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Physical, chemical, and organoleptic characteristics of chiffon cake with pregelatinized candi banana flour substitution (*Musa paradisiaca* L.)

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Abstract

Chiffon cake is often made using low-protein wheat flour, an imported item. Bananas, on the other hand, are abundantly available and may be used to replace wheat flour in the production of chiffon cake partially. This research aimed to compare the attributes of best-treated and control chiffon cakes to establish the optimal replacement ratio between the two kinds of banana flour. This study used a randomized nested design (NESTED) with two major factors: raw candi banana flour (P1) and pregelatinized candi banana flour (P2). Minor factors were the ratios of wheat flour to Candi banana flour, including R1, R2, R3, and R4 (0:100, 25:75, 50:50, and 75:25). The chiffon cake was examined through the use of physical, chemical, and organoleptic techniques. The optimal ratio for making chiffon cake was discovered to be 50:50 when using raw candi banana flour with the characteristic development volume of 104.25%; 0.562 mm^2 pore uniformity; 226.30 g hardness; 0.62 cohesiveness; 7.73 mm springiness; 21244.03 ppm antioxidant activity, and total phenol content of 9.78 mg GAE/g. The best ratio when using pregelatinized candi banana flour was 75:25 with characteristic development volume of 121.22%; 0.57 mm^2 pore uniformity; 240.40 g hardness; 0.64 cohesiveness; 7.76 mm springiness; 25306.65 ppm antioxidant activity, and total phenol content of 8.57 mg GAE/g. The chiffon cake's properties differ significantly from the control by its fat content, antioxidant activity, and total phenol content. According to the results, pregelatinized and raw banana flour can be used instead of wheat flour. According to the sensory test, the panelists couldn't distinguish between the chiffon cake made completely of wheat flour and the one made with banana flour.

1. Introduction

A chiffon cake is a sponge cake with evenly spaced intercellular gaps or pores (Ningsih and Pangesthi, 2013). Chiffon cakes are made using low-protein wheat flour and additional ingredients such as vegetable oil, eggs, salt, sugar, baking powder, and cream of tartar (Sirisoontaralak *et al*., 2017). Chiffon cake created with wheat flour influences the development of gluten-produced dough. Gluten may trap gases in the dough, making it stickier, stretchier, and more formable (Prasetyo, 2019). Indonesia's wheat imports amounted to 6.4 million tonnes from January to August 2022 (Central Bureau of Statistics, 2022a). Finding a new equal or alternative for wheat flour is thus critical. Regional commodities such as banana flour might serve as alternatives (Yasinta *et al*., 2017).

Indonesia's banana output was 8.74 million tonnes in 2021 (Central Bureau of Statistics, 2022b). Candied banana flour is more attractive and has a brighter color than other banana kinds. It also has a higher starch content (68.89-75.20%) and a lower sugar content (17.77 -18.31%) (Permata, 2018). Given that chiffon cake requires low-protein flour, banana flour may be substituted for wheat flour. Banana flour has 2% more fiber than wheat flour, which increases its water-binding ability (WHC) (Fida *et al*., 2020). Even while candied banana flour offers benefits over wheat flour, it has drawbacks such as low water absorption and a poor gel consistency when used in cakes.

Pregelatinization is a physical modification process that includes heating starch in water until it becomes gelatinized at a temperature higher than the gelatinization point, then drying it in a cabinet drier (Florentina *et al*., 2015). Banana flour was pregelatinized by making a 1000 mL solution with a 35% w/v concentration, heating it for 10 mins at 75°C, and then

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drying it for 6 hrs at 50°C in a cabinet drier (Permata, 2018). Pregelatinization may be altered to improve the functional properties of flour, such as its solubility, water absorption capacity, and swelling power (Kuswandari *et al*., 2013). According to Carillo-Navas *et al*. (2016), pregelatinized flour in cakes increases a softer texture and dough rheology that may keep elasticity, lessens water loss from the dough during baking and storage, and reduces product staling. Pregelatinized flour may be found in cake mixes, baby food, and fast dinners (Kusnandar, 2019).

To create chiffon cakes with the optimum physical, chemical, and organoleptic features, this study seeks to determine the ratio of pregelatinized candi banana flour to candi banana flour. Additionally, to see if the chiffon cake made using pregelatinized candi banana flour in place of candi banana flour differed in any way from the control chiffon cake in terms of its chemical properties (moisture, ash, protein, fat, and carbohydrate content).

