

# The Effect of Different Particle Sizes of Sweet Potato Flour on the Characteristics of Cookies

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## Abstract

Sweet potato (*Ipomoea batatas*) is a nutrient-packed crop abundant in protein, vitamins, minerals, and bioactive phytochemicals like polyphenols, dietary fiber, ascorbic acid, and beta-carotene. Cookies are widely consumed bakery products valued for their crispiness, chewiness, convenience, and ability to incorporate functional ingredients. This study aimed to evaluate the effect of incorporating sweet potato flour (SPF) of varying particle sizes (30, 60, and 120 mesh) into cookie formulations and assess their sensory acceptance. Four formulations were developed: a control (100% wheat flour) and three with SPF incorporated into wheat flour at different particle sizes. Results showed that the control cookies had the highest spread ratio (9.26) and lowest (3032g) hardness, while SPF30 exhibited the highest force (4671g) during the compression test, indicating a firmer texture. Among all formulations, cookies made with SPF120 received the highest overall acceptance scores, making it the most favourable formulation for enhancing cookie quality and nutritional value.

## 1. Introduction

Cookies are ready-to-eat bakery products, a mixture of flour, brown sugar, unsalted butter, vanilla essence, eggs, a pinch of salt, and baking soda. The cookies come with different appealing features such as crispiness, chewiness, convenience, cheap cost, vast consumption, and the ability to transport vital nutrients [1]. It can transport vital nutrients through various fortification techniques and ingredient enhancements, such as incorporating functional ingredients. For instance, cookies can be fortified with plant extracts, such as chestnut shell extract, which are rich in antioxidant properties. These cookies are nutritionally more beneficial than conventional ones since they contain more phenolic and antioxidant compounds [2]. Therefore, cookies became more popular among consumers ranging from kids to the elderly. Based on a recent survey, the global cookies market was valued at USD 30.62 billion in 2018 and is expected to grow at a CAGR of 5.3% from 2019 to 2025 [3]. It shows consumers' demand for cookies is high and can be maintained and improved over time. As of 2024, the market has continued to expand, valued at around USD 38.66 billion, with projections suggesting it could grow at a CAGR of 5.5% between 2025 and 2034, potentially reaching USD 62.77 billion by 2034. This shows the evolution of consumer preferences; for example, most consumers now favour healthier options and gluten-free varieties that are still rich with unique flavours. This suggests that the demand for cookies can be maintained and improved over time as manufacturers adapt to these changing trends.

Sweet potato, or its scientific name *Ipomoea batatas*, is ranked as the world's seventh most significant food crop after wheat, rice, maize, potato, barley, and cassava [4]. Sweet potato is also a suitable plant that can be converted into a raw ingredient to promote baked food products; for instance, sweet potato flour to make baked products, such as bread, muffins, cakes, and cookies, which have a long shelf life due to its moisture retention properties, making it advantages for transportation and storage issues [5]. Thus, making it one of the most important plants that have been studied.

However, a limited number of studies focus on the effect of the particle sizes of sweet potato flour in producing cookies. Particle size has a significant impact on the key properties of the final product. Variations in particle size affect the characteristics of cookies, particularly their physical attributes, including thickness, lightness, and texture. Therefore, this research aims to analyse the effect of different particle sizes of sweet potato flour on the characteristics of cookies and to assess the sensory acceptance of cookies incorporated with different-sized particles of sweet potato flour. This study prepared the cookies by incorporating sweet potato flour with different particle sizes with wheat flour. The cookies were evaluated on their physical properties, such as weight, spread ratio, textural-related properties, and sensory test.

## 2. Material and Method

### 2.1 Material

The fresh sweet potatoes were purchased from a local Pagoh, Johor, Malaysia shop. They were washed thoroughly to ensure they are free from soil and other contaminants.

### 2.2 Flour Preparation

The sweet potatoes were peeled and cut into thin slices manually. Each slice was cut into a uniform size of 2mm thick and then immersed in the distilled water for 15 minutes [6] (Azeem et al., 2020). Drying of sweet potato was conducted using a food dehydrator (Hendi Profi Line Dehydrator, Hendi, The Netherlands) at 60°C for 5 to 8 hours. The dried slices were milled into flour using a dry blender (Panasonic MX-V310KRA Blender, Panasonic, Japan.) and sieved using a stainless-steel sieve with different mesh sizes (30, 60, and 120 mesh sizes). Wheat flour was procured from the local market around Universiti Tun Hussein Onn Malaysia, Pagoh, Johor, Malaysia.

