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Impact of Butter, Margarine, and Coconut Oil on the Sensory Quality of Baked Brownies: A Descriptive Sensory Analysis Approach

Lucy Fridayati*, Reska Mayefis, Ifnalia Rahayu, and Nadira Ulfach

Department of Family Welfare Education, Faculty of Tourism and Hospitality, Universitas Negeri Padang, West Sumatra, Indonesia
*Corresponding author: Lucy Fridayati | Email: lusifridayanti@fpp.unp.ac.id

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Abstract: This study investigated the effect of different fat sources; butter, margarine, and coconut oil on the sensory quality of baked brownies using a descriptive sensory analysis approach. Sensory evaluation was conducted based on five organoleptic attributes: shape, color, aroma, texture, and taste. The experiment employed a completely randomized design (CRD) consisting of three treatments with three replications. Sensory data were collected from five expert panelists using a structured hedonic questionnaire and subsequently analyzed using analysis of variance (ANOVA), followed by Duncan's multiple range test when significant differences were detected. The results indicated that the substitution of butter with margarine or coconut oil did not produce statistically significant differences ($p > 0.05$) across all sensory attributes evaluated. Although brownies formulated with butter generally obtained slightly higher mean scores, particularly for aroma, texture, and flavor intensity, these differences were not sufficient to demonstrate a significant treatment effect. All formulations exhibited comparable sensory profiles characterized by a dense and moist crumb, a dry surface texture, a blackish-brown color, and a characteristic chocolate flavor. These findings suggest that margarine and coconut oil can serve as viable alternatives to butter in brownie production without compromising overall sensory quality. The study provides practical implications for bakery product formulation by supporting flexibility in fat selection based on economic, nutritional, or availability considerations rather than sensory performance alone.

Keywords: food; organoleptic test; sensory quality

1. INTRODUCTION

Baked brownies are a chocolate-based bakery product typically formulated from wheat flour, sugar, eggs, fat, and a high proportion of chocolate, resulting in a dense structure with a moist interior and a relatively dry surface layer. Unlike conventional cakes, brownies exhibit limited volume expansion and a compact crumb, characteristics largely attributed to formulation composition and processing conditions. Recent studies have demonstrated that variations in fat type significantly influence the physicochemical and sensory properties of brownies, including texture, moisture retention, and overall acceptability [1], [2]. The functional role of fat in brownies extends beyond energy contribution, as lipids interact with starch and proteins to stabilize the batter matrix and enhance structural integrity during baking [3].

Furthermore, fat plays a critical role in shaping the sensory profile of baked goods by enhancing flavor release, mouthfeel, and perceived moistness, all of which contribute to consumer preference. Studies on fat replacers and lipid modification in baked products have shown that altering fat composition can markedly affect rheological behavior, texture firmness, and sensory acceptance, emphasizing fat's multifunctional role in bakery systems [4]. Recent research on functional and reformulated baked products also indicates that while alternative ingredients may reduce fat content, maintaining desirable sensory attributes remains challenging due to fat's influence on aroma perception, texture development, and overall palatability [5].

Fats such as butter, margarine, and plant-derived oils provide essential functional properties in baked goods by modifying the dough matrix and contributing to the final product's texture. They interfere with gluten network formation by coating protein and starch granules, which limits gluten development and results in a softer, more tender crumb — a crucial feature for brownies that are expected to be moist rather than tough. Furthermore, fats help trap air during mixing, which enhances volume and influences mouthfeel, moisture retention, and overall acceptability in bakery products [1].

Margarine, typically formulated from hydrogenated or structured vegetable oils, mimics many functional properties of butter and serves as a reliable and economical substitute in baked products such as brownies. Its water-in-oil emulsion structure contributes to plasticity and dough handling properties, while its fat composition influences dough rheology and sensory attributes. Studies show that margarine improves dough viscoelasticity and network stability, which can translate to desirable texture and softness in the final baked product, making it a valuable ingredient in commercial and artisanal formulations [6], [7].

Recent advancements in bakery science highlight the potential of plant-based oils, including nut oils and coconut oil, to replace traditional fats like butter to enhance nutritional quality without severely compromising texture. For instance, research involving partial or complete substitution of butter with nut oils (e.g., almond, walnut) in brownie formulations showed that such substitutions could produce a softer, more elastic crumb, which may be more appealing for certain sensory preferences while also improving the lipid profile of the product [8], [9].