2. Materials and methods

2.1 Banana flour making

One thousand grams of fresh bananas with three different maturity levels were weighed and sliced into chips. Banana chips were dried for five hrs at 45°C in a cabinet dryer. Then ground and sieved using a 120-mesh sieve.

2.2 Pregelatinization of banana flour

Three hundred and fifty grams of flour were used. The 1000 mL water and 1000 mL of a suspension with a 35% w/v concentration of banana flour were mixed. The suspension was heated for ten mins at 75°C. The banana suspension sheets were dried for 6 hrs at 50°C in a cabinet dryer. The dried suspension was then grounded and sieved.

2.3 Chiffon cake production

Soybean oil, water, skim milk, salt, and sugar were all mixed with the egg yolk batter. The egg yolk batter was made by combining flour, banana flour and baking powder. These components were sifted before being thoroughly combined with a dough mixer. In a separate bowl, the egg whites were mixed with the cream of tartar. Combine with a high-speed mixer until frothy. Once a meringue that is neither too hard nor too soft is obtained, add sugar gradually and evenly to all components to make an egg-white combination. The egg white mixture was gradually added to the egg yolk mixture. The dough should be baked in a 165°C oven for 40 mins on top and bottom and 10 mins on the bottom.

2.4 Development volume characteristics analysis

V1 was the volume of the dough measured before baking. V2 was the volume of cakes that had been baked and allowed to cool at room temperature for an hr. The following formula was used to determine the expansion volume:

$$\%\,Development = \frac{V2 - V1}{V} \times 100$$

Where V1: Measurement results on the dough before baking and V2: Measurement results on the dough after baking.

2.5 Pore uniformity analysis

The sample was sliced to expose the pores' whole surface. Samples were scanned and then picked for the most exact scan results. Image J was used to analyze the scan results.

2.6 Texture profile analysis

The sample was cut into 5×3×2 cm squares. The sample was placed under the probe of the texture analyzer. The Texture Analyzer CT3 was set up to gather data on cohesion, springiness, and hardness (Ametek, 2013).

2.7 Color analysis

Cut samples were placed in transparent plastic. The color was measured by aiming the color reader at the sample and pushing the target button. The readings of L, a*, and b* were noted, with L* representing the brightness and a* and b* describing the chromaticity coordinates (Yuwono and Susanto, 2001).

2.8 Antioxidant analysis

After weighing up to 1 g, the sample was dissolved in 10 mL of pro-analysis methanol and macerated for 4 hrs. The solution samples' concentrations varied from 5000 ppm to 9000 ppm. A total 2 mL of 0.1 mM DPPH reagent was added to a 2 mL test tube containing the sample solution and methanol pro-analysis (only methanol with no sample as blank control). The solution was well blended in a vortex and then incubated for 30 mins in a dimly lighted area. The absorbance of the solution at 517 nm was measured using a UV-VIS spectrophotometer. The % of DPPH inhibition was calculated using the method of Chen *et al*. (2013) with some modifications:

$$\%\text{ DPPH inhibition} = \frac{\text{Absorbance control} - \text{Sample}}{\text{Absorbance control}} \times 100$$

2.9 Phenol analysis

A total of 5 g of sample was dissolved in 10 mL of

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pro-analytical methanol and macerated for 4 hrs. A 0.5 mL test tube was filled with the sample solution. The Folin-Ciocalteu reagent was diluted to 10% (v/v) in a 2.5 mL test tube. Na_2CO_3 was put in a two mL test tube. The solution was well blended in a vortex and then incubated for 30 mins in a dimly lighted area. The solution's absorbance was measured at 765 nm using a UV-VIS spectrophotometer. According to the following formula (a modification of Sharma *et al*., 2011), the percentage of total phenol was determined.

$$Total\ Phenol\ Concentration\ (\%)\ \frac{(x) \times F \times V}{g} \times 100$$

2.10 Organoleptic analysis

The hedonic test for the panels included 50 participants. Each participant gets eight samples of chiffon cake with varied ratios. The panelists were given the sample in a container. Each sample was assigned a three-digit code. The panelists taste the sample before assessing it on a hedonic scale of 1 to 7, based on their individual tastes.

2.11 Experiment design

The experimental design was a Nested Random Design (NESTED) with two treatment components. The type of flour with two levels, Candi banana flour and pregelatinized Candi banana flour, was in factor I (major). The ratio of wheat flour to candied banana flour, also known as pregelatinized candi banana flour, has four levels: 0: 100, 25: 75, 50: 50, and 75: 25. This was called factor II (minor). Using this experimental design, eight experimental combinations with multiple variables were created. The measurement was repeated three times to acquire 24 experimental units. Meanwhile, hedonic test questionnaires were utilized to collect data on the panelists' level of preference, and the data was then processed using software to conduct the organoleptic research (Minitab 17).

