

Research Article

Effects of Avocado Puree as a Fat Replacer on the Quality Characteristics of Gluten-Free Brownies

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ABSTRACT

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Avocado is categorized as a superfruit owing to its elevated concentration of monounsaturated fatty acids, which may help reduce LDL cholesterol. It is beneficial both for direct consumption and for use in nutritious food products. The aim of this research was to maximize the replacement of butter with avocado to produce a gluten-free brownie product with a lower lipid content than conventional products. The research studied the effects of three avocado ripeness levels (AR; 50%, 75%, and 100%) and butter-to-avocado puree ratios (Butter/AP; 50:50, 25:75, and 0:100) on the quality of gluten-free brownies, resulting in nine formulations. Sensory evaluation indicated that the formulation prepared with 100% avocado ripeness and a butter-to-avocado puree ratio of 25:75 achieved the highest overall liking score (7.72), classified as "like very much" on a 9-point hedonic scale ($p < 0.05$). The brownie height was 5.25 cm, and its redness value (a^*) was 8.33, yellowness value (b^*) was 8.13, and lightness value (L^*) was 15.18, with a specific volume of 1.49 cm³/g. Compared to the control brownie prepared with 100% butter (17.12 g/100 g) and without avocado puree, the developed brownie showed a 43.79% reduction in fat content and a 16.03% reduction in energy. The results demonstrate that replacing butter with avocado can enhance the nutritional profile of gluten-free brownies, offering benefits for individuals with health concerns and providing a suitable alternative for those with cardiovascular disease, obesity, or gluten intolerance.

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1. Introduction

Recently, the incidence of cardiovascular diseases (CVDs) has surged, posing a significant global public health challenge that affects nearly every country. Cardiovascular disease is one of the leading non-communicable diseases (NCDs) that is associated with various health conditions, including hypertension, stroke, diabetes, dyslipidemia, and obesity (Powell-Wiley *et al.*, 2021; Budreviciute *et al.*, 2020). According to the World Health Organization (WHO), CVDs are the highest number of deaths in NCDs groups, totaling 17.9 million deaths annually, and this number is expected to rise to 22.2 million by 2030 (Şahin and Ilgün, 2022). In Thailand, CVDs result in 70,000 deaths annually, which averages to 8 deaths per hour (Department of Disease Control, 2023). The causes

of CVDs are closely related to the consumption of foods high in sugar and fats, particularly saturated fats (Jessri *et al.*, 2023; Valk *et al.*, 2022). These fats tend to elevate low-density lipoprotein (LDL) cholesterol levels, which are commonly found in products with high butter or margarine content (Guggisberg *et al.*, 2022; Zhang *et al.*, 2021), especially in bakery products. Globally, all age groups widely consume brownies among the diverse range of bakery products (Mulyati *et al.*, 2019). However, these products usually have high amounts of saturated fat from butter and wheat flour, making them potentially inappropriate for people susceptible to cardiovascular diseases (CVDs) or individuals with gluten sensitivity. In 100 grams of brownies, the primary components are butter, sugar, flour, chocolate, and eggs, yielding 575

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kilocalories, 7.44 grams of protein, 56.18 grams of carbohydrates, and 35.61 grams of fat, with 63.82% of the fat being saturated fatty acids (SFA) (Martínez *et al.*, 2025). This high concentration of SFA primarily originates from butter. Due to the high fat content in brownies, numerous researchers have attempted to create recipes that are more nutritionally beneficial.

