Physical and Chemical Characteristics of Cookies Made from Yellow Sweet Potato (*Ipomoea* batatas L.) and Porang Flour (*Amorphophallus muelleri*)

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Abstract. Indonesia's reliance on imported wheat flour highlights the need to utilize local tuber crops as alternative food ingredients. Yellow sweet potato flour is a promising source due to its high β-carotene content and its ability to enhance product color; however, its lack of gluten results in a fragile texture. Conversely, porang flour, rich in glucomannan, functions as a binder and gel-forming agent. This study aimed to evaluate the physical and chemical characteristics of cookies formulated from combinations of yellow sweet potato flour and porang flour as a wheat flour substitute. The flour ratios used were 60:95, 45:110, and 30:125 (yellow sweet potato flour:porang flour). Cookie characteristics evaluated included texture, color, caloric value, moisture, ash, fat, protein, carbohydrate, and crude fiber contents. The results showed variations in physical and chemical properties among formulations. Fracture distance ranged from 3.34 to 7.68 mm, while hardness values were 416.60–622.50 N. Color parameters showed L* values of 46.43–48.84, a* values of 7.16–7.99, and b* values of 33.10–35.02. Moisture content ranged from 4.79–6.99%, ash 3.04–3.16%, fat 22.51–23.29%, protein 3.34–4.17%, carbohydrates 62.41–65.39%, and crude fiber 3.28–4.14%. The caloric value ranged from 237.14 to 242.55 kcal per 50g.

1 Introduction

Wheat flour is the most widely used primary ingredient in food products in Indonesia. Domestic wheat flour production relies entirely on imported wheat, mainly sourced from Australia, Canada, and Ukraine. Approximately 99% of these imports are utilized in food products such as noodles, bread, and cookies [1]. According to the National Statistics Agency, imports of wheat and wheat flour from January to August 2025 reached 7.13 tons. This high dependence on imported raw materials may weaken the local agricultural sector, as imported commodities, particularly wheat and wheat flour, are generally more affordable. Conversely, Indonesia possesses abundant local tuber crops, such as sweet potato, cassava, porang, and others, which can be processed into flour. The utilization of flour derived from local tubers represents a promising alternative for strengthening national food security.

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One potential substitute for wheat flour is yellow sweet potato (*Ipomoea batatas* L.). In addition to being a carbohydrate source, the yellow sweet potato is rich in β-carotene, a natural pigment responsible for its yellow color and dietary fiber. β-Carotene functions as a provitamin A compound that supports eye health and exhibits strong antioxidant activity, contributing to immune protection [2]. Processing yellow sweet potato into flour can enhance the sensory quality of food products by imparting an attractive color and providing added functional properties [3]. However, the use of sweet potato flour often results in products with a brittle and crumbly texture due to the absence of gluten, which normally acts as a structural binding agent in wheat-based products [4]. Therefore, an additional binding ingredient is required, such as porang flour.

Porang flour is produced from porang tubers (*Amorphophallus muelleri*) and is characterized by its high glucomannan content. Glucomannan is a water-soluble hydrocolloid polysaccharide capable of forming viscous gels, making it suitable as a binding and texturizing agent [5]. Glucomannan can absorb water up to 19 times its own weight, exhibits high viscosity (3,000–14,666 mPa·s), and has relatively low density (0.498–0.559 g/cm^3). These properties allow glucomannan to function as a gluten substitute by binding dry components and preventing dough from becoming fragile or crumbly [6]. The incorporation of porang flour in combination with yellow sweet potato flour is therefore expected to improve the texture of food products.

One food product that can be developed using a combination of yellow sweet potato flour and porang flour as a wheat flour substitute is cookies. [1] reported that cookies are among the most widely consumed snack foods in Indonesia during the period of 2018–2022. Cookies are classified as baked snack products with a crispy texture, diverse flavors, and typically small and thin shapes. Their sensory characteristics are strongly influenced by the types of ingredients used in formulation [7]. The combination of yellow sweet potato flour and porang flour is expected to serve as a viable alternative to wheat flour in cookie production. Therefore, this study aimed to evaluate the physical and chemical characteristics of cookies produced from a combination of yellow sweet potato flour and porang flour.

2 Methods

2.1 Materials

The main ingredients used for cookie production were porang flour, yellow sweet potato flour, sugar, egg yolk, margarine, baking powder, salt, and milk powder. All ingredients were obtained from local markets in Surakarta, Indonesia.

