.36±0.70	2.72±0.68

Description: Numbers followed by different superscript in the same column are significantly different at the 5% level according to the DnMRT test.

* Texture score = 1: not very soft, 2: not soft, 3: somewhat soft, 4: soft, 5: very soft

** Color score = 1: very purple, 2: not purple, 3: somewhat purple, 4: purple, 5: very purple

Hedonic score = 1: dislike very much, 2: dislike, 3: somewhat like, 4: like, 5: like very much

Multiple comparison score = 1: very worse than R, 2: worse than R, 3: equal to R, 4: better than R, 5: very better than R

Taste

Taste is a key attribute in the sensory evaluation of food products and is primarily influenced by the chemical compounds present in the ingredients (Yuniartini & Dwiani, 2021). The average hedonic taste scores for brownies with varying ratios of purple yam paste to mocaf are presented in Table 5. Statistical analysis revealed that the ratio of purple yam paste to mocaf did not significantly affect the taste of the brownies. However, there was a general trend indicating that the panelists' liking scores for taste increased with higher proportions of purple yam paste. This suggests that while the differences were not statistically significant, the addition of more purple yam paste may contribute positively to the overall flavor perception of the product.

Overall acceptance

Sensory evaluation of overall acceptance aims to assess consumer preferences based on multiple attributes, including color, aroma, flavor, texture, and overall appearance. Such evaluations are crucial for determining product acceptance and market feasibility, as sensory quality plays a significant role in influencing consumer purchasing and consumption behavior (Suryana et al., 2022). The average scores for overall acceptance of the gluten-free brownies are presented in Table 5. Statistically, the ratio of purple yam paste to mocaf had no significant effect on overall acceptance. Variations in panelist preferences were likely influenced by individual perceptions of specific sensory attributes, particularly texture, color, and flavor.

Multiple comparisons

A multiple comparison test on the texture and overall acceptability of brownies with a ratio of purple yam paste to mocaf was conducted by comparing the texture of gluten free yam brownies with commercial gluten brownies. The results of this test can be seen in Table 5. The result showed that the texture of brownies is not affected by the ratio of purple yam paste to mocaf. The average value obtained ranged from 2.16 to 2.44. All treatments obtained an average value below 3.00, indicating that the texture of brownies with a ratio of purple yam paste to mocaf was perceived by panelists as worse than the gluten brownies as reference. Similar to that, the result for overall acceptability of gluten free yam brownies.

Chemical content of best formula mocaf

Chemical composition analysis was conducted on brownies made with a 75:25 ratio of purple yam paste to mocaf flour—identified as the best formulation based on prior evaluations. The results are presented in Table 6. Ash content, representing the total mineral (inorganic) content of a food product, was found to be 1.42% in the selected brownie formulation. Similarly, Budaraga et al. (2023) reported that purple sweet potato flour combined with other ingredients yielded an ash content of approximately 1.23%. Protein content in the 75:25 purple yam to mocaf brownie was 4.82%, indicating a moderate level for a gluten-free bakery product. This value is notably lower than the protein content of wheat flour (approximately 10.5%), which is typically used in conventional baked goods (Selvakumaran et al., 2019). In this formulation, protein is not only derived from the plant-based flours but also from animal-based ingredients, particularly eggs. Fat content was recorded at 29.12%. This relatively high fat percentage is likely due to the inclusion of rich fat-contributing ingredients such as butter, eggs, and white chocolate. While purple yam itself contains only 0.16% fat (Fauziah et al., 2020), its high inclusion rate in the formulation may have contributed marginally to the total fat content. In comparison, Jannah et al. (2024) reported fat content ranging from 11.47% to 14.49% in brownies made from yellow pumpkin flesh and wheat flour, which also included fat-contributing ingredients like eggs, margarine, and chocolate. Similarly, Selvakumaran et al. (2019) observed fat content between 21.95% and 29.96% in orange sweet potato brownies, which included egg yolk, corn oil, and chocolate chips in their formulation. Carbohydrate content, calculated by the by-difference method (subtracting the sum of moisture, ash, protein, and fat from 100%), was found to be 44.49%, making it the predominant component of the brownies. According to Cornejo-Ramírez et al. (2018), an increase in carbohydrate content can be attributed to the swelling of starch granules during hydration and heating, which enhances the starch availability in the final product.

Table 6. Proximate content of brownies with the best ratio of purple yam paste and mocaf treatment (75:25)

Proximate	Content (%)
Moisture	20.16
Ash	1.42
Protein	4.82
Fat	29.12
Carbohydrate	44.49

Conclusion

This study found that the ratio of purple yam paste to mocaf in gluten-free brownies significantly influenced texture, color parameters (L^* , a^* , b^*), and organoleptic properties—specifically the scores for

texture and color. The optimal formulation was identified at a 75:25 ratio of purple yam paste to mocaf (P5). This formulation yielded a hardness of 105.5 N, a moisture content of 20.16%, $L^* = 37.1$, $a^* = 7.8$, and $b^* = -2.9$. Organoleptic evaluation showed a texture score of 3.48 (rather soft), color score of 4.40 (purple), taste score of 4.00 (like), and an overall acceptability score of 4.04 (like). However, multiple comparison tests indicated that the texture and overall acceptance of this formulation were still rated lower than the reference product (R). In terms of chemical composition, the brownies with a 75:25 ratio contained 1.42% ash, 4.82% protein, 29.12% fat, and 44.49% carbohydrates.

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