

TEKNOBUGA Vol. 15 No.1 (2027)

p-ISSN 2085 4056
e-ISSN 2528 7087

**JURNAL TEKNOLOGI BUSANA DAN BOGA**

https://journal.unnes.ac.id/journals/teknobuga/index

# Dragon Fruit Peel Puree Substitution in Quality of MOCAF Crispy Brownies

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**ABSTRACT** - This study aimed to evaluate the effects of red dragon fruit peel puree substitution on hedonic acceptance, water and protein contents, color, and texture characteristics of MOCAF crispy brownies. A one-factor completely randomized design was employed with four substitution levels (0%, 20%, 25%, and 30%) and two repetitions. Hedonic acceptance was assessed by 40 semi-trained panelists using a nine-point scale. The data were analyzed using the Kruskal–Wallis and Mann–Whitney tests for sensory attributes and Duncan's Multiple Range Test for physicochemical properties. The 25% substitution level achieved the highest overall acceptance (7.55) and texture preference (7.73). The 30% substitution level produced the highest protein content (8.19%), while moisture contents ranged from 1.92% to 2.71% across treatments. Color analysis revealed no significant differences in lightness (L*), whereas redness (a*) and yellowness (b*) differed significantly among treatments. The 20% substitution level exhibited the highest instrumental hardness, while the 30% level showed the highest cohesiveness. Substituting 25% red dragon fruit peel puree offers the most promising formulation for sensory acceptance, demonstrating its potential as a value-added ingredient in MOCAF crispy brownies.

**Keywords**: MOCAF; crispy brownies; red dragon fruit peel puree; hedonic acceptance; physicochemical properties.

## INTRODUCTION

Red dragon fruit peel puree represents a major processing byproduct that remains underutilized despite being rich in dietary fiber and antioxidant betacyanins. Concurrently, incorporating high-moisture ingredients into crispy brownies poses a technical challenge because excessive moisture directly compromises the crisp texture required for thin bakery products. Additionally, there is a growing market demand to develop gluten-free bakery products using locally sourced composite materials like Modified Cassava Flour (MOCAF) to reduce national dependency on imported wheat. Making red dragon fruit peel puree is such a diversification effort of agricultural waste on bakery formulation.

Brownies are bakery products that categorized as dense cakes. They are composed by wheat flour, sugar, eggs, fat (butter or oil), and chocolate or cocoa powder. They could have variety of textures, from light and cake like to fudgy and chewy, and they have a rich chocolate flavor (Jenkins, 2026).

Steamed brownies have a water content which ranges from 22.76% to 37.51%. since that, they fall under the intermediate-moisture food group. The type of flour formulation and steaming time have an impact on water content (Mointi et al., 2023; Setyadjid & Setiyaningrum, 2022). Steamed brownies without artificial preservatives often only survive three to four days at room temperature before quality degradation starts because of their relatively high-water content and water activity. However, their shelf life may increase to 8-10 days if kept in the closed container in a refrigerator (Hasna et al., 2022). Crispy brownies that packed in aluminum-foil pouches can last for 10-11 months (Liesetiasari et al., 2025). Biscuits or cookies packed in metallized or aluminum-foil packaging have a a shelf life approximately 6-12 months (Singh et al., 2023). Whereas, ordinary transparent plastic packaging may provide a

shorter shelf life of only 3-4 months (Rajini et al., 2021). In order to reduce water content, crispy brownies are made in a thin form to produce a crisp texture (Tanuwijaya et al., 2025).

Dry brownies, also known as crispy brownies, are low-moisture baked goods that have a crisp texture and are rather stable in storage. Wheat flour, chocolate or cocoa powder, fat like butter or oil, granulated or powdered sugar, and eggs are some of their primary ingredients (Lubis et al., 2021; Prezeor et al., 2025; Situmorang et al., 2025). Shabrina et al. (2025) reported that crispy brownies produced by wheat flour, and breadfruit flour had water contents ranging from 3.54% to 7.13%, and the formulation with 100% breadfruit flour had the lowest water content, at 3.54%. According to Praseti & Fathonah (2026), gluten-free thin brownies made from rice flour and mung bean flour had protein values ranging from 7.64% to 10.69% and water contents of 1.03-1.54%, meeting the maximum water requirement of 5% in SNI 2973:2022. Red dragon fruit peel puree is a potential ingredient for crispy brownies because it contains bioactive elements, and may add values as a functional food ingredient (Cahyani et al., 2025).