3. Results

3.1 Characteristics of raw materials

Table 1 shows that both types of banana flour have better water content, total sugar, and total phenol than wheat flour. According to Table 1, both varieties of banana flour contain more water, total sugar, and total phenol than wheat flour. The overall sugar content of banana flour and pregelatinized banana flour was considerable due to the presence of sugar in the major ingredient, banana. Total sugar consists of all types of monosaccharides or disaccharides in the product regardless of the source (Mela and Woolner, 2018). Since bananas are rich in phenolic components such as phenolic acids, flavonoids, and catecholamines, banana flour has a greater total phenol concentration than wheat flour (Mahloko *et al*., 2019). While the highest starch content is in wheat flour because starch is the primary component of whole wheat seeds, which are frequently utilized to create various food products (Kim and Kim, 2021).

3.2 Physical characteristics of chiffon cake

According to Table 2, the quantity of wheat flour used significantly influences the volume of chiffon cake ($\alpha = 0.05$). The expansion volume was the capability of the dough to produce and store gas. Volume development was a vital factor in customer product acceptance (Justicia *et al*., 2012). The expansion volume and pore homogeneity were strongly connected. Good expansion volume will increase pore uniformity. It is commonly known that the different types of flour considerably impact how uniform the pores are. The pores of the chiffon cake created with banana flour were smaller than those made with pregelatinized flour because the starch granules were still intact.

A higher percentage of banana flour or pregelatinized banana flour results in lower hardness, cohesiveness, and springiness properties. Hardness is a property that shows how much force must be applied to a product before it changes or deforms (Muhandri and Subarna, 2019). Cohesiveness is the product's intrinsic bonding force that creates and maintains the structure (Muhandri and Subarna, 2019). The capacity of a product to resume its initial state following the application of the first style is known as springiness (Syah, 2018). A softer texture may be inferred from chiffon cake produced with or without modified banana flour.

3.2.1 Color crumb

The L, a, and b values received from the color reader

Table 1. Characteristics of raw materials.

Parameter	Banana flour	Pregelatinized banana flour 75°C	Wheat flour
Water content (%)	9.49±0.12	7.99±0.08	12.5 (USDA, 2019)
Starch content (%)	41.54±1.88	33.76±1.55	70-75 (Moiraighi *et al.,* 2019)
Total sugar (%)	5.78±0.21	6.10±0.10	0.31 (USDA, 2019)
Total phenol (mg GAE/g)	12.51±0.27	9.68±0.17	0.177-0.257 (Vaher *et al.,* 2010)

Values are presented as mean±SD of triplicates.

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Table 2. Physical characteristics of chiffon cake are due to differences in ratio contained in type of flour.

Type of flour	Ratio (wheat flour: banana Flour)	Volume expansion (%)	Uniformity (mm2)	Hardness (g)	Cohesiveness	Springiness (mm)
Banana flour	0:100	64.39±4.91^{d}	0.378±0.02^{d}	286.63±10.84	0.52±0.04^{d}	7.95±0.39
	25:75	91.57±10.92^{c}	0.469±0.02^{c}	229.95±24.33	0.62±0.03^{bc}	7.12±0.77
	50:50	104.25±3.82^{b}	0.562±0.01^{a}	226.30±54.98	0.62±0.02^{c}	7.73±1.60
	75:25	117.94±4.04^{a}	0.497±0.05^{b}	263.18±57.83	0.62±0.02^{abc}	8.35±0.56
Pregelatinized Banana flour	0:100	67.39±7.75^{d}	0.508±0.01^{c}	221.78±71.99	0.61±0.03	8.04±0.64
	25:75	89.20±1.14^{c}	0.528±0.02^{b}	182.70±53.30	0.63±0.01	7.55±1.10
	50:50	102.23±5.05^{b}	0.550±0.01^{a}	214.65±56.20	0.65±0.01	7.83±0.44
	75:25	121±2.41^{a}	0.457±0.03^{d}	40.40±78.85	0.64±0.04	7.76±1.23

Values are presented as mean±SD of triplicates. Values with different superscripts within the same column are statistically significantly different (α = 0.05).

may be used to determine the color of a chiffon cake made using pregelatinized and regular banana flour. Figure 1 depicts the outcomes of converting the data (L*, a*, and b*) into #HEX and RGB codes. The brightness of chiffon cake created with pregelatinized banana flour was lower than that of chiffon cake made with raw banana flour. The hue of banana flour was brighter than pregelatinized banana flour, which accounts for the difference in brightness of the ingredients.

