Physicochemical and sensory characteristics of steamed brownies partially substituted with breadfruit flour

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Abstract. Steamed brownies are one of processed foods that are favored by consumers because of its delicious taste and its soft texture. Generally, wheat flour was used to make steamed brownies. In this study, breadfruit flour was used in making steamed brownies by partially substituting wheat flour. This study aimed to determine the effect of breadfruit flour substitution on the physicochemical and sensory characteristics of steamed brownies. The experimental design used was a Randomized Block Design (RAK) with 6 treatments and 3 replications. Breadfruit flour substitutions were BS0 (0%), BS1 (5%), BS2 (10%), BS3 (15%), BS4 (20%), and BS5 (25%). Physical analysis performed were texture, specific volume, color and yield. Chemical analysis performed were moisture content, ash content and crude fiber. Sensory test was hedonic test. Data was analyzed using Analysis of Variance (ANOVA) and the difference between treatment was tested using Duncan Multiple Range Test (DMRT). The result indicated that partial substitution of breadfruit flour significantly affected (P>0,05) specific volume, water contents, ash content, fiber content and yield of steamed brownies. But it didn't significantly affect the texture of steamed brownies. Partial substitution of 5% of breadfruit flour was preferred by panelist.

1. Introduction

Breadfruit (*Artocarpus altilis*) is a fruit rich in properties and benefits. Breadfruit plants have the potential to be used as an alternative staple food to replace rice because they contain high nutrients [1]. Breadfruit is rich in nutrients, so it has a good effect on health. The fiber content in breadfruit is believed to be able to lower cholesterol levels, lower blood pressure, protect the intestines from cancer and prevent excess weight. Breadfruit is very abundant in Indonesia but has a relatively short shelf life. As an option to extend the shelf life is by processing it become an added value product. Currently, breadfruit processing is limited to boiling, frying, drying, and making flour and chips.

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Breadfruit flour is a processed breadfruit product that can be used as an ingredient for food diversification. It can be processed into Oroti products and cakes [2]. Breadfruit flour is rich in calcium and fiber, making it a suitable substitute for wheat flour in making bakery products [3]. Several bread and cake products have been made using breadfruit, such as sweet bread [2], steamed sponge cake [4], semprong cake [5], and brownies made with orange sweet potato flour [6].

Brownies are a type of cake with a dark brown color with a denser texture. The creation of brownies stemmed from a failed attempt to make a chocolate cake that can't rise [7]. There are two types of brownies available on the market, namely steamed brownies and baked brownies with distinct characteristics. With the advancement of technology, brownies can be made by substituting wheat flour to make gluten-free products. Over the years, modifications have been made to make brownies, such as brownies made from eMOCAF flour, sweet potato flour, jackfruit seed flour, and rice flour mixtures (rice, starch, and cornstarch) [8]. However, sensory characteristics of products made with modified flour tend to be hard or dense, less elastic, and break easily [9].

Based on previous findings, this study was conducted to make steamed brownies using breadfruit flour as a substitute. This study aimed to determine the effect of breadfruit flour on physicochemical and sensory characteristics of steamed brownies using. This research is useful as an alternative to diversify local food ingredients and provides information on breadfruit flour substitutions in making steamed brownies.

2. Materials and Methods

2.1 Materials

In this study, the ingredients used were breadfruit flour (Mama Kamu) obtained from e-commerce (Kampoeng Organik) Surabaya, medium protein wheat flour (Segitiga Biru), eggs, granulated sugar (Gulaku), margarine (Palmia), chocolate bars (Collata), cocoa powder (Windmolen), SP (Ryoto), and salt (Cap Daun) obtained from cake ingredients shops.

2.2 Methods

2.2.1 Steamed brownies ingredients

The raw materials used in making steamed brownies are wheat flour, breadfruit flour, sugar, margarine, eggs, chocolate bars, cocoa powder, SP, and salt. The ingredient formulation for making steamed brownies using breadfruit flour can be seen in Table 1.