### 2.3 Cookies Formulation

The cookie prepared by following this recipe: 150g of flour (75g of wheat flour and 75g of sweet potato flour), 75g of unsalted butter, 30g of brown sugar, one egg, 0.8g of salt, 2.3g of baking powder and 1.8mL of vanilla extract [7].

### 2.4 Cookies Preparation

The melted unsalted water was whisked together with brown sugar until reached a light and fluffy texture. An egg was beaten lightly and poured into the mixture. Then, 1.8mL of vanilla extract was added and the mixture was agitated for about 3 minutes. The next step is to combine the dry ingredients and wet ingredients together and mix until a homogenous dough is formed. The well-formed dough is then scooped by using a spoon onto the baking sheet lined with parchment paper, ensuring that they are at least two inches apart from each other. Then, it was placed in the preheated conventional oven (180 °C) for about 12 to 15 minutes. The cookies were permitted to cool to room temperature for 1 hour prior to being packed in airtight high-density polyethylene (HDPE) bags for further analysis.

### 2.5 Evaluation of Cookies

#### 2.5.1 Physical Properties

The cookies' physical characteristics were analysed, including their weight, diameter, thickness, and spread ratio. The cookies' weight was assessed using a precision scale (Smith A2957-LT602), and the average was determined as the weight for each cookie. The cookies' diameter and thickness were measured using a vernier calliper with  $\pm 0.05$  mm accuracy, adhering to standard procedures, and the spread ratio was calculated by dividing the diameter (D) by the or height (H) of the cookies, as shown in equation (1).

$$\text{Spread Ratio} = \frac{\text{Diameter (D)}}{\text{Height (H)}} \quad (1)$$

### 2.5.2 Colour Analysis

Colour is one of the most crucial attributes because it can influence consumer choices and shape their preference and opinions about food [8]. In this research, the colour of cookies was measured using a colorimeter. It was expressed by lightness ( $L^*$ ), chroma  $a^*$ , chroma  $b^*$ , chroma ( $C^\circ$ ), and hue angle ( $H^\circ$ ). Both  $C^\circ$  and  $H^\circ$  were calculated by using the equations (2) and (3) [9].

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (2)$$

$$\text{hue angle} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (3)$$

### 2.5.3 Texture Analysis

The textural properties of the cookies were determined by a compression test using a Texture Analyzer (Stable Micro Systems TA.XT Plus) equipped with a blade set with a knife attached to it. The test was repeated in triplicate. Besides fracturability, the texture analysis was conducted to determine the hardness of the cookies, defined as the maximum peak force during the cookie's compression. The pre-test, test, and post-test speeds were set at 1.50, 2.00, and 10.00 mm/s, respectively. The hardness of the cookies was evaluated by compression at the center of the cookies [10].

### 2.5.4 Sensory Analysis

The sensory assessment was carried out utilizing a 9-point hedonic scale. The 9-point hedonic scale is a descriptive assessment employed in sensory evaluation. The most frequently used hedonic scale is the nine-point one, which ranges from 1 = Dislike extremely to 9 = Like extremely. The hedonic scale posits that participants' preferences lie on a spectrum, allowing for their responses to be classified into like and dislike [11]. The panellists needed to express their views and impressions regarding the cookies' characteristics, including appearance, colour, texture, flavour, and overall acceptance. About fifty untrained panellists were chosen randomly from the students at Universiti Tun Hussein Onn Malaysia (UTHM), Pagoh Branch Campus, to assess the quality of the cookies.

### 2.5.5 Statistical Analysis

The data obtained was analysed using statistical analysis using Statistical Product and Service Solutions (SPSS) software. The data was represented as a means. The ANOVA or Analysis of Variance in the software was used to measure the statistically significant difference between each sample that contains a different particle size of sweet potato flour. The level of significance difference is measured by  $p \leq 0.05$ . It is considered significant if the p-value is below or equal to 0.05.

## 3. Result and Discussion

### 3.1 Physical Properties

Table 1 lists the average of three readings.

**Table 1** Physical properties of cookies incorporated with sweet potato flour

Sample	Weight (g)	Diameter (mm)	Thickness (mm)	Spread Factor
Control	± 21.00	± 6670	± 720	9.26
SPF 30	± 15.63	± 4670	± 1750	2.66
SPF 60	± 16.18	± 5100	± 1730	2.95
SPF 120	± 24.00	± 5710	± 1400	4.08

The average weight ranges from 15.63 g to 24.00 g. Unlike a previous study, the weight of cookies incorporated with SPF 120 is higher than that of the control cookies [7]. The spread ratio was calculated by dividing the diameter of the cookies by their thickness, which determines the quality of the cookies. According to a study, cookies with a higher spread ratio are considered superior to those with a lower spread ratio [12]. It is considered superior because, generally, the cookies that are characterized by a higher spread ratio are favoured due to their enhanced textured and sensory attributes [13].