MOCAF is cassava flour modified through fermentation using microorganism (Lubis et al., 2021). It contains approximately 85-87% carbohydrates, and 2-6% dietary fiber. Its fat content is below 1%, while its protein content is about 1-2%, because some proteins are broken down during fermentation (Situmorang et al., 2025; Marlina & Refialy, 2025). Therefore, this study used red dragon fruit peel puree as a substitute ingredient in a MOCAF formulation. The benefit of MOCAF is completely gluten-free, making it safe for anyone with celiac disease or gluten intolerance (Lubis et al., 2021). It holds great potential as a substitute for wheat flour. In this study, MOCAF was used in the production of crispy brownies incorporating red dragon fruit peel puree as a substitute ingredient.

Red dragon fruit peel puree has a smooth, porridge-like texture and is semi-processed. It is made by mechanically blending the peel of red dragon fruit (*Hylocereus polyrhizus*) after it has been cleaned and briefly heated (Cahyani et al., 2025).

Red dragon fruit peel puree (*Hylocereus polyrhizus*) may be used as a dietary fiber source to improve the nutritional value of MOCAF-based crispy brownies. It contains 82-90% water, 6-12% carbohydrates, 3-6% dietary fiber, 0.6-1.5% protein, 0.1-0.6% fat, and 0.5-1.2% ash. The puree also contains betacyanin, flavonoid, and phenolic chemical that acts as natural antioxidants and provide a reddish-purple color. These fiber and bioactive compounds may improve the nutritional and functional properties of crispy brownies (Alhafiz & Suprapto, 2025; Cahyani et al., 2025).

Previous studies have interested MOCAF and fruit-based ingredients in bakery products. Rahman et al. (2021), used MOCAF to replace wheat flour in coconut butter cookies at levels of 0% as control, 20%, 50%, 75%, and 100%. the 50% formulation was the most preferred because it produced a crisp texture and desirable flavor. Parameswari & Handayani (2024) found that replacing 20% of the MOCAF-based cookie with tempeh flour was well accepted and increased protein content. Pratama et al. (2022) added red dragon fruit puree at 10%, 20%, and 30% to MOCAF cookies. The 20% formulation was most preferred in terms of color and crispness. Lestari & Handayani (2023), reported that dry brownies with 15% banana puree were the most preferred and had optimal crispness. Fitriani & Rosida (2024) found that up to 20% of a red dragon fruit and papaya puree mixture in MOCAF-based biscuits maintained good sensory acceptance and product structure.

Previous literatures demonstrated an isolated applications of these ingredients in bakery formulations. However, none of these studies analyzed the combined integration of red dragon fruit peel puree and MOCAF specifically inside low-moisture crispy brownies, leaving a critical gap regarding how this fiber-dense waste matrix alters gluten-free thin-baking structures. The core contribution of this study is utilizing red dragon fruit peel puree to optimize the quality parameters of gluten-free MOCAF crispy brownies. This configuration provides a novel functional product evaluated comprehensively across sensory parameters, water and protein content, CIE L* a* b* color analyze, and texture profile analysis.

Therefore, this study aimed to examine red dragon fruit peel puree substitution at 0% (control), 20%, 25%, and 30% on hedonic acceptance, water and protein content, and the physical characteristics on color and texture of MOCAF crispy brownies. The hypothesis states that the substitution levels will significantly influence the hedonic acceptability, water and protein content, and the physical characteristics of the crispy brownies results.

# METHOD

## Study Design

The results of the preliminary trials that had been done, red dragon fruit peel flour was first used to substitute wheat flour in crispy brownies and used *Collata* dark compound chocolate at concentrations of 20%, 25%, and 30%.

The chocolate flavor was not strong enough, and the products still had an astringent, sap-like taste. Then it was continued to the second trial by changing the main ingredient, the wheat flour with MOCAF also changed the red dragon fruit peel flour into a puree. The second trial conducted at the same concentration: 20%, 25%, and 30%, did not yet produce optimal results. In the third trial, two types of dark compound chocolate, *Colatta* and *Callebaut*, were compared while using the puree. The 20% formulation with *Colatta* produced better crispness, although a slight sap-like taste remained. In the final optimization trial, the 20% and 25% puree formulations produced crisp brownies without the sap-like taste, whereas the 30% formulation retained a slight aftertaste.