Emerging research in lipid science and bakery technology explores how structured fats and oleogel-based systems (including combinations of plant oils and structuring agents) can achieve textural and sensory outcomes similar to traditional solid fats. These innovations aim not only to tailor texture and mouthfeel but also to meet consumer demands for healthier baked goods with reduced saturated fat content. Such strategies are particularly relevant in the development of brownies and similar products where both sensory quality and nutritional profile are key product differentiators [10].

Based on the discussion above, it is evident that fat type plays a critical role in determining the physicochemical and sensory characteristics of brownies, including texture, moisture retention, flavor perception, and overall acceptability. While numerous studies have investigated fat substitution in bakery products, existing research predominantly focuses on partial fat replacement or nutritional modification, with limited emphasis on a direct and systematic comparison of commonly used fat sources, namely butter, margarine, and coconut oil under standardized formulation and processing conditions. Furthermore, inconsistencies remain regarding the extent to which alternative fats can maintain sensory equivalence with butter in chocolate-based baked products such as brownies.

Therefore, the novelty of this study lies in its comprehensive comparative evaluation of butter, margarine, and coconut oil as primary fat sources in brownie formulations using a controlled experimental design and descriptive sensory analysis. This approach provides a clearer understanding of how different lipid matrices influence sensory attributes without confounding variations in processing parameters.

Accordingly, this study aims to: (1) evaluate the effect of different fat types (butter, margarine, and coconut oil) on key sensory attributes of baked brownies, including shape, color, aroma, texture, and taste; (2) determine whether substitution of butter with alternative fats results in statistically significant differences in overall sensory quality; and (3) identify viable fat alternatives for brownie production based on sensory performance and product acceptability. The findings of this study are expected to contribute to the advancement of bakery science by clarifying the functional equivalence of different fat sources and to provide practical implications for product formulation in both household and industrial contexts.

2. MATERIALS AND METHODS

This study conducted experimental direct tests on baked brownies using fats derived from butter, margarine, and coconut oil. A completely randomized design (CRD) method was used in this study, with three treatments and three replications. Data were obtained from five expert panelists.

The tool used to collect data was a questionnaire containing questions about the sensory quality of baked brownies using different fats, including shape (neat), color (dark brown), aroma (chocolate-like aroma), texture (dry on the surface and dense), and taste (typical chocolate). Data were obtained after conducting organoleptic tests, tabulated in table form, given a score, and analyzed using analysis of variance (ANOVA). If the data obtained F count was greater than the F table, then the Duncan test was continued. Several recent studies have employed experimental designs and sensory evaluation methods to assess the effect of fat substitution in baked products, particularly brownies. [1] applied a completely randomized design combined with sensory panel evaluation and one-way ANOVA followed by Duncan's multiple range test to compare brownies formulated with different lipid sources.

Similar approaches using trained or semi-trained panelists to evaluate attributes such as color, aroma, texture, and taste have been widely adopted in bakery product research, confirming the appropriateness of CRD and organoleptic analysis for evaluating fat-based formulation differences in brownies and other cocoa-based bakery products [6], [11]. In this study, a total of five semi-trained panelists were recruited based on specific inclusion criteria, including prior experience in sensory evaluation, familiarity with bakery products, and the absence of sensory impairments (e.g., taste or olfactory disorders).

Prior to evaluation, panelists underwent a brief training session to standardize their understanding of the sensory attributes assessed, including shape, color, aroma, texture, and taste, using reference samples and descriptive guidelines. Sensory evaluation was conducted using a structured hedonic scale (1–4), where 1 = poor, 2 = fair, 3 = good, and 4 = very good, to quantify panelists' perceptions of product quality.

All sensory tests were carried out under controlled conditions in a well-lit, odor-free environment at room temperature to minimize external bias. Each brownie sample was coded and presented randomly to avoid order effects. Between sample evaluations, panelists were instructed to cleanse their palate using drinking water to prevent flavor carryover and ensure the accuracy of sensory judgments. The standard recipe used in this study was adapted from Thomas Law's *Classy Cake*. The composition of baked brownies using different fat sources is presented as follows:

Table 1. Composition for making baked brownies using different fats

No	Ingredient	Butter (%)	Coconut Oil (%)	Margarine (%)
1.	Flour	100	100	100
2.	Butter	55.6	55. 6	55.6
3.	Fine granulated sugar	166.7	166.7	166.7
4.	Cocoa powder	38.9	38.9	38.9
5.	Chocolate Covering	166.7	166.7	166.7
6.	Vegetable oil	44.4	44.4	44.4
7.	Egg	133.3	133.3	133.3
8.	Milk powder	11.1	11.1	11.1
9.	Salt	0.6	0.6	0.6
10.	Chopped Almonds	quantum satis	quantum satis	quantum satis
11.	Chocochips	quantum satis	quantum satis	quantum satis

The formulation is expressed as baker's percentages, where flour is set as 100% and all other ingredients are calculated relative to the flour weight.