The control cookies, which do not contain sweet potato flour, have the highest spread ratio compared to the modified sample (SPF) at 9.26. All modified cookies (SPF) showed a lower spread ratio compared to control.

However, it is shown that SPF 120 have the highest spread ratio compared to the other two sample, SPF 30 and SPF 60, which have spread ratio 2.66 and 2.95, respectively.

Cookies with a higher spread ratio tend to appear thinner and flatter than those with a lower spread ratio. Cookies made with SPF 120 have the largest diameter and the lowest thickness among the samples, as shown in Table 1. This highlights the significance of ingredient selection and formulation in achieving desired cookie characteristics, especially in terms of texture and appearance [14].

### 3.2 Colour Analysis

Table 2 highlights the observation of the cookie colours.

**Table 2** Effect of incorporation of sweet potato flour on the Colour Values

Sample	L*	a*	b*	Chroma (C*)	Hue Angle
Control	66.59	4.86	18.62	19.24	75.37
SPF 30	63.74	4.20	18.78	19.24	77.40
SPF 60	63.56	9.13	27.58	29.05	71.68
SPF 120	52.81	12.00	16.52	20.42	54.00

The control cookies demonstrated the highest L\* value (66.59), indicating a lighter colour compared to cookies made with sweet potato flour of various particle sizes. These cookies exhibited a relatively low a\* value (slight reddish tint) and a high b\* value (yellowish tint). This finding differs slightly from the previous study, who reported lower a\* and b\* values but a higher L\* value for control cookies [7]

The SPF120 sample exhibited the lowest L\* value (52.81), indicating darker coloration. It had an a\* value of 12.00 (slight reddish tint) and a b\* value of 16.52 (less pronounced yellowish tint). The reduction in L\* value was attributed to colour degradation processes, including the Maillard reaction and sugar caramelization [15]. Additionally, the larger diameter of SPF120 cookies and increased oven temperature effects likely contributed to this degradation.

Both SPF30 and SPF60 showed similar L\* values (~63), reflecting comparable lightness. SPF60 had an intermediate a\* value (9.13), indicating a moderate reddish tint, while SPF30's lower a\* value (4.20) suggested a less pronounced reddish tint. SPF60 displayed the highest b\* value, indicating the most pronounced yellowish tint, while SPF30's b\* value (18.78) was comparable.

Chroma analysis revealed that SPF60 had the highest saturation, indicating the most intense colour. The hue angle results showed that SPF30 and the control samples shared a similar dominant colour, while SPF60's intermediate hue angle (71.68) suggested a slightly different dominant colour. SPF120 had the lowest hue angle, indicating a distinct dominant colour.

Consistent with the previous study, this study found that flour particle size had minimal impact on cookie colour, with only slight variations in L\*, a\*, and chroma values [7]. Factors such as the Maillard reaction, caramelization, and baking conditions played more significant roles in influencing colour parameters.

### 3.3 Texture Analysis

Food texture encompasses hardness, smoothness, thickness, and other mouthfeel characteristics [11]. Hardness refers to the force required to compress a food item. In this study, it specifically denotes the force applied to compress cookies. Ensuring that the cookies are not excessively hard is crucial, as this would minimize the effort required by consumers during consumption.

**Table 3** Texture Analysis of cookies incorporated with sweet potato flour

Sample	Force (g)
Control	3032
SPF 30	4671
SPF 60	4530
SPF 120	4463

The data presented in Table 3 indicate that the reduction in flour particle size significantly influences the textural properties of cookies. Specifically, the hardness of cookies decreases as the particle size of the flour becomes smaller. Among the four samples, the control cookies exhibited the lowest compression force compared to samples containing SPF with varying particle sizes. A notable decrease in compression force, from 4671 to 4463, was observed as the particle size decreased from 30 mesh to 120 mesh.

Previous studies, including those by [7] have established that cookie hardness is closely linked to water absorption. Previous study reported that finer flour particles enhance the water absorption capacity of the dough

due to their increased surface area [16]. This characteristic allows finer particles to retain more water than coarser particles. Higher water absorption typically results in a stiffer dough, which spreads less during baking and yields thicker cookies. Conversely, it was suggested that smaller flour particles facilitate greater gluten development, resulting in a more elastic dough that spreads more readily during baking [17]. Previous study further highlighted that flour particle size influences the functional properties of flour, including water absorption, enzymatic starch conversion, starch damage, and baking quality [16].