The primary objective is to substitute the two major components: flour and fat. Diverse flours have been utilized as substitutes for wheat flour, which contains the allergic gluten protein responsible for Celiac Disease (Cabanillas, 2020; Strońska *et al.*, 2021). Presently, gluten-free brownie goods have been produced by substituting wheat flour with other flours, including black rice (Sumonsiri *et al.*, 2022), kidney beans (Yadav *et al.*, 2021), orange sweet potato (Selvakumaran *et al.*, 2019), and sweet potato (Dameswary *et al.*, 2023). The second step is to decrease the fat content of butter in the recipe or replace it with vegetable oil. A study investigated the effect of replacing margarine with rice bran oil organogel emulsions in chocolate brownies (Manakla *et al.*, 2020) and replacing butter with cold-pressed nut oils (pistachio, walnut, and almond) in brownies (Martínez *et al.*, 2025). Moreover, flaxseed and okra gum have been used as fat replacements in the production of cakes (El-Sayed *et al.*, 2014). In addition to vegetable oils, there are initiatives to use avocados, regarded as a high-unsaturated-fat fruit and part of the superfood group (Ohlau *et al.*, 2023; Arumugam *et al.*, 2021), to replace fats or oils in baked items. This is due to its texture, which resembles butter or cream, and its high unsaturated fatty acid content (Hu, 2021; Rizkiyah *et al.*, 2022). Avocados contain 71% monounsaturated fatty acids (MUFA), 13% polyunsaturated fatty acids (PUFA), and 16% saturated fatty acids (SFA) (Flores *et al.*, 2019; USDA, 2011), which can improve good cholesterol (HDL-Cholesterol) and reduce bad cholesterol (LDL-Cholesterol) (Faizah *et al.*, 2024). This minimizes the accumulation of blood lipids and reduces the risk of stroke, heart disease, and atherosclerosis (Okobi *et al.*, 2023). Previously, researchers have used avocado flesh instead of butter, margarine, or shortening, which contain a large amount of trans fats in baked products. For example, avocado can replace 50% of the trans fats in cake cream (Phungbunhan *et al.*, 2021), 35% in oatmeal cookies (Wekwete and Navder, 2008), and up to 32.5% in muffins (Baniya, 2022). However, replacing avocados with more fat in many baked goods will result in lower general acceptance due to the limited bitter taste. When avocado is heated, it will taste bitter and darken due to the browning reaction that occurs during thermal treatment (Degenhardt and Hofmann, 2010; Eteng *et al.*, 2020; Eteng *et al.*, 2020).

Therefore, to reduce these limitations, the researchers have the idea of using avocado to replace butter in brownies, which contain chocolate with acceptable bitterness for

consumers. It is expected that avocado can be substituted in higher proportions than other products. This aligns with the development of chocolate custard filling products that can use avocado to replace fat entirely (Dholvitayakhun *et al.*, 2025). Additionally, the use of domestically produced red jasmine rice flour as a substitute for wheat flour enhances nutritional value and offers an option for gluten-intolerant consumers in gluten-free brownie products, while also promoting the expansion of the avocado food product market.

2. Materials and Methods

Main materials used in this research for the preparation of gluten-free brownies (GFB) were avocado (PP08 varieties, sourced from Phop Phra District, Tak Province, Thailand), harvested during the 2023 growing season, and other food-grade ingredients (Moonfarms® red jasmine rice flour (Thailand), Super Find® corn starch (Thailand), eggs, granulated sugar, dark chocolate, butter, xanthan gum, baking powder, and salt) were purchased from the local market (Tak, Thailand).

2.1 Preparation of avocado puree

Thai avocados (PP08 varieties) were matured in a room at ambient temperatures ($28 \pm 2^\circ\text{C}$) before use, and there were three ripeness levels for the experiment: starting with 50% ripeness (5 days of ripening) because if the ripeness exceeds this, the texture will not be smooth when blended. The skin will have a greenish-purple color, and the flesh will be yellowish-green, soft, and bland. The 75% ripeness level (7 days of ripening) will have a purple skin, yellow flesh, very soft texture, and bland taste. The 100% ripeness level (9 days of ripening) exhibited a dark skin, brownish flesh, mushy texture, and a bland taste, as shown in Table 1. All avocados were washed with water and cut into two parts with a kitchen knife. Then, the flesh was taken and cut into big chunks. Next, the avocado flesh was mashed using a domestic blender to obtain avocado puree and kept in polyethylene bags at -20°C until use.

