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Article

Effect of Cinnamon Addition on the Quality of Tofu Dregs Flour-Substituted Baked Brownies

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Abstract: This study investigated the substitution of wheat flour with tofu dregs flour, a nutrient-rich by-product of tofu processing, to improve the nutritional quality and sustainability of cinnamon-flavored baked brownies (*Cinnamomum burmannii*). The research aimed to evaluate the effect of different substitution levels on the brownies' chemical composition and sensory characteristics. The experiment employed a completely randomized design (CRD) consisting of five treatments with substitution levels of 20%, 25%, 30%, 35%, and 40% tofu dregs flour, each replicated three times. Proximate analyses were conducted to determine moisture, ash, fat, protein, and total sugar content using standard laboratory methods, while sensory evaluation was performed by 30 panelists using a 9-point hedonic scale to assess color, aroma, flavor, texture, and overall acceptability. Results showed that increasing tofu dregs flour substitution significantly affected the chemical composition of brownies, increasing protein, ash, and fat contents, while reducing moisture and total sugar levels. Sensory analysis indicated that brownies with 30% tofu dregs flour substitution were the most preferred, exhibiting balanced flavor, aroma, and texture, with cinnamon effectively masking the beany odor of tofu dregs. In conclusion, tofu dregs flour can serve as a functional ingredient that enhances the nutritional and sensory properties of baked products while contributing to food waste reduction. Further research is recommended to assess the dietary fiber content, antioxidant properties, and shelf-life stability of tofu dregs–based brownies.

Keywords: Tofu dregs flour; wheat flour substitution; *Cinnamomum burmannii*; baked brownies; sensory evaluation

1. Introduction

Tofu dregs are the solid residue produced during tofu production (Ayunir & Hermanto, 2017). They are a by-product formed when solid tofu is made and are derived from the pressed soybean pulp (Herlinae et al., 2017). Due to their origin from soybeans, tofu dregs are rich in protein content (Ariawan et al., 2024). In Indonesia there are many tofu processing industries, and on average the processing still uses traditional technology which produces a by-product of tofu, namely tofu dregs which is relatively large (Rahayu et al., 2016). However, the use of tofu dregs is still lacking. Tofu waste, commonly regarded as a by-product, is nutritionally rich but remains underutilized in many communities (Rachma et al., 2020). Studies indicate

that fresh tofu pulp consists of 11.07% carbohydrates, 4.71% protein, 1.94% fat, and 0.08% ash per 100 g of the material (Rahayu et al., 2016).

Fresh tofu pulp has a high moisture content, so it can cause a relatively short shelf life. The drying process is one way to reduce the high-moisture content of fresh tofu pulp (Salim, 2012). Wet tofu dregs are easily damaged and decayed, so they need further handling to increase their shelf life, one way to handle this is to make flour (Prabowo & Tanone, 2025). As the results of drying tofu dregs, it can be processed into tofu dregs flour products which can meet higher nutritional content and are flexible in their use (Nurasyifa et al., 2024). Given the habits of people who prefer to consume ready-to-eat products which are generally low in fiber, tofu dregs flour can be an option (Sabir et al., 2020).

Tofu dregs are crushed and then grinded and sieved with a fineness of approximately 80 mesh (Sari & Syamsudin, 2019). The tofu dregs flour is brownish white in color and has a characteristic unpleasant aroma of tofu dregs (Ginting et al., 2024). Tofu dregs flour is produced by placing fresh tofu in a pressing machine or squeezing it by hand and then drying it in a dryer/drying machine (Wati et al., 2024), then crushing it with a blender and filtering it to obtain tofu dregs with uniform particle sizes (Dahniar et al., 2014). Tofu dregs flour can be an alternative to processing products made from wheat flour (Kusumaningtyas et al., 2020).