Table 1. Steamed brownies formulations

Ingredients	Samples					
	BS0	**BS1**	**BS2**	**BS3**	**BS4**	**BS5**
Wheat Flour (g)	50	47.5	45	42.5	40	37.5
Breadfruit Flour (g)	-	2.5	5	7.5	10	12.5
Sugar (g)	75	75	75	75	75	75
Margarine (g)	50	50	50	50	50	50
Eggs	2	2	2	2	2	2
Chocolate bar (g)	40	40	40	40	40	40
Chocolate powder (g)	15	15	15	15	15	15
SP (g)	5	5	5	5	5	5
Garam (sdt)	¼	¼	¼	¼	¼	¼

Note: Control (BS0); 5% breadfruit flour (BS1); 10% breadfruit flour (BS2); 15% breadfruit flour (BS3); 20% breadfruit flour (BS4); 25% breadfruit flour (BS5)

2.2.2 Brownies making

The process of making steamed brownies involves weighing the ingredients according to the recipe as depicted in Figure 1. The mixing process was divided into three stages. The first stage involved mixing eggs, sugar, salt, and SP using a mixer on speed 3 for 9 minutes until the mixture color turned white. The second stage was adding the sifted wheat flour, breadfruit flour, cocoa powder, and salt to the mixture using a mixer on speed 1 until the mixture was homogeneous, then beating for 1 minute. The third stage involved adding melted chocolate to the mixture using a spatula until evenly mixed, then pouring it into a baking pan. The next stage involved steaming for 20 minutes over medium heat until thoroughly cooked, then cooling [10].

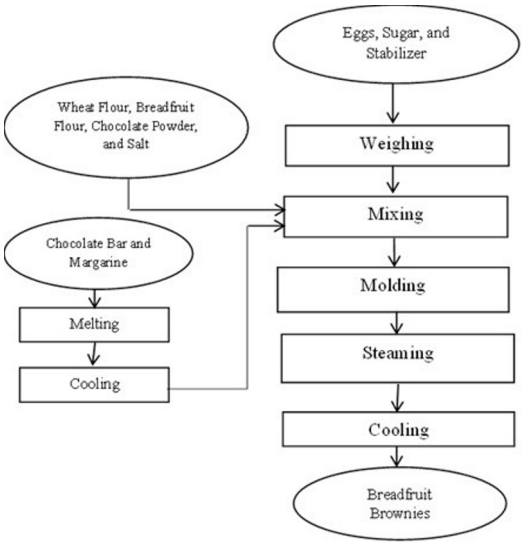

Fig. 1. Process flow in making steamed brownies

2.2.3 Experimental Design

This study used a Randomized Block Design (RAK) with 6 treatments and 3 replications. The treatments carried out in the study were as follows: BS0 (0% Breadfruit Flour), BS1 (5% Breadfruit Flour), BS2 (10% Breadfruit Flour), BS3 (15% Breadfruit Flour), BS4 (20% Breadfruit Flour), BS5 (25% Breadfruit Flour).

2.2.4 Texture

Texture profile analysis of steamed breadfruit brownies was conducted using a texture analyzer [11]. The steps involved placing a 3x3x3 cm sample on the machine table. Sample was then pressured with a probe used on texture analyzer. Texture analyzer was equipped with pre-installed computer and was run using a computer. The analysis results were displayed on the computer as a graph.

2.2.5 Specific volume

Specific volume measurements used small, uniformly sized grains (millet) [12]. The first step was to place the weighed steamed brownies sample into the steamed brownies container, filling it completely. Specific volume calculation was done using the following equation:

$$Specific\ volume\ (cm^3/g)\ = \frac{brownies\ volume}{brownies\ weight}$$

2.2.6 Yield

Yield measurement for steamed brownies was carried out based on [13]. The total flour used was compared to the weight of the resulting brownies. Yield calculation was done using the following formula:

$$Yield\ (\%) = \frac{W_3}{W_2} \times 100\ \%$$

Description:
W3 = weight of flour used (wheat flour + breadfruit flour)
W2 = final weight of steamed brownies

2.2.7 Color

Color testing was conducted on the crumb of the brownies using a chromameter [14]. Firstly, chromameter was calibrated using white color standard on the device. The measurement was done twice on each sample. Chromameter recorded the values of *L* (brightness level), *a* (redness), *b* (yellowness).