2.1. The ingredients used in making baked brownies are as follows:

Amount of Ingredient A

- 2 eggs
- 150 grams of powdered sugar

Amount of Ingredient B

- 90 grams of medium-protein wheat flour
- 10 grams of powdered milk
- A Pinch of Salt
- Amount of Material C
- 50 grams of butter
- 150 grams of Couverture Chocolate
- 40 ml Vegetable Oil
- Topping
- Almond Slice
- Choco Chip

2.2. The ingredients used in making baked brownies are as follows:

- Preheat the oven to a temperature of 175°C
- Ingredient C (fat and chocolate mixture) was melted using a water bath (bain-marie method) to ensure uniform heating and prevent burning, and then allowed to cool to room temperature
- Beat ingredient A with a balloon whisk until pale. Pour in ingredient C and beat until the mixture thickens.
- Add the sifted ingredients B and beat again until smooth.
- Pour the batter into an 18 or 20 cm square pan lined with baking paper. Sprinkle with topping and bake for 25-30 minutes for a fudgy and chewy crust.

The research implementation procedure is illustrated in Figure 1.

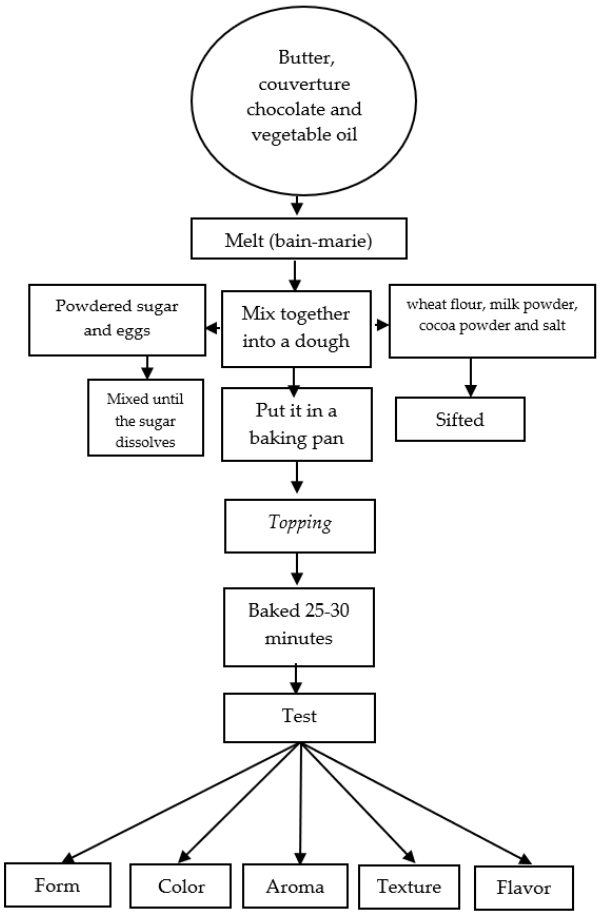

Figure 1. Manufacturing flow chart Brownies Bake Using Different Types of Fat

3. RESULTS AND DISCUSSION

Research results on quality brownies bake using butter, Margarine, and coconut oil can be seen in Figure 2 below:

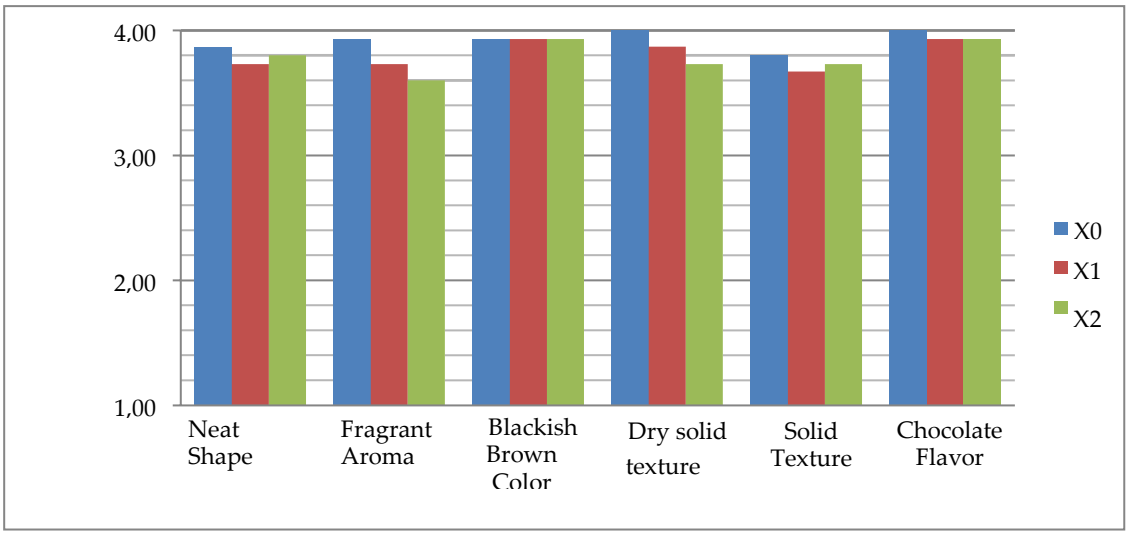

Figure 2. Average sensory quality of baked brownies prepared using different fat sources. The blue bars (X0) correspond to butter, red bars (X1) to margarine, and green bars (X2) to coconut oil

Based on the Figure 2, it can be concluded that for shape quality, butter had the highest score, indicating that the brownies turned out more evenly than those using coconut oil and margarine. Margarine came in second, and coconut oil came in third. However, these differences were not statistically significant. In terms of aroma quality, butter has the highest value, meaning that the aroma of brownies is more fragrant than that of coconut oil and margarine. Coconut oil is second, followed by margarine. The difference between using butter and margarine was significant. Furthermore, butter, coconut oil, and margarine have the same color quality in their manufacture, namely, a blackish brown color. For a dry, solid texture, butter has the densest, dryest texture compared to using coconut oil and margarine, second only to coconut oil and lastly to margarine. Meanwhile, for a dense texture, use butter has the densest texture. Next is the use of margarine, and finally, the use of coconut oil. In terms of taste, the use of coconut oil and margarine has the same chocolate flavor, and the use of butter has a more pronounced chocolate flavor.

Differences in sensory attributes such as shape uniformity, aroma intensity, and color of brownies can be attributed to the physicochemical characteristics of the fat used in the formulation. Butter is known to possess superior plasticity and a balanced solid fat content, which contributes to more even batter aeration and structural stability during baking, resulting in a neater and more uniform brownie shape compared to plant-based fats such as margarine and coconut oil [1], [6]. Additionally, butter contains volatile flavor compounds formed during milk fat processing, which enhance the characteristic chocolate aroma in baked products and explain its significantly higher aroma score compared to margarine [9], [11]. In contrast, coconut oil contributes a distinctive aroma profile but may partially mask chocolate notes depending on concentration, while margarine generally exhibits lower aroma complexity due to deodorization processes during manufacture [8], [12]. The absence of significant color differences among treatments aligns with previous studies reporting that brownie color is primarily governed by cocoa content and Maillard reactions rather than fat source [1], [13].

Textural and taste variations observed among brownies prepared with butter, margarine, and coconut oil are closely related to differences in fatty acid composition and fat crystallization behavior. Butter, which contains a higher proportion of saturated fatty acids and a well-defined crystalline structure, has been reported to produce denser and drier crumb textures, consistent with its highest scores for dry and dense texture in sensory evaluation [6], [7]. Margarine, formulated as a water-in-oil emulsion with emulsifiers, tends to yield softer and less compact textures due to improved moisture

retention and gluten-shortening effects [9], [14]. Coconut oil, while rich in saturated fats, melts rapidly at near-body temperature, resulting in brownies with a softer mouthfeel and less dense structure, which explains its lower density scores and comparable chocolate taste perception with margarine [8], [11]. These findings support previous sensory studies indicating that fat type significantly influences textural perception and flavor release in cocoa-based bakery products, even when overall acceptability differences are not statistically significant [1], [6], [15].