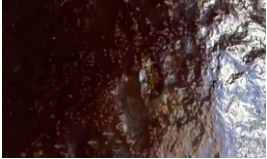
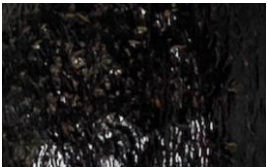
2.2 Preparation of gluten-free brownies

The procedure for preparing gluten-free brownies (GFB) using red jasmine rice flour was based on Mahasaengsawan (2018), with modifications to the formulation involving three avocado ripeness levels (AR: 50%, 75%, and 100%) and three butter-to-avocado puree ratios (Butter/AP: 50:50, 25:75, and 0:100), resulting in nine GFB treatments. All ingredients were prepared and weighed according to the formulation shown in Table 2. All formulations except avocado and butter were the same amount for each ratio. Red jasmine rice flour, xanthan gum, and salt were sieved during preparation to prevent lumps when they were added into the batter. Next, eggs, vanilla extract, and white granulated sugar were mixed in a bowl using a hand mixer at a slow speed for two minutes until the sugar melted. Then, add the melted butter or avocado and

chocolate to the beaten egg mixture. In the mixing bowl, slowly add the mixed red jasmine rice flour after combining them together and mixing to combine. Lastly, bake at 180°C for 40

minutes. When finished, the GFB were then cooled and wrapped in food-grade zip-lock polyethylene plastic bags prior to further analysis.

Table 1 Visual appearance and descriptive characteristics of avocado fruit and puree at different ripeness levels (0%, 25%, 50%, 75%, and 100%) used in this study.

Day	ripeness level (%)	External appearance	Internal appearance	Description
1	0			Dark green peel; firm texture with a bitter and astringent taste; light green flesh.
3	25			Dark green peel; firm texture with a bitter and astringent taste; greenish-yellow flesh.
5	50			Greenish-purple peel; soft texture with a mild, fatty taste; yellowish flesh.
7	75			Purple peel; softer texture than day 5 with a mild, fatty taste; yellow flesh.
9	100			Dark black peel; very soft to mushy texture with a mild, fatty taste; brownish flesh.

Note: All photographs presented in this table were taken by the authors.

2.3 Color determination

The color of the brownies was measured using a chromaticity instrument (Hunter, MiniScan EZ 4500L Spectrophotometer, USA) under illuminant D65 with a 10° standard observer. The color values were measured using a CIE L^* a^* b^* scale in 4 random zones of 4 different baked brownies (3 × 3 × 3 cm) that were randomly selected, and the means were recorded as L^* (whiteness/darkness), a^* (redness/greenness), and b^* (yellowness/blueness).

2.4 Determination of the specific volume and height of brownies

The specific volumes (cm³/g) of brownies were measured by using the seeds displacement method (American Association of Cereal Chemists (AACC), 2000). Heights of the brownies were measured using a vernier caliper (Mitutoyo Corp., Japan). Height was measured from the highest point of the brownie to the bottom, and the photos were taken by

placing the cakes on a flat surface and placing a ruler vertically on each cake to show the height in centimeters.

2.5 Sensory evaluation

This study was approved by the Human Research Ethics Committee of [Rajamangala University of Technology Lanna], Thailand (Approval No. RMUTL-IRB 049/2021). All panelists participated voluntarily and provided informed consent prior to sensory evaluation. A hedonic test was used to determine the degree of overall liking for brownies by using the BIB unbalanced block design ($t = 9$, $k = 4$, $r = 8$, $b = 18$, $\lambda = 3$) in four replication, randomized trials. Seventy-two untrained panelists were given four random samples (2 cm x 2 cm) from nine treatments of brownies that had been held at room temperature for 24 hours. Each sample was coded with a 3-digit random number. The brownies were evaluated for acceptance of appearance, color, texture, flavor, and overall

acceptability based on a nine-point hedonic scale (1 = extremely dislike, 9 = extremely like). The next section will select the formula with the highest average liking score for testing.

2.6 Nutrient evaluation

Following the development and sensory evaluation of the products, the highest score was deemed acceptable. The brownie sample was analyzed for nutritional evaluation.

Moisture, crude protein, fat, and ash contents were determined using standard AOAC methods (AOAC, 2000), including oven-drying, Kjeldahl, Soxhlet extraction, and dry ashing, respectively. Carbohydrate content was calculated by difference. Energy value was determined by bomb calorimetry. Compare with basic GFB prepared with 100% butter (17.12 g/100 g) and without the addition of avocado puree.