Indonesia's dependence on wheat is increasing due to the increasing number of processed wheat flour products as a staple food (Syarbini, 2013). This causes an increase in wheat imports to Indonesia every year. In 2017, it is estimated that the national demand for wheat will reach 8.79 tons. Without realizing it, imports of wheat in large quantities can threaten the stability of the country's economy. One way to reduce dependence on the need for wheat flour is to use alternative flours that are equivalent to wheat flour (Rahmawany & Ginting, 2021). Replacing wheat flour with tofu dregs flour in cake recipes, like brownies, can decrease the amount of wheat flour needed (Nurhayati et al., 2019).

Tofu dregs flour is not only rich in protein but also contains a substantial amount of fiber, which helps fulfill the body's daily fiber requirements. When processed into flour, tofu residue gains a longer shelf life and can be incorporated into various food products like cakes, biscuits, sticks, and more. Brownies are foods that are widely known by Indonesian people (Adisty et al., 2020). Generally, the raw material for brownies is wheat flour (Dwiani & Yuniartini, 2022). Wheat flour functions as a shaper of texture and structure, binds other ingredients so that they blend together and plays a role in forming flavors (Sari & Syamsudin, 2019; Aristyarini et al., 2025). Brownies are a popular variety of processed food widely enjoyed by the public. There are two main types of brownies: steamed brownies and baked brownies (Nurasyifa et al., 2024). They belong to the category of pound cakes and are characterized by their deep brown color. In terms of texture, brownies resemble cakes, as their crumb shows consistent pore distribution when sliced, and they offer a soft, moist sensation along with a pleasant taste when consumed (Widayati et al., 2021). Compared to regular cakes, brownies tend to be denser because they use minimal or no chemical leavening agents, resulting in a more compact structure (Purlis, 2010; Lestari et al., 2019).

In contrast to conventional snacks or cakes that generally spoil within a day, brownies have a longer shelf life, typically lasting two to three days even without the addition of preservatives (Inayah et al., 2025; Nugroho et al., 2023; Chaniago et al., 2025). Brownies can be prepared using two distinct methods: baking and steaming. Each method yields different product characteristics, where steamed brownies tend to have a higher water level and a softer consistency (Walgiyanti et al., 2023; Mumtaza et al., 2025). The primary distinction between the two techniques lies in their moisture content (Ambar et al., 2025). Compared to steamed varieties, baked brownies contain less water, which contributes to their extended shelf life. In terms of flavor, baked brownies are generally richer, whereas steamed brownies are considered safer and more health-friendly, as the absence of the roasting process prevents the formation of free radicals (Walgiyanti et al., 2023; Ronie et al., 2021). Additionally, baked brownies maintain their quality longer than their steamed counterparts (Aristyarini et al., 2025).

Baked brownies made from tofu dregs flour have a weakness, namely the unpleasant aroma (Aristyarini et al., 2025). Therefore, the use of cinnamon powder in making brownies is intended to add to the flavors of the brownies (Inayah et al., 2025; Diyono et al., 2022; Prabowo & Tanone, 2025). Besides that, cinnamon powder has a fragrant and sweet aroma so that it can reduce and even eliminate the unpleasant taste found in tofu dregs (Prabowo & Tanone, 2025; Inayah et al., 2025). The benefits of cinnamon are of course quite extraordinary, having chemical compounds in the form of saponins, phenols and terpenoids which are a source of anti-oxidants. Cinnamon plants are a type of spice that contains the highest antioxidants compared to other spices (Walgiyanti et al., 2023; Wati et al., 2024). Every 100 g of cinnamon provides a nutritional value of 247 kcal of energy, 3.19 g of fat, 79.85 g of carbohydrates, and 3.89 g of

protein (Ginting et al., 2024). This research aimed to examine how substituting wheat flour with tofu dregs flour in the production of cinnamon-flavored brownies (*Cinnamomum burmannii*) influences both chemical properties and sensory attributes. The study also focused on identifying the type of cinnamon that is most favored by consumers.