The quality description brownies roast can be seen in the description below:

3.1. Form

Based on the results of the organoleptic test, the average value of the research on the quality of the form can be known brownies roasted in each treatment can be seen in the following picture:

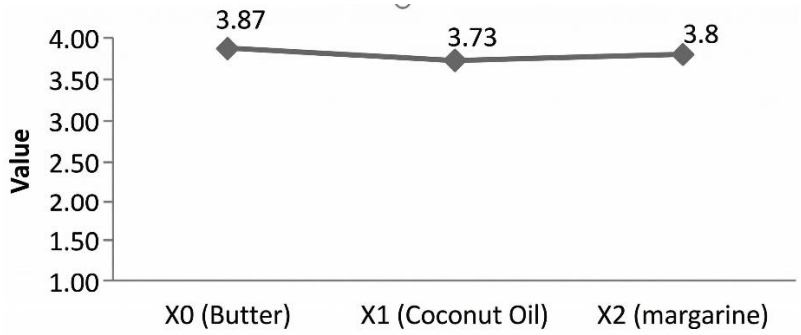

Figure 3. Average value of neat shape quality brownies roast by using different types of fat

Based on Figure 3, the mean sensory scores (Mean ± Standard Deviation) for brownie shape quality in each treatment were as follows: treatment X0 (butter) achieved a mean score of 3.87 ± 0.12, treatment X1 (margarine) obtained 3.73 ± 0.15, and treatment X2 (coconut oil) recorded 3.80 ± 0.10. All treatments were categorized as having a fairly neat shape.

Among the treatments, X0 showed the highest mean score, indicating that brownies prepared with butter tended to exhibit a more uniform and visually appealing shape compared to those prepared with margarine and coconut oil. However, the relatively small standard deviation values indicate that panelist responses were consistent across evaluations.

Based on the statistical analysis, the calculated F value for shape quality (Fcount = 1.71) was lower than the critical F value at the 5% significance level (Ftable = 4.46). Therefore, no statistically significant difference was observed among the treatments ($p > 0.05$). This result indicates that variations in fat type did not significantly influence the shape quality of baked brownies. Consequently, Duncan's multiple range test was not performed.

The absence of a statistically significant difference in brownie shape quality among treatments with different fat types is consistent with findings from previous bakery product studies, which indicate that shape uniformity is more strongly influenced by processing conditions and mold geometry than by fat composition. Research has shown that when standardized baking pans and identical baking parameters are applied, variations in lipid sources such as butter, margarine, or vegetable oils have minimal impact on the external shape of baked products [6], [12]. Instead, shape stability is primarily governed by batter viscosity, pan dimensions, and thermal expansion during baking, which explains why all treatments in this study resulted in a similarly neat brownie appearance. Furthermore, Martínez reported that while fat type significantly affects texture and flavor perception, it does not necessarily lead to observable differences in product geometry when molds and formulation ratios are controlled [1]. These findings support the present result that differences in fat type did not significantly influence the neatly grilled shape of brownies, validating the use of uniform rectangular pans as an effective method for controlling visual appearance in sensory evaluation studies [11].

3.2. Color

Based on the results of the organoleptic test, the mean sensory scores (Mean ± Standard Deviation) for color quality were identical across all treatments. Treatment X0 (butter) achieved a mean value of 3.93 ± 0.10, while treatments X1 (margarine) and X2 (coconut oil) each recorded 3.93 ± 0.10. All treatments were classified within the fairly good category, characterized by a chocolate-blackish color. The identical mean values and low standard deviations indicate a high level of agreement among panelists and consistent perception of color across all formulations.

Statistical analysis showed that the calculated F value (Fcount = 0.02) was lower than the critical F value at the 5% significance level (Ftable = 4.46), indicating no statistically significant difference among treatments ($p > 0.05$). Therefore, the type of fat used did not significantly influence the color quality of baked brownies, and Duncan's test was not conducted.

In sensory science, color is recognized as one of the primary organoleptic attributes that influences consumer perception and acceptance, often evaluated alongside other sensory parameters such as aroma and texture. Food color significantly influences emotional responses, taste expectations, and hedonic acceptance, highlighting its role as a critical quality attribute in sensory evaluation protocols for food products [16]. In line with this, recent studies on chocolate and related products have shown that variations in formulation, including the use of alternative fats or fat replacers can influence physicochemical characteristics and organoleptic outcomes such as color, although not always to a statistically significant level [17]. These findings support the present result that no significant differences were found in the color scores among treatments X0, X1, and X2 (all mean = 3.93), and that the type of fat used did not have a real influence on color quality at the 5% level (Fcount < Ftable), confirming that under the conditions tested, different fat sources yielded comparable color acceptance by panelists [16], [18].