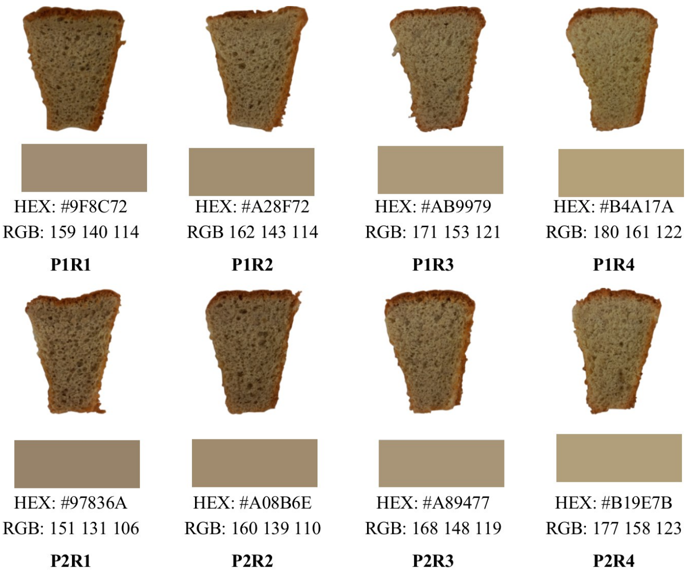

Figure 1. Color spectrum chiffon cake. P1R1: Banana flour 0:100, P2R1: Pregelatinized banana flour 0:100, P1R2: Banana flour 25:75, P2R2: Pregelatinized banana flour 25:75, P1R3: Banana flour 50:50, P2R3: Pregelatinized banana flour 50:50, P1R4: Banana flour 75: 25 and P2R4: Pregelatinized Banana flour 75:25.

3.3 Chemical characteristics of chiffon cake

Substituting banana flour and pregelatinized banana flour in chiffon cake resulted in antioxidant activity varying from 21095.63 ppm to 25458.29 ppm. The results showed that the raw banana flour chiffon cake had higher antioxidant activity (IC_{50}) than the pregelatinized banana flour chiffon cake (Table 3). Antioxidants are natural compounds in food that may neutralize free radicals in cells. The presence of antioxidant components in the ingredients influences the high antioxidant activity in non-pregelatinized cakes. Making banana flour requires just one heating step without pregelatinization. Pregelatinization was achieved by repeated heating. Heating at greater temperatures for longer periods destroys more phenolic compounds. Compared to the decrease in phenolics, antioxidant action was low (Zahara *et al*., 2017).

3.4 Sensory

Color, aroma, texture, taste, and overall likeness were all assessed using Friedman Test criteria, demonstrating that the treatment had a substantial effect across samples (p = 0.05). On the other hand, aroma and flavor traits remained unaffected (Table 4). The ratio of chiffon cake with the greatest average preference was 50:50, while the ratio with the lowest was 100:0. Nonetheless, the panelists found the sample with the lowest average preference to be pleasant. They liked it since the average result for all samples was still more than three. It indicated that consumers continued to accept the replacement of wheat flour for banana flour in all ratios.

4. Discussion

In this investigation, a larger percentage of wheat flour yielded a better development value. These findings support the findings of Basuki *et al*. (2016), who found that the volume of development caused by the gluten protein rises with the quantity of wheat flour. Gluten impacts the volume and strength of the finished product due to its ability to trap gas during baking. This makes it easier for the dough to expand. However, utilizing pregelatinized banana flour resulted in a very excellent volume development based on the typical value of chiffon cake product development. One purpose of pregelatinized flour was to improve the ultimate

Table 3. Antioxidant activity of IC_{50} and total phenol due to differences in nested ratio in type of flour.

Type of flour	Ratio (wheat flour: banana flour)	Antioxidant activity (ppm)	Average total phenol content (mg GAE/g)
Banana flour	0:100	22272.86±3139.41	12.57±0.21[a]
	25:75	21095.63±2873.33	10.88±1.00[b]
	50:50	21244.03±2009.63	9.78±0.52[c]
	75:25	24088. 00±2681.28	8.51±0.45[d]
Pregelatinized Banana flour	0:100	23992.98±3325.69	11.95±0.70[a]
	25:75	22326.55±2358.67	10.26±0.23[b]
	50:50	25458.29±2986.94	9.83±0.17[c]
	75:25	25306.65±2910.63	8.57±0.50[d]

Values are presented as mean±SD of triplicates. Values with different superscripts within the same column are statistically significantly different (α = 0.05).