2. Materials and Methods

This study took place at the Laboratory of Agricultural Product Technology, Faculty of Agriculture, Ekasakti University, Padang. The research was conducted during the period of September to October 2022. The research aimed to evaluate the chemical composition and sensory quality of baked brownies produced by substituting wheat flour with tofu dregs flour and incorporating cinnamon (*Cinnamomum burmannii*).

The materials utilized in this study included high-protein wheat flour (Cakra Kembar brand from Bogasari), which contains 12% protein. tofu dregs flour (produced from locally sourced tofu dregs and processed into fine flour), the tofu itself used Anjasmoro soybean from Pasaman West Sumatra, margarine (Blue Band Margarine) with a fat content of approximately 85%, and compound chocolate bars (Colatta Dark Compound) with a fat content of 39%. Other ingredients used were fresh eggs obtained from local suppliers, each weighing approximately 65 g, powdered sugar (Rose Brand), pasteurized liquid milk (Ultra Milk Full Cream), and refined table salt (Garam Lososa).

The substances used for chemical testing in this study included sulfuric acid, distilled water, sodium hydroxide, methyl red, phenolphthalein, and n-hexane. Equipment employed in the research included basins, spoons, baking pans/trays, molds, ovens, analytical balances, tampah (winnowing trays), spatulas, sieves, and knives. For chemical analysis, the instruments utilized comprised porcelain crucibles, filter paper, Kjeldahl flasks, burettes, Erlenmeyer flasks, sockets, condensers, desiccators, furnaces, electric heaters, pipettes, and beakers.

The experiment used a completely randomized design (CRD) with five substitution levels of tofu dregs flour (20%, 25%, 30%, 35%, and 40%), each replicated three times. The collected data were evaluated using Analysis of Variance (ANOVA) followed by Duncan's New Multiple Range Test (DNMRT).

Sensory evaluation was conducted using the hedonic test with a 9-point scale, where panelists were asked to rate their preference for color, aroma, taste, texture, and overall acceptability of the product. The use of a 9-point hedonic scale is a common method in food research because it provides measurable and reliable consumer preference data (Meilgaard et al., 2016).

Provide a detailed explanation of the research framework, including the type of study conducted, duration of the research, subject selection process, and inclusion or exclusion criteria. Ensure the methodology is thoroughly explained, covering aspects such as sample collection, handling procedures, laboratory testing, and the statistical methods applied for data interpretation.

2.1. Manufacture of Tofu Dregs Flour

(1) Four kg of tofu was taken and pressed to reduce the moisture content and squeezing process was repeated.
(2) Steaming: Tofu dregs are steamed for 40 min with the addition of pandan leaves, pandan leaves were added to help reduce the beany odor typically present in tofu dregs and to impart a mild, pleasant aroma to improve the sensory quality of the final product.
(3) Drying in the sun for 3 × 8 h to dry.
(4) Puree using a blender then sifted with 80 mesh sieve.
(5) Tofu dregs flour is stored in a dry place (Santos et al., 2019).

2.2. Preparation of Baked Brownies

The brownies were prepared following a standard formulation modified from Sari and Syamsudin, (2019), with adjustments in the proportion of wheat flour and tofu dregs flour according to the treatment. The experiment consisted of five substitution levels of tofu dregs flour (20%, 25%, 30%, 35%, and 40%), replacing part of the total flour content (100 g). All other ingredients were kept constant to ensure uniformity.

(1) Melting Phase: Combine 40 g dark compound chocolate and 50 g margarine in a stainless steel bowl. Heat over a water bath until fully melted, then add 0.3 g salt and let the mixture cool slightly.

(2) Mixing Phase: Beat one egg (≈65 g) with 50 g powdered sugar for 5 min until creamy and light in texture. Gradually add 34 mL full-cream milk while stirring continuously.
(3) Incorporation of Dry Ingredients: In a separate bowl, mix wheat flour, tofu dregs flour, and 1 g cinnamon powder according to the substitution treatment (Table 1). Slowly add the dry ingredients into the wet mixture while stirring until evenly distributed.
(4) Baking: Pour the batter into a rectangular baking pan (20 × 10 × 4 cm) previously greased with margarine. Bake in a preheated oven at 180 °C for 25 min.
(5) Cooling and Storage: Remove from the oven, cool at room temperature (25–27 °C), and store in airtight food-grade containers before proximate and sensory analysis (Mumtaza et al., 2025).