3.3. Aroma

Based on the results of the organoleptic test, the average value of the aroma quality can be determined. Brownies roasted in each treatment can be seen in the following picture:

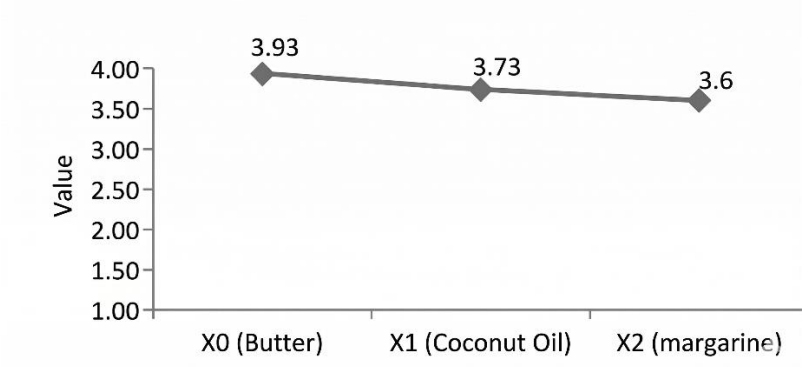

Figure 4. Average value of chocolate aroma quality brownies roast by using different types of fat

As illustrated in Figure 4, the mean sensory scores (Mean ± Standard Deviation) for aroma quality were as follows: treatment X0 (butter) obtained 3.93 ± 0.12, treatment X1 (margarine) recorded 3.73 ± 0.15, and treatment X2 (coconut oil) achieved 3.60 ± 0.18. All treatments were categorized as having a moderately chocolate-like aroma. Among the treatments, X0 exhibited the highest mean score, indicating a stronger chocolate aroma compared to the other fat sources. The slightly higher standard deviation in X2 suggests more variability in panelist perception for coconut oil aroma.

Statistical analysis revealed that the calculated F value (Fcount = 1.07) was lower than the critical F value at the 5% significance level (Ftable = 4.46). This indicates that no statistically significant differences were found among treatments ($p > 0.05$), and thus Duncan's test was not performed.

In sensory evaluation studies, aroma is a key organoleptic attribute contributing to overall product perception, yet small variations in formulation do not always lead to statistically significant differences in aroma scores when hedonic tests are applied under controlled conditions. Research in chocolate and

food product sensory science has shown that different formulations can yield comparable sensory scores for aroma and other sensory attributes when the overall sensory profiles remain within a similar range of volatility and consumer perception thresholds, resulting in non-significant statistical differences ($p > 0.05$) among samples. For example, sensory assessments of chocolate products with functional additives demonstrated that mean hedonic scores for aroma and other sensory attributes did not differ significantly across treatment groups, suggesting that moderate formulation changes may not substantively alter perceived aroma intensity or quality when panelists evaluate products using standardized hedonic scales and ANOVA testing ($p > 0.05$), negating the need for post hoc comparisons [19], [20].

Aroma plays a crucial role in sensory perception and has been widely shown to influence appetite and eating behavior. Studies indicate that exposure to food odors can enhance appetite and the desire to eat by triggering sensory-specific appetite responses, in which food-related smells increase desire for congruent flavors and promote food approach behavior even in the absence of hunger. For example, research on food-related odors has demonstrated that exposure to food aroma cues increases appetite for foods that match the odor's sensory characteristics, suggesting that aroma perception can modulate appetite and contribute to anticipatory eating behavior through olfactory signals that activate neural and psychosensory pathways linked to appetite regulation [21], [22].

3.4. Texture

3.4.1. Texture quality brownies dry roast on the surface

Based on the results of the organoleptic test, the average value of the texture quality can be determined. Brownies roasted in each treatment can be seen in the following picture:

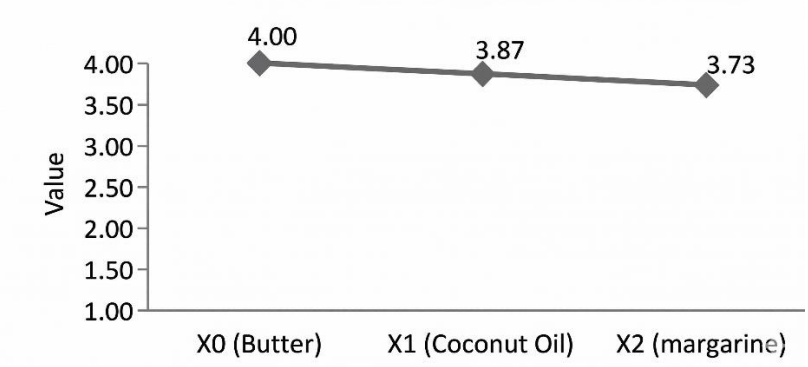

Figure 5. Average value of dry texture quality on the surface brownies roast using the right type of fat different