Table 4. Sensory characteristics due to differences in nested ratio in types of flour.

Type of flour	Ratio (wheat flour: banana flour)	Colour	Aroma	Texture	Taste	Overall liking
Banana flour	0:100	4.82±0.92	5.26±1.27	5.36±1.19	5.20±1.14	5.10±0.84
	25:75	5.12±0.98	5.26±1.14	5.44±0.97	5.48±1.13	5.48±0.97
	50:50	5.34±1.00	5.28±1.16	5.68±1.00	5.56±1.13	5.58±0.93
	75:25	5.44±1.25	4.98±1.38	5.50±1.16	5.26±1.32	5.44±1.13
Pregelatinized Banana flour	0:100	4.42±1.39	4.90±1.16	4.58±1.42	4.84±1.31	4.62±1.16
	25:75	5.06±1.02	5.02±0.82	5.16±1.11	5.38±0.97	5.18±0.94
	50:50	5.02±1.22	5.14±1.16	5.46±1.43	5.38±1.40	5.30±1.18
	75:25	5.16±1.06	5.05±1.07	5.56±1.30	5.44±1.16	5.42±0.86

Values are presented as mean±SD of triplicates.

development of the cake. Because pregelatinized flour has a more open starch structure, it absorbs more water and has stronger hydrogen bonds. As a result, there was minimal water loss during baking, and the cake developed to its full potential (Carillo-Navas *et al*., 2016). Using varied proportions of banana flour may increase the sugar content of the dough as well as the gelatinization temperature during baking. The volume of the cake rises because of the more tenuous gluten generated by a temperature increase (Muhandri *et al*., 2021). Adding eggs to the dough will help it rise by trapping air throughout the mixing process (NZIC, 2017). Temperature and baking time are two more factors that influence volume expansion. The heat from the oven induces many chemical reactions that affect the volume and chiffon structure of the result (Sitanggang, 2021).

The pore homogeneity of the chiffon cake was improved by employing pregelatinized banana flour. Bread pores (tiny cells or air holes) form during the fermentation and baking processes. The formation of cake pores during dough preparation, when air was introduced, and CO_2 gas was produced (Murtini *et al*., 2020). Because the starch granules are still intact, the pores of banana flour chiffon cake are smaller than those of pregelatinized flour. Pregelatinized starch absorbs water more effectively than ordinary starch. Little water loss during baking results in a moister cake with outstanding texture and expansion (Liu *et al*., 2019). This was consistent with pregelatinized banana flour's higher water absorption value of 75.50% against banana flour's 67.00%. The cake with the best pore homogeneity had a well-balanced ratio of wheat flour to banana flour. Gluten's propensity to retain water, air, and carbon dioxide gas allows the cake to expand and form more consistent pores, influencing these results (Valentine *et al*., 2015). Adding meringue created from egg whites and extra sugar also affects pores. Because meringues with air bubbles are protected by egg protein walls, the cake texture added to the meringue was softer, and the pores are better (Suryaatmadja *et al*., 2021).

The high addition rate of modified or unmodified banana flour resulted in a softer cake. Changes to the gelatinization process of the flour may result in cake softness. The open nature of pregelatinized starch makes it easy to bind water. High quantities of bound water may soften the cake's texture (Salsabilla and Fahruroji, 2021). Using heat during cooking increases the possibility of water loss due to evaporation, which might impact the product's hardness. Furthermore, water

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evaporation toughens the cake's texture (Sholichah *et al*., 2020).

Pregelatinization improves the texture of the product and makes it more compact. One way to get a compact texture was to increase water absorption. High water absorption leads to a more solid texture. According to the properties of pregelatinized flour, which rapidly homogenizes the dough and improves the overall quality of the cake (Ntau *et al*., 2017). According to pregelatinized flour, heating reduces amylose and increases amylopectin. Amylopectin from the amorphous area improved the starch's ability to expand and provide a stable outcome (Haryanti *et al*., 2014). The amylose in the flour leaches owing to cooking, raising the amylopectin content and improving the flexibility of the pregelatinized chiffon cake. According to Fadhallah *et al*. (2021), the springiness of a material was inversely proportional to its amylopectin content. The quantity of springiness produced rises as amylopectin levels rise. Amylopectin more efficiently and less rigidly attaches to the gel.