Table 2 Formulations of gluten-free brownies (GFB) prepared using three avocado ripeness levels (AR) and three butter-to-avocado puree (Butter/AP) ratios.

Ingredients	50% AR			75% AR			100% AR		
	50:50	25:75	0:100	50:50	25:75	0:100	50:50	25:75	0:100
Butter	8.56	4.28	0	8.56	4.28	0	8.56	4.28	0
Avocado puree	8.56	12.84	17.12	8.56	12.84	17.12	8.56	12.84	17.12
Granulated sugar	17.12	17.12	17.12	17.12	17.12	17.12	17.12	17.12	17.12
Eggs	25.66	25.66	25.66	25.66	25.66	25.66	25.66	25.66	25.66
Dark chocolate	25.66	25.66	25.66	25.66	25.66	25.66	25.66	25.66	25.66
Red jasmine rice flour	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42
Corn starch	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42	6.42
Salt	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Vanilla extract	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Baking powder	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Xanthan gum	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Note: AR represents the avocado ripeness level (50%, 75%, and 100%). Butter/AP indicates the ratio of butter to avocado puree used in the formulation.

2.7 Statistical analysis

The completely randomized design or CRD was applied to create the different formulations of brownies for the physicochemical properties study. The randomized complete block design (RCBD) was applied for sensory evaluation. Three replications were performed for each sample. The mean values recorded for each test were compared using analysis of variance (ANOVA). Duncan's multiple range test (DMRT) was applied to indicate a significant difference at a 95% confidence level (using SPSS statistical software version 30, IBM Corp., New York, USA).

3. Results and Discussion

3.1 Effect of substitution level on color

Figure 1 and Table 3 show the physical characteristics of the results of color tests, respectively. The color of gluten-free brownies (GFB) prepared using avocado ripeness levels (AR) and butter-to-avocado puree ratios (AP) across nine formulations was evaluated. Red values (a^*) and yellow values (b^*) are statistically significant differences at the level of $p <$

0.05. Both the avocado content and the ripeness level exhibited an interactive effect on the lightness of the product. The formulation of the results showed that brightness (L^*), prepared with 100 AR and AP of 0:100, exhibited the highest brightness value of 17.18. As the avocado matures, its color intensity often decreases, leading to increased lightness (L^*) and reduced values of redness (a^*) and yellowness (b^*) (Thomya *et al.*, 2025). Furthermore, Han *et al.* (2023) revealed that ripening significantly affects the color characteristics of avocado flesh, L^* values increase while a^* and b^* values decrease as ripeness increases. The findings correspond with the results of this study, which found that brownies made with fully ripened avocado had increased lightness and reduced a^* and b^* values.

3.2 Effect of substitution level on specific volume and height of brownies

The specific volume and height of GFB formulated with avocado substitutions for butter across nine treatments were analyzed. The results revealed statistically significant differences at the 0.05 level ($p < 0.05$). Both avocado ripeness

(AR) and butter-to-avocado puree ratio (AP) exhibited interactive effects on the specific volume and height of the products. Brownies prepared with 100% AR and higher levels of butter substitution demonstrated increased specific volume and height, as presented in Table 3 and Figure 1. A higher specific volume was associated with a lighter and more aerated texture of the product, with values ranging from 1.11 to 1.67 across the nine formulations. These values were consistent with brownie height, which increased within the range of 3.14–5.32 cm, as shown in Figure 1. When the

amount of avocado used to replace fat increased, the specific volume of the cake tended to rise, which is consistent with the findings of El-Sayed (2019), who reported that muffins incorporated with avocado and cantaloupe puree exhibited significantly higher specific volume compared to the control sample. The specific volume of baked cake determines the quantity of air that can remain in the finished product. Higher gas retention and product expansion result in higher specific volume (Ain *et al.*, 2016).



Figure 1 Effect of avocado ripeness (AR) and butter-to-avocado puree ratio (AP) on the physical appearance of GFB.

Table 3 Effect of avocado ripeness (AR) and butter-to-avocado puree ratio (AP) on height, specific volumes, and color value of GFB.