2.2.8 Water content

Moisture content analysis was conducted using gravimetric method [15]. An empty cup was dried in an oven for 1 hour, then cooled in a desiccator for 30 minutes, and then weighed (W0). Afterward, 1 gram of sample was weighed in the cup (W1). The sample in the cup was then dried in an oven at 105°C for 4 hours. After 4 hours, the sample and cup were cooled in a desiccator. The sample in the cup was then weighed to obtain the final weight (W2). If a constant weight has not been achieved, this process was repeated until a constant weight was achieved. Moisture content was calculated using the following formula:

$$Water\ content\ (\%) = \frac{W1 - W2}{W1 - W0} \times 100\%$$

2.2.9 Ash content

Ash content analysis was conducted using the gravimetric method [15]. An empty porcelain cup and its lid were dried in an oven at 105ºC for 1 hour. After that, the porcelain cup and its lid were cooled in a desiccator. The porcelain cup was weighed, and its weight was recorded. A sample of 3 grams was weighed in a porcelain cup and then was put in a furnace at 600ºC for approximately 8 hours. Sample was cooled to room temperature in a

desiccator and then weighed. Weighing was repeated until a constant weight was obtained. Ash content was calculated using the following formula:

$$Ash\ content\ (\%) = \frac{ash\ weight\ (g)}{sample\ weight\ (g)} \times 100\%$$

2.2.10 Crude fiber content

Crude fiber content was tested using a method in accordance with SNI 01-2891-1992. A sample of 2-4 g was weighed then the fat was removed using the Soxhlet extraction method for 4 hours. Sample was heated in an oven for 1 hour then put it into a 250 ml Erlenmeyer. A 50 ml of H_2SO_4 solution was added and heated to 200°C. A 50 ml of 3.25% NaOH was then added and heated for 30 minutes at 200°C. Then filtered it using filter paper. Afterward, put it in an oven at 105°C for 4 hours then cool it in a desiccator for 15 minutes. The crude fiber content was calculated using the following formula:

$$Fiber\ content\ (\%) = \frac{Initial\ Weight - Final\ Weight}{Sample\ weight} \times 100\%$$

2.2.11 Sensory evaluation

The hedonic test was conducted by 20 semi-trained panelists. The sensory attributes tested were color, aroma, taste, and appearance. The scale used to assess sensory attributes was from 1 to 5, where 1 means extremely dislike and 5 means extremely like.

2.2.12 Statistical analysis

Statistical analysis was performed using a 1-way ANOVA test. Duncan Multiple Range Test (DMRT) was performed with a significant level of 5%. Statistical analysis was performed using SPSS software for Windows 10.

3. Results and Discussion

3.1 Physical properties

The physical characteristics analysis that has been carried out includes texture, specific volume, yield and color. Tabel 2 represents effect of breadfruit flour on texture, specific volume, and yield of steamed brownies.

Table 2. Effect of breadfruit flour on texture, specific volume, and yield of steamed brownies

Sample	Texture (N)	Specific Volume (cm^3/g)	Yield (%)
BS0	3.63 ± 0.20^{a}	2.13 ± 0.12^{a}	15.69 ± 0.28^{a}
BS1	3.83 ± 0.31^{a}	2.04 ± 0.05^{ab}	15.43 ± 0.17^{b}
BS2	3.73 ± 0.70^{a}	2.00 ± 0.01^{bc}	15.29 ± 0.20^{bc}
BS3	3.62 ± 0.59^{a}	1.92 ± 0.06^{cd}	15.05 ± 0.17^{cd}
BS4	2.97 ± 0.27^{a}	1.88 ± 0.07^{de}	14.96 ± 0.13^{de}
BS5	2.96 ± 0.65^{a}	1.79 ± 0.02^{e}	14.73 ± 0.13^{e}

Note: Control (BS0); 5% breadfruit flour (BS1); 10% breadfruit flour (BS2); 15% breadfruit flour (BS3); 20% breadfruit flour (BS4); 25% breadfruit flour (BS5);
Different letters in the column indicated a significantly different analyzed by Duncan Multiple Ranga Test (DMRT) at 5%.