2.2 Cookies Preparation

The cookie preparation method was adopted from previous studies [8], with slight modifications. Initially, all ingredients were weighed according to the formulations presented in Table 1. Porang flour, yellow sweet potato flour, sugar, egg yolk, margarine, baking powder, salt, and milk powder were then mixed thoroughly in a mixing bowl until a homogeneous dough was obtained. The dough was shaped into flattened round forms and arranged on a baking tray. Subsequently, the dough was baked in a preheated oven at 130 °C for 35 min. After baking, the cookies were cooled at room temperature and packed in appropriate packaging for further analysis.

Table 1. Cookies Formulations Using Yellow Sweet Potato Flour and Porang Flour.

Ingredient	F1	F2	F3
Porang flour (g)	95	110	125
Yellow sweet potato flour (g)	60	45	30
Sugar (g)	80	80	80
Egg yolk (g)	18	18	18
Margarine (g)	85	85	85
Baking powder (g)	1	1	1
Salt (g)	2	2	2
Milk powder (g)	26	26	26

2.3 Physical and Chemical Analyses

2.3.1 Texture Analysis

Texture analysis was conducted to determine the fracturability and hardness of the cookie samples. The measurements were performed using a texture analyzer under different compression speeds and forces. The test procedure involved placing the sample on the designated platform, after which the sample was compressed using a cylindrical probe with a diameter of 0.5 inches at predetermined speeds and forces until fracture occurred [9].

2.3.2 Color Analysis

Color measurement was carried out using a CR-200 chromameter (Minolta). The CIE L*, a*, and b* color parameters were used to numerically describe the visual appearance of the products. The L* value represents lightness, the a* value indicates the green–red axis, and the b* value represents the blue–yellow axis [9].

2.3.3 Proximate Analysis

Proximate analysis was conducted according to [10] methods, including the determination of moisture, ash, fat, protein, and carbohydrate contents. Moisture content was analyzed using the thermogravimetric method, ash content by dry ashing, fat content using the Soxhlet extraction method, and protein content using the Kjeldahl method. Carbohydrate content was calculated by difference, expressed as 100 minus the sum of moisture, ash, fat, and protein contents.

2.3.4 Total Caloric Value

Total caloric value was calculated using the following equation, in accordance with the Indonesian National Standard [11].

$$\text{calories per 100 g} = (9 \times \%\,\text{fat}) + (4 \times \%\,\text{protein}) + (4 \times \%\,\text{carbohydrate}) \quad (1)$$

2.3.5 Crude Fiber Content

Crude fiber is defined as the fraction of plant material that is resistant to digestion by human digestive enzymes, consisting primarily of cellulose, hemicellulose, lignin, and cutin. Crude fiber content was determined using [10] method.

3 Result and Discussion

3.1 Physical Characteristics

The physical characteristics of cookies prepared from yellow sweet potato flour and porang flour are presented in Table 2.

Table 2. Physical Characteristics of Cookies Prepared with Yellow Sweet Potato Flour and Porang Flour.

	Texture		Colour		
	Fracturability (mm)	**Hardness (N)**	**L***	**a***	**b***
F1	3.34^{a}	416.60^{a}	46.43^{a}	7.16^{a}	35.02^{b}
F2	5.93^{b}	492.58^{ab}	47.70^{b}	7.63^{ab}	34.49^{b}
F3	7.68^{b}	622.50^{c}	48.84^{b}	7.99^{b}	33.10^{a}

Notes:
Values followed by different superscript letters within the same column indicate significant differences ($p < 0.05$). Formulations were as follows: F1 (yellow sweet potato flour 60 g : porang flour 95 g), F2 (45 g : 110 g), and F3 (30 g : 125 g).

3.1.1 Texture

Texture parameters evaluated in this study were fracturability and hardness. Fracturability refers to the force at which a product cracks, fractures, or breaks when subjected to a certain pressure, such as during biting, while hardness represents the force required to determine the resistance of a product to deformation [15]. In this study, fracturability was expressed as fracture distance, defined as the distance traveled by the probe at the point of cookie breakage. A shorter fracture distance indicates a more brittle product.