This study used a one-factor Completely Randomized Design (CRD), with two repetitions for each formulation. The treatments consisted of four red dragon fruit peel puree substitution levels: 0%, 20%, 25%, and 30%; the amount of MOCAF flour was adjusted according to each substitution level.

## Experimental Procedure

The main ingredients used to make brownies include wheat flour, granulated sugar, and cocoa powder (Gusnita & Holinesti, 2022; Babe et al., 2022). The batter also required fat, such as butter or margarine, and eggs (Marlina & Refialy, 2025). These five ingredients are always used in the basic brownie formulation (Amalia et al., 2026). The formulation was modified by varying the proportions of MOCAF and red dragon fruit peel puree, as presented in **Table 1**. Preliminary trials were conducted to ensure acceptable product quality.

**TABLE 1**. Formulation (g) MOCAF Crispy Brownies with Red Dragon Fruit Peel Puree

| Ingredient | 0% | 20% | 25% | 30% |
|---|---|---|---|---|
| MOCAF | 180 g | 144 g | 136 g | 128 g |
| Red Dragon Fruit Puree | - | 36 g | 44 g | 56 g |
| Cocoa Powder | 20 g | 20 g | 20 g | 20 g |
| Dark Chocolate | 400 g | 400 g | 400 g | 400 g |
| Egg | 200 g | 200 g | 200 g | 200 g |
| Margarine | 240 g | 240 g | 240 g | 240 g |
| Powdered Sugar | 440 g | 440 g | 440 g | 440 g |

Source: (Praseti & Fathonah, 2026)

The analyses included hedonic acceptance, nutritional composition, and physical characteristics. The hedonic test involved 40 semi-trained students from the Culinary Education Program, Universitas Negeri Semarang. The inclusion criteria required panelists to have successfully completed in Food Quality Analysis subject, possessed documented experience in organoleptic profiling, and passed basic taste-acuity tests to ensure rigorous, reliable, assessments. The panelists rated color, taste, texture, aroma, and overall acceptability using a 9-point scale.

**TABLE 2**. Hedonic Scale

| Skala | Hedonic Grate |
|---|---|
| 9 | Like Extremely |
| 8 | Like Very Much |
| 7 | Like Moderately |
| 6 | Like Slightly |
| 5 | Neither Like or Dislike |
| 4 | Dislike Slightly |
| 3 | Dislike Moderately |
| 2 | Dislike Very Much |
| 1 | Dislike Extremely |

Source: (Badan Standardisasi Nasional, 2021)

## Statistical & Analytical Methods

Protein and water contents were analyzed in duplicate at the Saraswati Indo Genetech Laboratory Semarang. Color was measured at the Poultry Production Laboratory (UPT) Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, using a CR-400 *Chroma Meter*. The measured parameters were *lightness* (L*), *redness* (a*), dan

*yellowness* (b*) (Minolta, 2021). Texture was analyzed at the *Unit Pelaksana Teknis* (UPT) Laboratory Universitas Diponegoro Semarang using *Texture Profile Analysis (TPA)*, with *hardness, cohesiveness, springiness*, dan *chewiness* (Bourne, 2002; Trinh & Glasgow, 2021). Hedonic data were analyzed using SPSS software (IBM Corp, 2023)**.** The Kruskal–Wallis test was applied, followed by the Mann–Whitney test when a significant difference was found ($p < 0.05$) (Field, 2018; Hintze, 2024).

# RESULTS AND DISCUSSION

## Hedonic Acceptance Analysis

The hedonic test was conducted to determine panelists' acceptance of MOCAF crispy brownies containing different levels of red dragon fruit peel puree. The assessed attributes were color, aroma, texture, taste, and overall acceptability. Hedonic testing is a sensory evaluation method used to determine the extent to which consumers like a food product (Xia et al., 2021). In this study, 40 students from the Culinary Education Program at Universitas Negeri Semarang participated and rated the samples on a 9-point scale. The data were first tested for normality. Because the data were not normally distributed, the non-parametric Kruskal–Wallis test was used to compare treatments. When a significant difference was detected ($p < 0.05$), pairwise comparisons were performed using the Mann–Whitney test (Kurniawan et al., 2022).