As shown in Figure 5, the mean sensory scores (Mean ± Standard Deviation) for surface texture were: X0 (butter) 4.00 ± 0.00, X1 (margarine) 3.87 ± 0.12, and X2 (coconut oil) 3.73 ± 0.15. All treatments were categorized as having a dry surface texture. Treatment X0 showed the highest mean score with no variation among panelists, indicating a consistently perceived dry surface. In contrast, X1 and X2 showed slightly more variability.

The statistical analysis indicated that the calculated F value (Fcount = 2.60) was lower than the critical F value (Ftable = 4.46), meaning no statistically significant difference was observed ($p > 0.05$). Therefore, Duncan's test was not conducted.

Texture evaluation through tactile perception encompasses multiple attributes, including smoothness, roughness, softness, dryness, moisture, density, and oiliness. Texture is an integral component of sensory perception in food products, as it not only determines mouthfeel but also interacts with other sensory modalities to influence overall flavor experience and consumer acceptance. Scientific evidence demonstrates that the physical characteristics of food, including dryness, moisture, and surface texture, affect how flavor compounds are released and perceived during oral processing, thus shaping hedonic responses and sensory evaluation outcomes. For instance, research in food sensory science highlights that variations in texture such as dryness or crispiness can influence the perceived intensity of flavor attributes, because texture affects mastication and the kinetics of volatile compound release in the mouth, which in turn alters sensory integration of

texture and flavor. This multisensory integration underscores why surface texture remains a vital sensory attribute, and why its evaluation is central in studies of product quality even when no statistically significant differences are detected among treatments in hedonic terms[23], [24].

3.5. Texture quality brownies dense roast

The mean sensory scores (Mean ± Standard Deviation) for density were as follows: X0 (butter) 3.80 ± 0.10, X1 (margarine) 3.67 ± 0.15, and X2 (coconut oil) 3.73 ± 0.12. All treatments were classified as moderately dense. Treatment X0 exhibited the highest mean value, suggesting a slightly denser texture compared to other treatments. The relatively small standard deviation values indicate consistent panelist responses.

Statistical analysis showed that the calculated F value (Fcount = 1.00) was lower than the critical F value (Ftable = 4.46), indicating no statistically significant difference among treatments ($p > 0.05$). Thus, Duncan's test was not performed.

Texture is a pivotal quality attribute in baked goods such as brownies because the physical structure and consistency of the product influence sensory perception, mouthfeel, and overall acceptability. Studies on bakery products show that textural attributes like density, moistness, and "crumb structure" affect how panelists evaluate texture during sensory tests, even when differences between sample groups are not statistically significant. For example, research in bakery sensory science highlights that texture profile parameters such as hardness, cohesiveness, and chewiness are commonly assessed in both instrumental and sensory evaluations because they are closely related to consumer perception of product quality [12]. When products share a similar moisture distribution and structural profile, sensory density scores may remain statistically comparable across formulations. This supports the present finding that all treatments were rated within the moderately dense category and that different fat types did not significantly affect the solid texture of the brownies (Fcount < Ftable). Furthermore, sensory research on brownie formulations with alternative fats shows that changes in fat type can influence perceived texture (e.g., softness or moistness), yet not always result in significant sensory differences, reinforcing the conclusion that the differences observed here are not statistically meaningful [1].

3.6. Flavor (Taste)

The mean sensory scores (Mean ± Standard Deviation) for flavor were: X0 (butter) 4.00 ± 0.00, X1 (margarine) 3.93 ± 0.10, and X2 (coconut oil) 3.93 ± 0.10. All treatments were categorized as having a typical chocolate flavor. Treatment X0 achieved the highest mean score with no variation among panelists, indicating a consistently strong chocolate flavor perception. Treatments X1 and X2 showed slightly lower but comparable scores with minimal variability.