The results of the current study reveal that SPF30 required the highest compression force, indicating that it produced the firmest cookies among the samples tested. This may be attributed to the tendency of coarser flour particles to absorb less water compared to finer particles. Reduced water retention leads to a drier dough, which can produce cookies that are harder and less chewy after baking. As noted, the hydration properties of the dough are critical in achieving the desired textural characteristics of cookies [18].

Furthermore, gluten development is influenced by flour particle size. Finer flours typically promote better gluten formation, contributing to a softer and more cohesive texture. In contrast, coarser flours may limit gluten development, resulting in denser and firmer cookies.

### 3.4 Sensory Evaluation and Statistical Analysis

The sensory evaluation results are presented in Table 4 and Table 5. The sensory attributes of the cookies were evaluated by 50 untrained panellists, consisting of students from UTHM, aged between 21 and 26 years. The panellists assessed five attributes: appearance, texture, colour, taste, and overall acceptance. The data collected from the evaluation were analysed using statistical analysis software, SPSS. This analysis reveals the acceptance of the cookies and the attributes affected by differences in the particle size of sweet potato flour.

**Table 4** Sensory characteristics of cookies incorporated with different particle sizes of sweet potato flour

Sample	Appearance	Texture	Colour	Taste	Overall Acceptance
Control	7.18 ± 1.424	7.00 ± 1.565	6.88 ± 1.520	7.48 ± 1.266	7.30 ± 1.199
SPF 30	7.42 ± 1.579	6.72 ± 1.819	7.48 ± 1.460	7.06 ± 1.921	7.14 ± 1.641
SPF 60	7.34 ± 1.733	6.28 ± 2.021	7.26 ± 1.601	6.92 ± 2.019	6.58 ± 1.970
SPF 120	7.74 ± 1.275	7.20 ± 1.629	7.58 ± 1.386	7.84 ± 1.346	7.62 ± 1.441

**Table 5** One-Way Anova Test of cookies

Attributes	Source	Degree of freedom (df)	Mean square	F	p-value
Appearance	Between groups	3	2.733	1.212	0.306
	Within groups	196	2.288		
	Total	199			
Texture	Between groups	3	7.947	2.544	0.57
	Within groups	196	3.123		
	Total	199			
Color	Between groups	3	4.813	2.156	0.095
	Within groups	196	2.322		
	Total	199			
Taste	Between groups	3	8.725	3.122	0.027
	Within groups	196	2.794		
	Total	199			
Overall Acceptance	Between groups	3	9.565	3.788	0.011
	Within groups	196	2.525		
	Total	199			

The results revealed no significant differences in the appearance of cookies ( $p = 0.306$ ), indicating that particle size did not notably affect visual characteristics. For texture, SPF 30 and SPF 60 received lower scores, suggesting these samples were less crispy and harder than the Control and SPF 120, although the differences were not

statistically significant ( $p = 0.057$ ). In terms of colour, SPF 120 and SPF 30 were rated higher, likely due to their richer hues, but the differences were not statistically significant ( $p = 0.095$ ).

Taste evaluations showed significant differences ( $p = 0.027$ ), with SPF 120 receiving the highest score and SPF 60 the lowest, likely due to the latter's harder texture affecting flavour perception. Lastly, for overall acceptance, SPF 120 was the most preferred ( $p = 0.011$ ), indicating that smaller particle sizes produced the most desirable cookies. In conclusion, while particle size influenced taste and overall acceptance, it did not significantly affect appearance, texture, or colour.

#### 4. Conclusion

This research concludes that the particle size of sweet potato flour significantly impacts cookies' physical, textural, colour, and sensory. The study showed that incorporating sweet potato flour (SPF) with varying particle sizes into cookies enhanced both their nutritional content and sensory qualities. Among the tested particle sizes, SPF120 produced cookies with the highest sensory acceptance, while SPF30 contributed to a firmer texture. These findings highlight the potential of sweet potato flour, particularly at the 120-mesh size, as a valuable ingredient for improving the nutritional value and consumer appeal of cookies. Future research should investigate the effects of other particle sizes and processing conditions on the texture, shelf life, and nutrient retention of sweet potato flour-based cookies.

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#### Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

#### Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Nursyafikah Aishah, Munira Zainal Abidin, Mohamad Zulhafiz Shafiq Zulhilmi Cheng; **data collection:** Nursyafikah Aishah; **analysis and interpretation of result:** Nursyafikah Aishah; **draft manuscript preparation:** Nursyafikah Aishah, Munira Zainal Abidin, Mohamad Zulhafiz Shafiq Zulhilmi Cheng. All authors reviewed the result and approved the final version of the manuscript.

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