3.1.1 Texture

The texture of brownies was obtained by measuring the force used to press the brownies to determine the level of hardness of the brownies. The higher the texture value indicates that the brownies produced were harder. From the data in Table 2, the texture value of steamed brownies ranges from 2.96 to 3.83 N. The results of the ANOVA test in Table 2 show that the substitution of breadfruit flour did not have a significant effect ($P>0.05$) on the texture of steamed brownies. The average results of the texture test showed that the higher the substitution of breadfruit flour, the lower the hardness value.

3.1.2 Specific volume

The test results in Table 2 show that breadfruit flour substitution in steamed brownies significantly affected ($P<0.05$) the specific volume. The greater the breadfruit flour substitution, the greater the decrease in the specific volume of steamed brownies. The average specific volume of steamed brownies ranged from 1.79 to 2.13 cm3/g. There was a significant difference between the BS0 (100% Wheat Flour) and BS2 (90% Wheat Flour: 10% Breadfruit Flour) sample, but not significantly different from the BS1 (95% Wheat Flour: 5% Breadfruit Flour) treatments.

The decrease in specific volume in steamed brownies was due to the increased amount of breadfruit flour used. Breadfruit flour does not contain gluten, so it cannot bind water effectively, preventing the water in the dough from evaporating during the steaming process, resulting in the dough not rising and not being elastic. Wheat flour has a balanced gluten content, which allows for high elasticity in food products. If more wheat flour is added during the mixing process, it will produce a dough with more development [16]. If the water and fat content in the dough is not proportional, the emulsion system becomes unstable, the distribution of air and fat is uneven so that steamed brownies do not rise easily [17]. According to Sarofa [18] flour with high fiber content can reduce the ability of gluten to develop so that it can reduce product volume. This is supported by the high crude fiber content in breadfruit flour used in making steamed brownies, causing the specific volume of the product to decrease as the use of breadfruit flour increases.

3.1.3 Yield

The results in Table 2 show that the substitution of breadfruit flour in steamed brownies had a significant effect ($P<0.05$) on the average yield. The higher the concentration of breadfruit flour, the lower the yield. Sample BS0 (100% wheat flour) had the highest yield (15.69%), while BS5 had the lowest yield (14.73%). The DMRT test results showed a significant difference ($P<0.05$) in steamed brownies yield between the treatments. Sample of BS0 (100% wheat flour) was significantly different ($P<0.05$) to those of the samples with the addition of breadfruit flour. However, sample of BS1 (5% breadfruit flour) was not significantly different to that of BS2 (10% breadfruit flour).

The yield of a product is closely related to the functional properties of the ingredients used. Breadfruit flour has a high starch content. Breadfruit starch contains higher amylose than amylopectin [19]. The high amylose content in starch produces food products with a hard texture because they don't expand [20]. Differences in yield values can also be influenced by several factors during the process of making steamed brownies, such mixing and steaming.

3.1.4 Color

Partial substitution of breadfruit flour didn’t affect significantly ($P>0.05$) on the color of steamed brownies. Table 3 shows the effect of breadfruit flour on the color of steamed brownies. Figure 2 shows the color and appearance of steamed brownies partially substituted with different proportion of breadfruit flour.