**TABLE 3**. Mann-Whitney Test Results for Hedonic Acceptance

| Substitution | Mean Value ± SD | | | | |
|---|---|---|---|---|---|
| | Color | Aroma | Texture | Taste | Overall |
| 0% | $6.63 \pm 1.56^{a}$ | $5.93 \pm 1.61^{a}$ | $6.30 \pm 1.64^{a}$ | $6.40 \pm 1.71^{a}$ | $6.43 \pm 1.57^{a}$ |
| 20% | $6.23 \pm 1.63^{a}$ | $6.28 \pm 1.41^{a}$ | $5.85 \pm 1.86^{a}$ | $6.50 \pm 1.58^{a}$ | $6.30 \pm 1.56^{a}$ |
| 25% | $7.18 \pm 1.39^{b}$ | $7.18 \pm 1.20^{b}$ | $7.73 \pm 1.06^{b}$ | $7.45 \pm 1.45^{b}$ | $7.55 \pm 1.32^{b}$ |
| 30% | $6.43 \pm 1.30^{a}$ | $6.15 \pm 1.46^{a}$ | $6.43 \pm 1.58^{a}$ | $6.60 \pm 1.30^{a}$ | $6.65 \pm 1.17^{a}$ |

Note: Means with the same superscript letter within a column are not significantly different ($p > 0.05$).

The mean panelist ratings for each sensory attribute and treatment are presented in **Figure 1**.

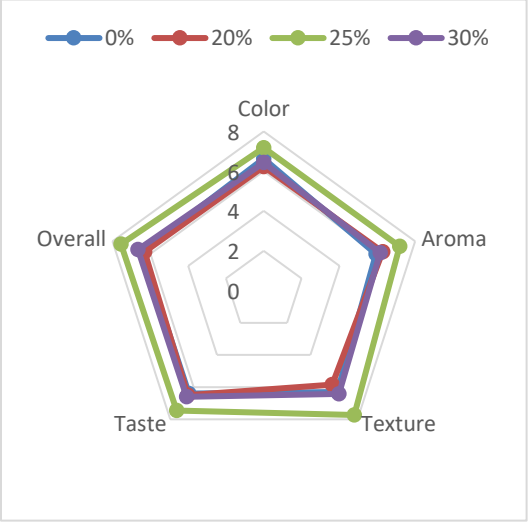



**Figure 1**. Hedonic Score Means

In the color preference, the 25% substitution level received the highest score. The color of crispy brownies results from the brown color of the main ingredients combined with betacyanin pigments in red dragon fruit peel puree, which can produce a reddish-purple hue (Khoo et al., 2022 in Adelina et al., 2024)**.** The color produced by the 25% substitution level reached the best score on the panelists' preferences. A higher puree level does not necessarily

improve acceptance, because the product may become darker due to pigment interactions and color changes during baking, including non-enzymatic browning. These changes are related with the heat in the baking process (Adelina et al. 2024).

Aroma is also influenced by compounds formed during baking and by the characteristic aroma of added ingredients (Ngasar et al., 2025). The 25% substitution level achieved the highest mean score (7.18), suggesting that the combination of chocolate aroma and red dragon fruit peel puree aroma was most preferred by the panelists. This finding is related to Mai et al. (2023), that reported adding 25% red dragon fruit peel flour in the cookies batter still remained acceptable to panelists. At a higher substitution level, the characteristic aroma of the peel may become more noticeable and may not be as well balanced with the chocolate aroma. The present finding is consistent with the general evidence that the level of fruit-derived ingredients can influence sensory acceptance, although the optimum level depends on the formulation and type of bakery product.

The 25% substitution level also received the highest texture-acceptance score, at 7.73. This finding is important because crispness is a defining characteristic of crispy brownies. Puree adds water to the batter and may affect the product structure after baking. The peel fiber also interacts with water and may therefore alter texture. Excessive puree may reduce crispness or make the product structure more fragile (Jannah, Laga, Abriana, Halik, et al., 2024). This finding is related to Adelina et al. (2024), who reported that the use of 25% red dragon fruit peel flour in cookies batter was the most preferred percentage that rated by panelist in terms of texture attribute. It shows that 25% substitute of red dragon fruit peel puree I s the optimum level on the formulation so it was acceptable to the panelists' preference.