Statistical analysis revealed that the calculated F value (Fcount = 1.00) was lower than the critical F value at the 5% significance level (Ftable = 4.46), indicating no statistically significant difference among treatments ($p > 0.05$). Therefore, Duncan's test was not conducted.

Taste is a fundamental attribute in the evaluation of food quality, as it integrates multiple sensory stimuli perceived during consumption. Visually appealing food products that emit pleasant aromas are more likel y to be perceived as palatable and acceptable to consumers. Taste is one of the most fundamental sensory attributes in food evaluation because it reflects the integrated responses of multiple sensory modalities, including gustation and retronasal olfaction, which together create the holistic perception of flavor during consumption. Research in food perception science has established that flavor is a complex multisensory experience shaped by the combined effects of taste compounds, aroma volatiles, texture, and even visual cues, all of which contribute to how the characteristic taste of a product is perceived and accepted by panelists [25]. For example, studies on food sensory evaluation emphasize that taste intensity and flavor perception emerge not solely from the chemical stimulation of taste receptors on the tongue, but also from the interaction with olfactory input released during mastication, which enhances the overall flavor profile and consumer response. This supports the present findings that the three treatments were rated with similar taste scores and that different fat types did not significantly affect the intensity of the characteristic chocolate taste (Fcount < Ftable), reflecting the multisensory integration underlying taste perception [26].

The results of this study demonstrate that the substitution of butter, margarine, and coconut oil in brownie formulations did not produce statistically significant differences in key sensory attributes, including shape, color, aroma, texture, and flavor ($p > 0.05$). Although butter consistently exhibited higher mean scores, particularly in aroma and overall flavor intensity, these differences were not sufficient to indicate a significant treatment effect. Similar findings have been reported in bakery product studies, where fat type influenced mean sensory scores but did not significantly affect overall acceptability when formulation ratios and baking conditions were standardized [27]. The uniform shape and blackish-brown color observed across all treatments are primarily attributed to controlled baking parameters and cocoa-driven Maillard reactions, which dominate visual quality in chocolate-based baked products rather than lipid source variation [28].

From a sensory and structural perspective, butter tended to enhance aroma and chocolate flavor perception due to its dairy-derived volatile compounds and favorable fat–flavor interactions during baking. However, brownies prepared with margarine and coconut oil also demonstrated acceptable sensory characteristics, particularly in texture and taste, confirming their suitability as alternative fat sources. The dense and moist internal texture observed in all samples aligns with the typical brownie structure, which relies on high fat and melted chocolate content rather than aeration for crumb development [12]. Previous studies have emphasized that while lipid composition may influence mouthfeel and flavor release, its effect on consumer-perceived quality remains limited when processing conditions are consistent [29]. Therefore, fat selection in brownie production can be guided by nutritional objectives, cost efficiency, or ingredient availability without compromising sensory quality.

4. CONCLUSION

Based on the research objectives, organoleptic evaluation, and analysis of variance (ANOVA), it can be concluded that the use of different fat types; butter, margarine, and coconut oil, does not result in significant differences in the sensory quality of baked brownies, including color, aroma, shape, texture, and taste ($p > 0.05$). Although butter tended to produce slightly higher mean scores for several attributes such as aroma, texture, shape, and overall flavor, these numerical differences were not statistically significant. This indicates that all formulations yielded brownies with comparable sensory characteristics and acceptable quality from the panelists' perspective.

Therefore, margarine and coconut oil can be considered suitable alternatives to butter in baked brownie production without compromising sensory quality. The findings of this study suggest that fat selection in brownie formulation may be based on factors such as nutritional considerations, cost efficiency, and ingredient availability rather than sensory performance alone. These results provide practical implications for both household-scale and commercial bakery production, particularly in developing flexible formulations that maintain product quality while accommodating diverse fat sources.

However, several limitations should be acknowledged. This study involved a relatively small number of panelists ($n = 5$), which may limit the generalizability of the sensory evaluation results. In addition, the assessment was restricted to sensory attributes without incorporating instrumental analysis such as texture profile analysis, moisture content, or lipid characterization. The study also focused on a single formulation and did not explore variations in fat ratios or combinations of fat types.

Future research is recommended to involve a larger and more diverse panel of participants to improve the robustness of sensory data. Further studies should also integrate instrumental and physicochemical analyses to complement sensory findings and provide a more comprehensive evaluation of product quality. In addition, exploring different fat ratios, fat blends, or structured lipid systems (e.g., oleogels) may provide deeper insights into optimizing both sensory and nutritional characteristics of brownie products.

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