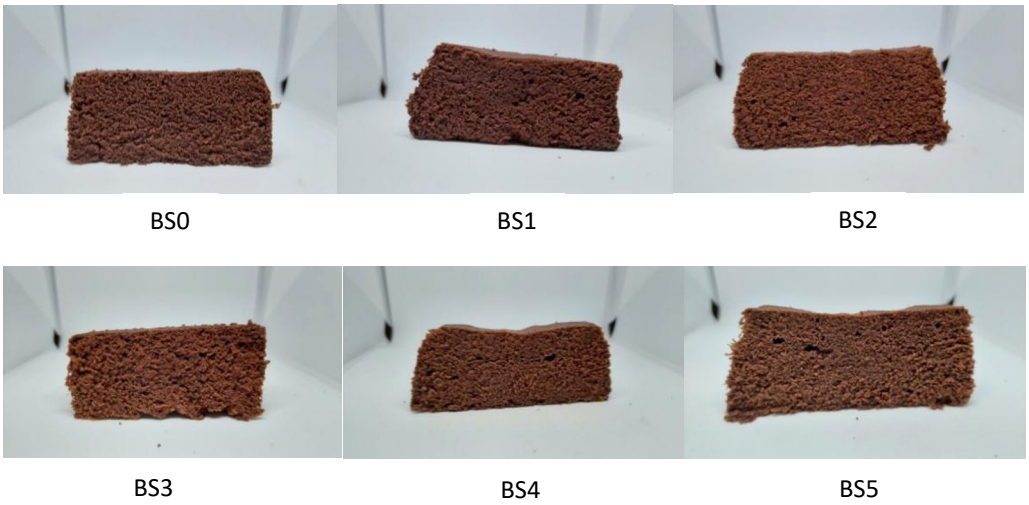

Fig. 2. Color and appearance of steamed brownies partially substituted with different proportion of breadfruit flour
Note: Control (BS0); 5% breadfruit flour (BS1); 10% breadfruit flour (BS2); 15% breadfruit flour (BS3); 20% breadfruit flour (BS4); 25% breadfruit flour (BS5)

Table 3. Effect of breadfruit flour on the color of steamed brownies

Sample	Crumb color		
	L	***a***	***b***
BS0	21.34 ± 1.96[a]	9.02 ± 1.02[a]	6.04 ± 1.49[a]
BS1	20.87 ± 2.62[a]	9.02 ± 1.16[a]	6.07 ± 0.89[a]
BS2	20.90 ± 2.20[a]	9.20 ± 0.74[a]	6.47 ± 0.32[a]
BS3	19.94 ± 3.63[a]	9.23 ± 1.30[a]	6.76 ± 2.61[a]
BS4	20.43 ± 1.85[a]	10.50 ± 1.37[a]	7.14 ± 0.82[a]
BS5	19.72 ± 2.83[a]	10.61 ± 2.97[a]	7.34 ± 2.20[a]

Note: Control (BS0); 5% breadfruit flour (BS1); 10% breadfruit flour (BS2); 15% breadfruit flour (BS3); 20% breadfruit flour (BS4); 25% breadfruit flour (BS5)
Different letters in the column indicated a significantly different analyzed by Duncan Multiple Ranga Test (DMRT) at 5%.

The results in Table 3 show that the color values (*L, a, b*) of steamed brownies with breadfruit flour were not significantly different (P>0.05). The color of food products is influenced by the raw materials used. Steamed brownies were made using the same amount of block chocolate and powdered chocolate, so the resulting color did not differ between all treatments. This was also because cocoa and chocolate pigments masked the color effect of breadfruit flour. This finding also in accordance with that of the results from Muhammad [10] that reported steamed brownies color made from arrowroot and barley flour were not significantly different among the samples.

3.2 Chemical properties

Chemical properties of steamed brownies partially substituted with breadfruit flour are presented in Table 4.

Table 4. Effect of partial substitution of breadfruit flour on chemical properties of steamed brownies

Sample	Water Content (%)	Ash Content (%)	Crude Fiber (%)
BS0	23.93 ± 0.73^{bc}	1.53 ± 0.07^{d}	0.27 ± 0.01^{f}
BS1	23.64 ± 0.46^{bc}	1.70 ± 0.06^{c}	0.47 ± 0.01^{e}
BS2	23.45 ± 0.28^{c}	1.75 ± 0.04^{c}	0.68 ± 0.01^{d}
BS3	24.01 ± 0.25^{bc}	1.78 ± 0.02^{bc}	0.87 ± 0.01^{c}
BS4	24.31 ± 0.06^{b}	1.87 ± 0.05^{b}	1.10 ± 0.20^{b}
BS5	25.10 ± 0.14^{a}	2.03 ± 0.09^{a}	1.31 ± 0.10^{a}