For taste, the highest score was again observed at the 25% substitution level (7.45). Red dragon fruit peel puree changes the batter composition and introduces components such as fiber and phenolic compounds that may affect sensory properties (Jiang et al., 2021 in Adelina et al., 2024). Red dragon fruit peel has a characteristic bitter taste, which may be associated with tannins interacting with glycoproteins in the peel (Noor et al., 2016). The preliminary trials in this study similarly found that the 30% formulation retained a slight aftertaste, whereas the 20% and 25% formulations did not. This provides a plausible explanation for why increasing the puree to 30% did not further improve taste acceptance. This result differs from some previous studies have reported that lower acceptance as the amount of red dragon fruit peel puree or flour increases (Dyah Kumalasari & Devira, 2024; Mai et al., 2023). In contrast, the 25% substitution level in this finding achieved the highest acceptance, suggesting a more balanced and preferred flavor. Such differences may arise from the ingredient form (puree or flour), the product matrix, the proportion used, and the intensity of the peel's characteristic flavor.

Overall acceptance was highest for the 25% substitution level, and this result differed significantly from the other treatments. Overall evaluation reflects panelists' judgment after considering several sensory attributes, including color, aroma, texture, and taste (Rahardjo et al., 2026). The highest overall score for the 25% formulation indicates that its combined sensory characteristics were more acceptable than those of the other formulations. This may be due to a balance among the individual sensory attributes. Cookies that made from a mixture of MOCAF and red dragon fruit peel flour could achieve good sensory acceptance (Adelina et al., 2024). It is consistent with study of Mai et al. (2023), who reported that cookies containing 25% red dragon fruit peel flour remained sensory acceptable. It validates the fact that a moderate substitution level produces the most consumer acceptance to the MOCAF-based bakery products containing fruit-derived ingredient.

## Nutritional Value

**TABLE 4**. Duncan's Multiple Range Test on Nutritional Value

| Substitution | Mean Value ± SD | |
|---|---|---|
| | Water (%) | Protein (%) |
| 0% | $1.92 \pm 0.35^{a}$ | $6.91 \pm 0.07^{a}$ |
| 20% | $2.65 \pm 0.56^{b}$ | $7.01 \pm 0.13^{a}$ |
| 25% | $2.70 \pm 0.07^{b}$ | $7.05 \pm 0.13^{a}$ |
| 30% | $2.71 \pm 0.02^{b}$ | $8.19 \pm 0.09^{b}$ |

Note: Means with the same superscript letter within a column are not significantly different ($p > 0.05$).

*Water Content*

According to the DMRT results in **Table 4**, the 0% substitution treatment had the lowest water content and differed significantly from the 20%, 25%, and 30% treatments. Adding 20% red dragon fruit peel puree increased water content by approximately 38%. Subsequent increases in puree substitution did not produce significant differences; the increase from 20% to 25% was only about 2.65%. This pattern indicates that the addition of puree increases the water content of the final product. Bassey et al. (2024) reported that red dragon fruit peel contains a high-water level of approximately 82.91%, and drying significantly changes its water content. Therefore, adding the puree introduces additional water into the product. This finding is consistent with Jannah et al. (2024), who reported a 3% increase in cookie water content following the addition of 5% red dragon fruit peel puree. The increase may also be related to the peel's dietary fiber, pectin, and bioactive compounds. Pectin is present in both fresh and dried red dragon fruit peel. The peel has a high water-holding capacity, which may be related to interactions with starch during heating (Jiang et al., 2021; Chumroenvidhayakul et al., 2022; Tristanto et al., 2024). Flour composition is another factor that affects water content (Hartika et al., 2025). The stable water content across the three puree treatments suggests that the additional puree did not produce a proportional increase in residual moisture in the finished brownies, potentially because of moisture loss during baking and differences in water retention by the peel's fiber and pectin. All treatments had water contents below 5%, meeting the maximum water requirement stated in SNI 2972:2022 for biscuits. Nevertheless, water content alone does not establish crispness; water distribution, water activity, and the structure formed during baking may also influence texture.