Large quantities of banana flour substitute resulted in a brownish product with a color that was notably different from the yellow color of chiffon cakes. The brown color of the product was caused by phenolic compounds and heat-resistant natural pigments such as carotenoids and flavonoids (Tarigan, 2019). The cake's color may develop dark due to both enzymatic and non-enzymatic processes. An enzymatic reaction occurs when the phenol oxidase in banana flour catalyzes the oxidation process and browning (Anwar and Kristiastuti, 2019). Non-enzymatic reactions include caramelization processes, which occur when sugar was heated, and Maillard reactions, which involve reducing sugar groups and free amino groups in proteins. These interactions culminate in the formation of a dark melanoidin pigment (Muhandri *et al*., 2021).

According to Sriti *et al*. (2014), a lower IC_{50} value denotes enhanced antioxidant activity due to the concentration's efficiency in preventing free radicals from attaching to DPPH. The antioxidant activity shown was very weak because the concentration was more than 500 ppm (Kameliani *et al*., 2020). The decrease in antioxidants was caused by heating at higher temperatures and for a longer time, thereby damaging more phenolic compounds (Zahara *et al*., 2017). Because the raw material contains limited phenol, the cake has a low phenol level. Substitution using raw banana flour can increase the total phenol content because the raw banana flour was higher in phenolic compounds than pregelatinized banana flour. During heat and moisture treatment in pregelatinization, exposure to oxygen can activate phenoloxidase enzymes and destroy phenols in components (Pardede, 2017). As in the research of Mau *et al*. (2014) the more phenolic sources, the higher the total phenol product. Even though the phenolic compound of the product was significantly different between the treatments, the antioxidant content was not significantly different. This result was in agreement with Sulaiman (2011) who found that there was a low correlation between antioxidant activity with phenolic content in banana samples. This may also lead by the low phenolic content of the raw materials, but damage can still occur due to high temperatures used in producing wheat and chiffon cake. At temperatures exceeding 50°C, the bioactive components that make up antioxidants, such as phenols, tannins, and flavonoids, might be decreased (Yuliantari *et al*., 2017).

In this research, the organoleptic analysis was carried out using the hedonic test, or the panelists' degree of preference. The appearance, flavor, texture, and general acceptance of the chiffon cake samples were among the test criteria. Raw and pregelatinized banana flour is dark because it contains the enzyme phenol oxidase, which causes browning (Anwar and Kristiastuti, 2019). The panelists' cake choices show a preference for cakes with vibrant colors. The aroma measure cannot differentiate between the scents of various samples. Although the roasting process causes numerous volatile compounds to evaporate, adding banana flour is designed to bring out the distinct aroma of banana flour. This, however, does not affect the panelists' aroma preferences (Eriyana *et al*., 2016). The judges couldn't determine whether more or less flour had been added, indicating that the texture of the banana-flour chiffon cake was still satisfactory. The taste requirements include bitter, sour, salty, and sweet feelings (Tarwendah, 2017). The investigation results indicated that the banana flour treatment did not affect the panelists' assessment. The panelists provide a biased assessment of chiffon cake perceived preference, with varying ratios depending on overall like qualities ranging from 5.1 to 5.58. The panelist's preference for chiffon cake added with banana flour tends to like it because there was an increase in sweetness due to the high total sugar content in both banana flours. The increase in sweetness can be done by adding ingredients with high sugar content so that taste improvement is achieved and the panelists are more popular (Abdillah *et al*., 2014).

5. Conclusion

Pregelatinized banana flour has significantly different qualities than raw banana flour in redness, starch content, IC_{50} antioxidant activity, and total phenol concentration. The replacement ratio of nested flour in

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the type of flour had a significant ($p<0.05$) effect on the expansion volume, colour (L*, a*, b*), pore homogeneity, cohesiveness, and total phenol content. On the other hand, hardness, springiness, and antioxidant activity did not vary much. Variations in the replacement ratio of banana flour nested in various flour types significantly influenced the organoleptic test of color features and overall like. However, there was no discernible difference in taste, texture, or scent. The amount of pregelatinized banana flour in this kind greatly impacts the product's color, texture, flavor, and overall acceptability. Banana flour, both pregelatinized and raw, can replace wheat flour.

Conflict of interest

The authors declare no conflict of interest.

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