Note: Control (BS0); 5% breadfruit flour (BS1); 10% breadfruit flour (BS2); 15% breadfruit flour (BS3); 20% breadfruit flour (BS4); 25% breadfruit flour (BS5)
Different letters in the column indicated a significantly different analyzed by Duncan Multiple Ranga Test (DMRT) at 5%.

3.2.1 Water content

Moisture content is an important characteristic of food ingredients because it is related to their shelf life. Moisture content can affect the texture and taste of food products. Table 4 shows that the moisture content of steamed brownies ranges from 23.93 to 25.10%. The moisture content of steamed brownies does not exceed the moisture content standard for sweet breads in SNI 01-3840-1995, which is a maximum of 40%. This indicates that the moisture content of steamed brownies meets Indonesia National Standard (SNI).

The results showed that the substitution had a significant effect ($P<0.05$) on moisture content of breadfruit flour of steamed brownies. The higher the breadfruit flour was used, the higher the moisture content of steamed brownies. The BS5 sample showed the highest value of moisture content compared to those of the other treatments. The results of DMRT test showed that BS0 (100% Wheat Flour) was not significantly different to those of BS1 (5% Breadfruit Flour) and BS3 (15% Breadfruit Flour) but significantly different to those of BS2 (10% Breadfruit Flour), BS4 (20% Breadfruit Flour) and BS5 (25% Breadfruit Flour). Nurcahyo [21] reported that low gluten content resulted in a weaker water binding capacity so that the release of water molecules was easier.

The water content of steamed brownies in this study was in line with the research conducted by Paramita et al. [6], which showed that water content of steamed brownies made from composite flour (wheat flour, breadfruit flour and sweet potato flour) tended to increase with the increase of breadfruit flour.

3.2.1 Ash Content

Based on Table 4, it indicated that partial substitution of breadfruit flour significantly affected the ash content of steamed brownies. The DMRT test showed that the ash content in BS0 (100% Wheat Flour) was significantly different ($P<0.05$) to those of all samples. The sample BS5 (25% breadfruit flour) showed the highest ash content. As the concentration of breadfruit flour increased, the ash content of steamed brownies increased accordingly. According to Nurcahyo et al. [21], the increase in ash content was due to the higher ash content of breadfruit flour than that of wheat flour. Astuti et al. [22] reported that the higher ash content in non-flaky crackers was due to relatively abundant mineral content in breadfruit flour, such as potassium and calcium.

The ash content of steamed brownies in this study was in accordance with the finding by Paramita et al. [6], which showed that ash content increases with the use of breadfruit flour

in steamed brownies. Basrin's [5] showed that the higher the concentration of breadfruit flour, the higher the ash content of "Semprong" cake.

3.2.1 Crude Fiber Content

Table 4 shows that breadfruit flour substitution significantly affected ($P<0.05$) the crude fiber content of steamed brownies. The average fiber content obtained from steamed brownies with breadfruit flour substitution ranged from 0.27 to 1.31%. The crude fiber content in steamed brownies increased with increasing breadfruit flour. This is due to breadfruit flour having a higher fiber content than that in wheat flour. The highest fiber content (1.31%) was found in the BS5 sample (25% Breadfruit Flour). The lowest fiber content (0.27%) was found in the BS0 sample (100% Wheat Flour).

The higher proportion of breadfruit flour produced higher fiber content in non-flaky crackers [22], steamed brownies made from composite flour containing breadfruit flour [6], and "Semprong" cake [5].

3.3 Sensory Properties

Sensory properties of steamed brownies partially substituted with breadfruit flour are presented in Table 5. Partial substitution of breadfruit flour significantly affected ($P<0.05$) the sensory properties of steamed brownies.