*Protein Content*

Protein analysis showed a tendency for protein content to increase as the proportion of red dragon fruit peel puree increased. The 30% substitution treatment had the highest protein content and differed significantly from the 0%, 20%, and 25% treatments. The increase from 0% to 25% was relatively small (1.45%) and was not statistically significant. At the 30% substitution level, protein content increased by 18.52%. Astuti et al. (2025), reported a protein content of 9.24% in red dragon fruit peel. While MOCAF contains approximately 2% protein (Gaol et al., 2023). The puree may therefore contribute additional protein at the 20% and 25% levels, although the increase was not significant at these levels. At 30%, the greater proportion of peel puree may have contributed to the significant increase in protein content. This result is consistent with Adelina (2024), who found that protein content increased with increasing red dragon fruit peel flour addition. The sharp rise in protein at the 30% level perfectly supports the study by Parameswari & Handayani (2024), confirming that dragon fruit peel compounds provide significant raw protein replenishment when integrated into low-protein bases like MOCAF. The scientific explanation driving these matching trends lies in the high water-holding capacity of the peel's structural polysaccharides, which encapsulate moisture inside the matrix and prevent complete evaporation during baking. However, the present results indicate that a significant increase was only observed at the 30% level. Thus, the highest protein content did not coincide with the highest sensory acceptance, which occurred at 25%. Formulation selection should therefore consider the chemical content together with sensory quality and physical characteristics.

## Physical Characteristic

*Color*

Color is an important food attribute because it contributes to consumers' visual perception of a product. Product color depends on the ingredients, natural pigments, water content, and reactions occurring during baking. Red dragon fruit peel puree may impact the product color because it contains betacyanin, a pigment that produces red to reddish-purple hues and can be used as a natural food colorant (Nurbaya et al., 2023)**.** Color was analyzed at the Poultry Production Laboratory (UPT), Universitas Diponegoro. The parameters were L* for lightness [0 (black) to 100 (white)], a* for green (negative values) to red (positive values), and b* for blue (negative values) to yellow (positive values) (Brühl & Unbehend, 2021). The results are presented in **Table 5**.

**TABLE 5.** Duncan's Multiple Range Test on Color Analysis

| Parameter | Mean Value ± SD | | | | p-value |
|---|---|---|---|---|---|
| | 0% | 20% | 25% | 30% | |
| L* | $39.90 \pm 1.19^{a}$ | $37.74 \pm 0.20^{a}$ | $39.14 \pm 0.87^{a}$ | $37.23 \pm 0.16^{a}$ | 0.069 |
| a* | $3.47 \pm 0.04^{c}$ | $2.64 \pm 0.06^{b}$ | $2.79 \pm 0.14^{b}$ | $2.08 \pm 0.14^{a}$ | 0.001* |
| b* | $3.17 \pm 0.02^{c}$ | $2.31 \pm 0.11^{b}$ | $2.45 \pm 0.18^{b}$ | $1.49 \pm 0.12^{a}$ | 0.001* |

Note: Means with the same superscript letter are not significantly different ($p > 0.05$). An asterisk (*) indicates a significant difference ($p < 0.05$).

The L* (lightness) values of the crispy brownies did not differ significantly ($p > 0.05$). Thus, adding red dragon fruit peel puree at substitution levels of 0%–30% did not significantly affect product lightness. This suggests that the range of substitution used was insufficient to produce a significant difference in the final product. Heating can produce brown pigments through Maillard reactions and caramelization, and the pigments in the added ingredient may interact with these color changes during baking (Jati et al., 2024). This result is consistent with Chumroenvidhayakul et al. (2022), who found no significant difference in L* values in cookies substituted with red dragon fruit peel flour. The brown color of cocoa and chocolate, together with browning reactions during baking, may have reduced the visible effect of the puree pigments on lightness.

The a* (redness) values differed significantly among treatments ($p < 0.05$). Based on the DMRT results, the 0% substitution treatment had the highest value and differed significantly from the 20%, 25%, and 30% treatments. The 20% and 25% treatments did not differ significantly, whereas the 30% treatment had the lowest a* value and differed significantly from the other treatments. Although the pattern was not linear, the a* values generally indicated a significant decline in red color intensity as substitution increased. This differs from findings for other bakery products from the study by Jati et al. (2024), who reported that increasing a* values with increasing red dragon fruit puree in steamed buns and doughnuts. In the present study, puree addition significantly affected a*, but the direction of change was a decrease, indicating that puree concentration was not the only factor determining red color intensity. The contrasting pattern may reflect differences in the product matrix, pigment stability during baking, and interactions between the peel pigments and the dark cocoa-chocolate base.