AR level (%)	Butter/AP ratio	Parameter				
		L^*	a^*	b^*	Height (cm)	Specific volumes (cm^3/g)
50	50:50	12.42 ± 1.86^d	8.92 ± 0.43^b	9.23 ± 1.16^b	3.14 ± 0.05^d	1.11 ± 0.12^d
50	25:75	15.22 ± 1.38^b	8.88 ± 0.12^b	8.07 ± 1.56^c	3.39 ± 0.10^d	1.17 ± 0.04^d
50	0:100	13.82 ± 0.60^c	8.64 ± 0.26^b	8.90 ± 0.65^b	3.80 ± 0.05^c	1.18 ± 0.06^d
75	50:50	13.41 ± 0.47^c	9.02 ± 0.32^b	8.94 ± 0.32^b	4.64 ± 0.17^c	1.18 ± 0.04^d
75	25:75	16.42 ± 1.28^a	8.70 ± 0.76^b	9.34 ± 1.00^b	4.77 ± 0.18^c	1.21 ± 0.08^d
75	0:100	16.47 ± 0.41^a	9.31 ± 0.70^a	9.65 ± 0.76^a	4.90 ± 0.06^b	1.49 ± 0.14^b
100	50:50	13.18 ± 0.27^d	8.53 ± 0.54^b	8.09 ± 1.10^c	5.05 ± 0.19^b	1.33 ± 0.10^c
100	25:75	15.18 ± 1.04^b	8.33 ± 0.35^c	8.13 ± 0.57^c	5.25 ± 0.05^{ab}	1.49 ± 0.14^b
100	0:100	17.18 ± 1.20^a	7.53 ± 0.42^c	7.64 ± 0.44^d	5.32 ± 0.10^a	1.67 ± 0.08^a

The numbers represent the mean $\pm$ standard deviation. Different letters in the same column for each attribute indicate significant differences ($p < 0.05$).

3.3 Sensory analysis of GFB

Table 4 contains the sensory evaluations of the final products. In the color and taste of all the GFB organoleptic properties that the panelists tested, no significant differences ($p > 0.05$) were observed in color and taste preference among all GFB formulations. The color scores ranged from 6.94 to 7.56, indicating ratings from “like slightly” to “like moderately,” while taste scores ranged from 6.53 to 7.44, corresponding to “like moderately” on a 9-point hedonic scale. Nevertheless, there were statistically significant differences in aroma, texture, and overall preference at the 0.05 level ($p < 0.05$). Aroma scores ranged from “like slightly” to “like moderately,” texture scores ranged from “like slightly” to “like very much,” while overall preference scores were mainly within the “like moderately” category on a 9-point hedonic scale (Table 4). The treatment with 100% AR and a butter-to-avocado puree ratio of 25:75 showed the highest overall preference score (Table 4). The overall liking will gradually increase as the level of ripening increases. This effect is because the ripening of

avocados is directly related to bitter taste. Through changes in phenolic compounds, ripening avocados for 8 days at a temperature of about 20°C increases fatty acids and makes them less bitter (Thomya *et al.*, 2025). Additionally, the heat generated during processing increases the bitterness of the taste (Degenhardt and Hofmann, 2010; Eteng *et al.*, 2020).

Brownies formulated with completely mature avocado (100% AR) and a moderate butter-to-avocado puree ratio (25:75) attained the highest acceptability ratings, indicating that an ideal equilibrium between hydration, lipid substitution, and flavor perception is essential for consumer inclination. This decline may be attributed to customers' perception of undesirable qualities, characterized by a moderately bitter taste and lingering bitter aftertaste, together with the aroma of avocado. Consequently, the GFB that replaced butter with avocado formula 8 was selected for the subsequent step in the experiment.

Table 4 Influence of AR and AP substitution on sensory attributes of GFB.