Table 5. Effect of breadfruit flour on sensory properties of steamed brownies

Sample	Color	Aroma	Taste	Texture	Appearance
BS0	3.87 ± 0.20^{c}	3.93 ± 0.06^{ab}	3.92 ± 0.08^{ab}	4.02 ± 0.15^{ab}	3.95 ± 0.15^{bc}
BS1	4.18 ± 0.03^{a}	4.05 ± 0.15^{a}	4.17 ± 0.29^{a}	4.18 ± 0.23^{a}	4.23 ± 0.10^{a}
BS2	3.95 ± 0.09^{bc}	3.90 ± 0.05^{abc}	3.73 ± 0.08^{bc}	3.80 ± 0.09^{bc}	4.02 ± 0.13^{bc}
BS3	3.95 ± 0.17^{bc}	3.92 ± 0.06^{ab}	3.77 ± 0.03^{bc}	3.82 ± 0.06^{bc}	4.10 ± 0.10^{ab}
BS4	4.08 ± 0.03^{ab}	3.77 ± 0.16^{bc}	3.57 ± 0.17^{c}	3.83 ± 0.03^{bc}	3.98 ± 0.06^{bc}
BS5	4.08 ± 0.06^{ab}	3.68 ± 0.20^{c}	3.55 ± 0.26^{c}	3.73 ± 0.03^{c}	3.87 ± 0.03^{c}

Note: Control (BS0); 5% breadfruit flour (BS1); 10% breadfruit flour (BS2); 15% breadfruit flour (BS3); 20% breadfruit flour (BS4); 25% breadfruit flour (BS5)
Different letters in the column indicated a significantly different analyzed by Duncan Multiple Ranga Test (DMRT) at 5%.

Based on Table 5, partial substitution of breadfruit flour significantly affected ($P<0.05$) all parameters in the sensory test of steamed brownies, namely color, aroma, taste, texture, and appearance. In the color and appearance parameters, the panelists gave a higher preference rating for brownies with the addition of breadfruit flour compared to the control. Meanwhile, in the aroma, taste, and texture parameters, the panelists gave scores that were not significantly different ($P<0.05$) between the control brownies and those with the addition of breadfruit flour up to 20%.

Color is one of the factors that can determine quality because it appears visually first, making it an important sensory attribute [22]. The aroma of food ingredients significantly determines the deliciousness of the resulting food product [2]. The aroma is generated from the composition of steamed brownies such as chocolate, sugar, margarine, and breadfruit flour. Increasing the substitution of breadfruit flour decreased the preference score for the aroma of steamed brownies. This is due to the distinctive aroma of breadfruit flour, which slightly reduces the chocolate aroma. Taste is also an important factor in determining whether panelists will accept a food product or not ([2]. In terms of taste, each treatment influenced panelists' responses due to the presence of a distinctive breadfruit aftertaste (bitterness), which was unacceptable to most panelists. The cause of the bitter taste in breadfruit is because it contains components such as tannin, HCN and phytic acid [22]. According to Saepudin et al., [2], texture is related to taste during the process of chewing food because taste consists

of 3 main components, namely smell, taste, and oral stimulation. According to Manteu et al. [23], appearance is the primary factor that determines a panelist's preference for other sensory properties. Generally, consumers tend to evaluate a product's appearance when selecting food. Steamed brownies are characterized by their soft and fluffy texture.

4. Conclusions

Partial substitution of wheat flour with breadfruit flour significantly reduced the specific volume and yield of steamed brownies but did not significantly affect their texture and color. Partial substitution with breadfruit flour also significantly increased the moisture content, ash content, and fiber content of steamed brownies. All sensory properties of steamed brownies, namely color, aroma, taste, texture, and appearance, were significantly affected by the addition of breadfruit flour. Partial substitution of breadfruit flour increased the preference scores for color and appearance. However, the substitution decreased the preference scores for aroma, taste, and texture of steamed brownies. Based on the results of the physical, chemical, and organoleptic characteristics, partial substitution using breadfruit flour can be recommended in making steamed brownies.

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