The b* (yellowness) values also differed significantly ($p < 0.05$). The 0% substitution treatment had the highest value and differed significantly from the 20%, 25%, and 30% treatments. The 20% and 25% treatments did not differ significantly, while the 30% treatment differed significantly from the other treatments. This indicates a reduction in the yellow component of the measured color as puree substitution increased. The trend agrees with (Chumroenvidhayakul et al. 2022), who reported lower b* values in cookies containing more red dragon fruit peel flour. Similar decrease in b* values as red dragon fruit peel flour increased in cookies. This decrease was an impact of Maillard browning during heating may contribute to change in the surface color of the product (Adelina et al., 2024). Taken together, the L*, a*, and b* results show that the puree affected the red and yellow components more clearly than lightness.

*Texture*

**TABLE 6**. Texture Analysis Results

| Substitution | H1 (g) *(Hardness)* | H2 (g) *(Hardness)* | Cohesiveness | Springiness | Adhesiveness |
|---|---|---|---|---|---|
| 0% | 207.5 | 18.8 | 0.02 | 0.1 | 0.10 |
| 20% | 347.5 | 48.3 | 0.03 | 0.1 | 0.10 |
| 25% | 144.2 | 5.7 | 0.01 | 0.0 | 0.07 |
| 30% | 162.7 | 8.2 | 0.05 | 0.0 | 0.05 |

The texture results for the crispy brownie treatments are illustrated in **Figure 2** and **Figure 3**.

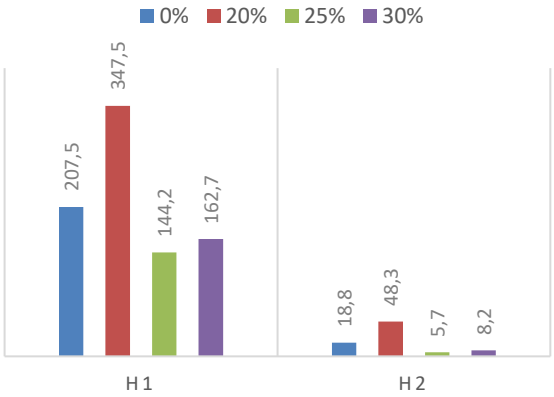



**FIGURE 2.** Hardness 1 & Hardness 2 Results

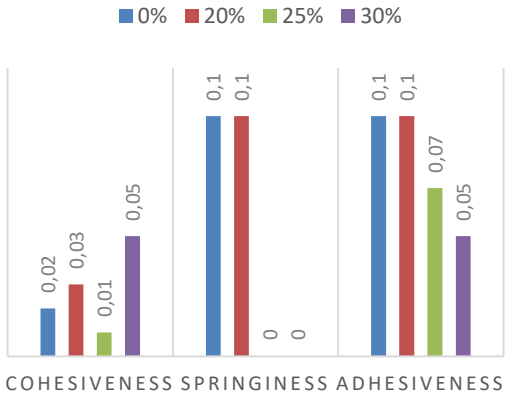



**FIGURE 3**. Cohesiveness, Springiness, Adhesiveness Results

Hardness during the first compression (H1) indicates the initial resistance of MOCAF crispy brownies to deformation, whereas hardness during the second compression (H2) indicates the resistance remaining after the first compression. H1 and H2 are obtained from the peak force in each cycle. H2 is lower than H1 because the sample has already undergone structural deformation during the first compression (Goh et al., 2026; Rosenthal, 2024). A higher H1 value means that greater force is required to deform the sample during the first compression. The highest H1 value was observed at 20% substitution, while the lowest was observed at 25%. The high H1 value at 20% indicates greater initial resistance to compression. This difference may be related to the balance among MOCAF, puree, and water in the brownie formulation (Jonkers et al., 2022).