The formulation of yellow sweet potato flour and porang flour had a significant effect on cookie texture. The fracturability results showed that increasing the proportion of porang flour led to higher fracture distance values, as presented in Table 2. Formulation F3 exhibited the highest fracture distance (7.68 mm), while F1 showed the lowest value (3.34 mm). A higher fracture distance indicates that the product is less prone to breaking. Similarly, hardness values increased with increasing porang flour content. The lowest hardness was observed in F1 (416.60 N), while the highest hardness was recorded in F3 (622.50 N). The incorporation of porang flour effectively reduced cookie fragility. This effect can be attributed to the high glucomannan content of porang flour, which acts as a gelling agent with strong water-binding capacity. Higher levels of porang flour increase the amount of bound water in the dough, thereby reducing the formation of fragile pores during baking. Consequently, the cookies exhibit a denser and harder texture, making them less brittle [12].

3.1.2 Color

Color is an important quality attribute that strongly influences consumer acceptance of food products. Color analysis of the cookies was conducted using a chromameter, which generated CIE L*, a*, and b* color parameters. An increase in porang flour content resulted in higher L* values, indicating brighter cookies, whereas higher levels of yellow sweet potato flour produced darker coloration. This trend is consistent with the inherent color characteristics of yellow sweet potato flour, which ranges from yellow to yellow-brown due to its β-carotene content [3], and porang flour, which is naturally bright white [12]. Consequently, formulation F3 exhibited the highest lightness value (48.84), while F1 showed the lowest (46.43). Higher L* values, approaching 100, reflect increased brightness in food products [19].

The highest a* (redness) value was observed in F3 (7.99), while the lowest value was found in F1 (7.16), indicating that increasing porang flour slightly enhanced the red color intensity of the cookies. The a* parameter represents the green–red axis, where positive values indicate redness and negative values indicate greenness. In contrast, the highest b* (yellowness) value was recorded in F1 (35.02), while the lowest value was observed in F3 (33.10). This trend is attributed to the higher content of yellow sweet potato flour in F1 compared to F3. The b* parameter represents the blue–yellow axis, with positive values indicating yellowness and negative values indicating blueness. These findings are consistent with the study by [8], which reported that the addition of yellow sweet potato flour resulted in more yellow cookie color than control, as indicated by higher b* values.

3.2 Chemical Characteristics

The chemical characteristics of cookies prepared with yellow sweet potato flour and porang flour are presented in Table 3.

Table 3. Chemical characteristics of cookies prepared with different ratios of yellow sweet potato flour and porang flour.

	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Energy (kkal/50gr)	Crude Fiber (%)
F1	4.798^{a}	3.16^{b}	23.29^{a}	3.34^{a}	65.39^{b}	242.55^{a}	4.14^{c}
F2	6.993^{b}	3.04^{a}	23.88^{a}	3.67^{a}	62.41^{a}	239.87^{a}	3.73^{b}
F3	6.607^{c}	3.08^{a}	22.51^{a}	4.17^{a}	63.61^{ab}	237.14^{a}	3.28^{a}

Notes:
Values followed by different superscript letters within the same column indicate significant differences ($p < 0.05$). Formulations were as follows: F1 (yellow sweet potato flour 60 g : porang flour 95 g), F2 (45 g : 110 g), and F3 (30 g : 125 g).

3.2.1 Moisture Content

The moisture content of the cookies increased significantly with increasing porang flour proportion. The lowest moisture content was observed in F1 (4.79%), followed by F2 (6.99%) and F3 (6.60%). This increase is primarily attributed to the high glucomannan content of porang flour, which exhibits strong water-binding and water-holding capacity. Glucomannan can absorb and retain large amounts of water, resulting in higher moisture retention in baked products [5]. The increase in the moisture content of the cookies is also caused by the water content in the ingredients. Porang flour is known to have a moisture content of 11.86-11.28%, while the moisture content of sweet potato flour is 7.39-7.89% [5, 13].

According to SNI 2973:1992 [11], the maximum allowable moisture content for cookies is 5%. Only formulation F1 met this requirement, whereas F2 and F3 exceeded the standard. Nevertheless, the moisture values obtained in this study were considerably lower than those reported by [14], who observed a moisture content of 14.80% in cookies formulated with a 50:50 ratio of wheat flour and porang flour. This indicates that the combination of yellow sweet potato flour and porang flour can still produce cookies with relatively low moisture content compared to wheat-based formulations containing porang.

3.2.2 Ash Content

Ash content reflects the total mineral content present in food products. In this study, ash content ranged from 3.04% to 3.16%, with the lowest value observed in F2 and the highest in F1. These values exceed the maximum ash content specified in SNI for cookies (1.5%). The elevated ash content is mainly attributed to the use of yellow sweet potato flour as a wheat flour substitute. Yellow sweet potato flour has a relatively high ash content (2.44%). The gradual decrease in ash content with increasing porang flour proportion can be explained by the low ash content of porang flour (1.34%) [13, 15]. Therefore, the high ash values observed in this study are primarily associated with mineral-rich yellow sweet potato flour rather than porang flour incorporation.