AR level (%)	Butter/AP ratio	Parameter				
		color ^{ns}	Aroma	Taste ^{ns}	Texture	Overall acceptability
50	50:50	7.38 ± 1.52	6.63 ± 2.15 ^c	6.53 ± 2.11	6.25 ± 2.37 ^b	6.69 ± 2.28 ^b
50	25:75	7.50 ± 1.02	7.25 ± 1.14 ^b	7.16 ± 1.37	6.84 ± 1.57 ^b	7.44 ± 1.33 ^{ab}
50	0:100	7.34 ± 1.26	6.62 ± 1.56 ^c	6.63 ± 1.96	6.50 ± 1.48 ^b	7.09 ± 1.44 ^b
75	50:50	7.19 ± 1.62	7.65 ± 1.31 ^a	7.44 ± 1.05	6.72 ± 1.69 ^b	7.50 ± 1.08 ^{ab}
75	25:75	7.16 ± 1.51	7.13 ± 1.50 ^b	7.13 ± 1.68	7.13 ± 1.52 ^b	7.44 ± 1.22 ^{ab}
75	0:100	6.94 ± 1.13	6.75 ± 1.41 ^c	6.50 ± 1.61	6.38 ± 1.74 ^b	7.06 ± 1.50 ^b
100	50:50	6.94 ± 1.78	6.66 ± 1.81 ^c	6.81 ± 1.73	6.53 ± 1.81 ^b	7.13 ± 1.58 ^b
100	25:75	7.56 ± 0.91	7.46 ± 1.27 ^b	7.41 ± 1.13	8.06 ± 1.43 ^a	7.72 ± 1.14 ^a
100	0:100	7.44 ± 1.27	6.19 ± 1.90 ^c	6.72 ± 2.00	6.63 ± 1.56 ^b	6.91 ± 1.49 ^b

The numbers represent the mean ± standard deviation. Different letters in the same column for each attribute indicate significant differences ($p < 0.05$).

Table 5 Calorific and nutritional value of GFB prepared with 100% AR and Butter/AP ratio of 25:75 (100 g).

Calorific and nutritional value	Control (100%butter)	GFB (100% AR, Butter/AP = 25:75)	Nutrient changes (%)
Protein (g)	6.20	5.05	- 18.55
Carbohydrate (g)	47.18	51.05	+ 8.20
Fat (g)	28.57	16.06	-43.79
Ash (g)	1.44	1.50	+4.17
Moisture (g)	16.61	26.34	+ 58.58
Energy (Kcal)	470.65	395.20	- 16.03

3.4 Nutrient evaluation of GFB

The nutritional analysis indicates that one serving (100 grams) of GFB prepared with an avocado ripeness level (AR) of 100% and a butter-to-avocado puree ratio (AP) of 25:75 contains 395.20 calories, 5.05 grams of protein, 51.05 grams of carbs, 16.06 grams of fat, 26.34 grams of moisture, and 1.50 grams of ash, as shown in Table 5. In contrast to a control brownie recipe, the GFB result shows decreased nutritional, protein, fat, and energy content by 18.55%, 43.79%, and 16.03%, respectively. In contrast, the carbohydrate, ash, and moisture content increased relative to the control brownie recipe. Avocado puree consists of greater quantities of carbs, ash, and moisture (10.5 g, 0.6 g, and 81.8 g/100 g, respectively) compared to butter (0 g, 85 g, and 15.7 g/100 g), which is usually used in normal brownies. This finding accords with Wongwaiwech *et al.* (2024), which showed that including avocado increased the energy, fat, and protein levels in Thai-style custard cake goods, while the fat and calorie content diminished in proportion to the butter substituted with avocado (Othman *et al.*, 2018; Baniya, 2022; Adeyeye *et al.*, 2023).

4. Conclusion

Gluten-free brownies prepared with 100% avocado ripeness and a butter-to-avocado puree ratio of 25:75 received the highest overall acceptability. The product contained protein, carbs, fat, ash, and moisture at 5.05%, 51.05%, 16.06%, 1.50%, and 26.34%, respectively, giving a total energy of 395.20 kcal per 100 grams. This formulation reduced fat content by 43.79% and caloric intake by 16.03% compared to the control formulation. The addition of avocado into the product relies not only on the quantity used but also on the state of preservation of the avocado to effectively replace the fat. To improve the real-world applicability of avocado-based gluten-free brownies, future work should emphasize storage stability assessments and consumer acceptance testing.

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