The second hardness value represents the maximum force required during the second compression and indicates the structural resistance remaining after deformation. In this study, H2 was highest at 20% substitution and lowest at 25%. The lower H2 value compared with H1 indicates that the brownie structure changed during the first compression, so less force was required during the second compression (Shin & Choi, 2021). The 20% brownies may therefore have been perceived as too firm, while the lower compression force of the 25% brownies may have provided a more acceptable crisp bite. This interpretation is consistent with Lestari & Handayani (2023), who reported that dry gluten-free brownies containing 15% banana puree were most preferred and had optimal crispness, and with (Pratama et al., 2022), who found the 20% red dragon fruit puree formulation most preferred for crispness in MOCAF cookies. Differences in optimum substitution levels may be related to the type of puree, fiber composition, product thickness, and baking conditions.

Cohesiveness describes the ability of a product's internal structure to remain intact despite deformation. It is calculated by comparing the work performed during the second compression with that during the first compression. The highest value was found at 30% substitution, suggesting that the sample's internal structure was more able to remain intact after compression (Jonkers et al., 2022). Increasing the concentration of red dragon fruit peel puree may increase cohesiveness in bakery products (Jati. et al, 2024). This result related to the fiber and pectin in the peel puree, which can affect water binding and the structure of a food matrix.

Springiness describes the ability of a product to return to its original shape after deformation. The 0% and 20% substitution treatments had springiness values of 0.1, whereas the 25% and 30% treatments had values of 0.0. This indicates a lower ability to recover the original shape at the 25% and 30% levels. Increased puree may raise the fiber content of the batter, restricting the matrix's ability to recover after compression (Jati. et al. 2024). Unlike soft, elastic foods, crispy brownies are generally expected to fracture rather than recover their original shape; therefore, springiness alone is not a direct indicator of desirable crispness.

Adhesiveness is the force required to detach the probe from the sample surface after contact. Adhesiveness values decreased as the concentration of red dragon fruit peel puree increased. This may be affected by the substitution level, test conditions, and TPA settings, particularly the compression ratio and probe speed. Changes in TPA conditions can produce differences in adhesiveness values (Shin & Choi, 2021).

Taken together, the sensory, moisture, and texture results show why the 25% formulation was preferred even though the 20% formulation had the highest hardness. Water content among the puree-containing treatments was

statistically similar (2.65%–2.71%), so the sensory difference cannot be explained by residual water content alone. The 20% sample's higher H1 and H2 values indicate greater resistance to compression, which may have produced a firmer bite that panelists liked less. At 25%, lower hardness coincided with the highest texture and overall acceptance scores, suggesting a more favorable balance of crispness and ease of biting. At 30%, water content changed very little, while cohesiveness was highest and the preliminary trial noted a slight aftertaste; these factors may help explain why greater puree addition did not improve acceptance. Because the texture results are descriptive and the study did not measure water activity or fracture behavior, these explanations should be treated as plausible interpretations rather than confirmed causal mechanisms.

## CONCLUSION

This study contributes evidence on the use of red dragon fruit peel puree as a value-added ingredient in MOCAF crispy brownies by evaluating sensory acceptance alongside nutritional, color, and texture characteristics. The 25% substitution level was the most promising formulation for sensory quality, with the highest overall acceptance score (7.55) and texture score (7.73). In contrast, the 30% level produced the highest protein content (8.19%), while water content in all treatments remained below 5%. The findings indicate that formulation decisions involve a trade-off: the treatment with the highest protein content was not the one most preferred by panelists, and the highest instrumental hardness at 20% did not correspond to the highest sensory texture acceptance. For product development, a 25% substitution level may therefore be a useful starting point when sensory acceptance is prioritized, while 30% may be considered when increasing protein content is a key objective. The results are specific to the ingredients, processing conditions, and panel used in this study. Limitations include the absence of measurements such as water activity, dietary fiber, antioxidant capacity, fracture force, and storage stability. Further research should validate the preferred formulation with a broader consumer panel, and examine crispness and shelf life during storage before making wider product or commercial claims.

## AUTHOR CONTRIBUTIONS STATEMENT

Karunia Bintang Alfiana: Conceptualization, Methodology, Data curation, Writing – original draft, and Writing – review & editing. Siti Fathonah: Supervision, Validation, and Writing – review & editing. All authors have read and approved the final version of the manuscript.

## DECLARATION OF GENERATIVE AI

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with English translation and language refinement. The authors reviewed and edited the output to ensure accuracy and consistency with the original research. The authors take full responsibility for the content of the manuscript.

## DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

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