3.2.3 Fat Content

Fat content among the cookie formulations showed no significant differences, ranging from 22.51% to 23.29%, and all samples met the SNI minimum fat requirement for cookies (9.5%) [11]. The relatively similar fat values across formulations indicate that flour substitution had minimal influence on fat content. Both porang flour and yellow sweet potato flour contain low fat levels. Several studies mention that the main component of porang flour is glucomannan, whereas the main component of sweet potato flour is starch. This indicates that the fat content in both types of flour is very low or almost nonexistent. The high fat content of the cookies was therefore mainly derived from other ingredients, particularly margarine, egg yolk, and milk powder. Similar findings were reported by [14], indicating that fat content in cookies is more strongly influenced by lipid-rich ingredients than by flour type.

3.2.4 Protein Content

Protein content was not significantly affected by flour formulation, although a slight increasing trend was observed with higher porang flour addition. Protein values ranged from 3.34% (F1) to 4.17% (F3). These values are substantially lower than the minimum protein requirement for cookies specified by SNI (9%) [11]. The increase in protein content is due to the addition of porang flour. In addition, it is also caused by the low protein content of sweet potato flour. This is indicated by the decrease in protein levels in cakes with the addition of sweet potato flour compared to the control cake [3]. In this case, porang flour is the more dominant ingredient in increasing the protein content in cookies.

3.2.5 Carbohydrate Content

Carbohydrate content ranged from 62.41% to 65.39%, with F1 exhibiting the highest value due to its higher proportion of yellow sweet potato flour. According to SNI 2973:1992 [11], cookies should contain a minimum carbohydrate content of 70%; therefore, none of the formulations met this requirement. This discrepancy can be attributed to the replacement of wheat flour, which typically contains approximately 70% carbohydrates, with yellow sweet potato flours, which have carbohydrate contents 58.59% [13]. It should also be noted that carbohydrate content was calculated by difference, and therefore strongly influenced by moisture, fat, protein, and ash contents. The relatively higher moisture and ash levels in the formulations contributed to lower calculated carbohydrate values.

3.2.6 Energy Content

Energy content was not significantly affected by flour formulation, although a decreasing trend was observed with increasing porang flour proportion. The highest energy value was recorded in F1 (242.55 kcal/50 g), decreasing to 237.14 kcal/50 g in F3. The insignificant results regarding the energy content of these cookies indicate that the use of porang flour and sweet potato flour does not affect the energy in the cookies. This is because porang flour contains glucomannan and sweet potato flour contains dietary fiber, neither of which contribute to an increase in calories [2, 5]. The other ingredients used to make the cookies, aside from porang and sweet potato flour, are the main sources of calories in the cookies. These findings are consistent with [12], who reported reduced caloric values in cookies enriched with porang flour. The incorporation of porang flour therefore shows potential for developing lower-energy bakery products.

3.2.7 Crude Fiber Content

Crude fiber content decreased significantly with decreasing yellow sweet potato flour proportion, ranging from 4.14% in F1 to 3.28% in F3. These values are substantially higher than the SNI crude fiber requirement for cookies (0.5%) [11], mainly due to the replacement of wheat flour with fiber-rich tuber flours, such as sweet potato flour [3]. Yellow sweet potato flour contains relatively high levels of insoluble dietary fiber, such as cellulose and hemicellulose, which are stable during thermal processing [2]. In contrast, porang flour is dominated by glucomannan, a soluble fiber that is highly hygroscopic and readily disperses or dissolves during processing, leading to lower measured crude fiber values [5]. Consequently, increasing porang flour and reducing yellow sweet potato flour resulted in decreased crude fiber content.

4 Conclusion

The combination of yellow sweet potato flour and porang flour affects the physical and chemical characteristics of the resulting cookies. An increase in porang flour produces cookies with a harder texture and greater resistance to breakage, a lighter color, higher moisture and protein content, and lower calorie and carbohydrate levels. The use of a combination of yellow sweet potato flour and porang flour has been proven to modify the physical and chemical properties of cookies, indicating its potential to be developed as an alternative non-wheat cookie product with specific characteristics depending on the proportion of flour used. Further in-depth research is needed on the functional properties of cookies, such as antioxidants and dietary fiber, so that they can contribute to the provision of functional foods.

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