Table 1. Proximate Composition of Baked Brownies Substituted with Tofu Dregs Flour.

Treatment	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Sugar (%)
A (20%)	21.93 ^{a} ± 0.01	1.46^{a} ± 0.05	9.23 ^{a} ± 0.11	8.49 ^{a} ± 0.44	36.78 ^{e} ± 0.05
B (25%)	18.14 ^{b} ± 0.01	1.54 ^{ab} ± 0.04	10.31^{b} ± 0.26	12.57 ^{b} ± 0.37	35.40 ^{d} ± 0.04
C (30%)	17.03 ^{c} ± 0.01	1.74 ^{b} ± 0.03	13.78 ^{c} ± 0.08	14.49 ^{c} ± 0.11	31.05 ^{c} ± 0.05
D (35%)	16.41 ^{d} ± 0.01	2.10 ^{c} ± 0.09	15.13 ^{d} ± 0.04	17.47 ^{d} ± 0.23	27.39 ^{b} ± 0.18
E (40%)	14.10 ^{e} ± 0.01	3.63 ^{d} ± 0.18	18.15 ^{e} ± 0.06	21.55 ^{e} ± 0.11	22.09 ^{a} ± 0.06

KK = 0.041%; Note: Values within the same column that are accompanied by different lowercase letters indicate a highly significant difference based on the DNMRT test at the 1% significance level.

2.3. Proximate Analysis

The chemical composition of baked brownies, including moisture, ash, fat, protein, total sugar, and crude fiber, was analyzed using standard methods of the Association of Official Analytical Chemists (AOAC, 2019) as follows:

- Moisture content was determined by oven-drying samples at 105 °C to constant weight (AOAC 925.10).
- Ash content was measured by incineration in a muffle furnace at 550 °C until white ash was obtained (AOAC 923.03).
- Crude fat was analyzed by Soxhlet extraction using n-hexane as the solvent (AOAC 920.39).
- Crude protein was determined using the Kjeldahl method, where total nitrogen was converted to protein using a factor of 6.25 (AOAC 981.10).
- Total sugar was quantified using the phenol-sulfuric acid method (AOAC 975.17).
- Crude fiber was analyzed by sequential acid and alkali digestion (AOAC 962.09), and the residue was ashed to determine fiber content.

2.4. Sensory Evaluation

A sensory test was conducted with 30 untrained panelists using a 9-point hedonic scale (1 = strongly dislike to 9 = strongly like) following Meilgaard et al. (2016). Attributes assessed included color, aroma, flavor, texture, and overall acceptability.

3. Results and Discussion

3.1. Chemical Properties Test

The results of chemical analysis (proximate test) are presented to show the effect of substituting wheat flour with tofu dregs flour on the composition of cinnamon-flavored baked brownies. Proximate analysis was conducted in order to evaluate key chemical parameters, including moisture, ash, fat, protein, and total sugar contents. These parameters are important indicators of both nutritional quality and product stability, since moisture content is closely related to texture and shelf life, ash content reflects the mineral and inorganic components, fat and protein contribute to both nutritional profile and sensory properties such as mouthfeel and texture, while sugar is strongly associated with sweetness, caloric value, and consumer preference. To provide a clearer and more integrated comparison, all proximate parameters are combined in one table instead of being presented separately. This presentation highlights how increasing levels of tofu dregs flour substitution influence the overall chemical composition of the brownies. The detailed results are summarized in Table 1.

As shown in Table 1, increasing the substitution level of tofu dregs flour significantly affected all proximate parameters of baked brownies. Moisture content decreased steadily from 21.93% at 20%

substitution to 14.10% at 40% substitution, while ash and protein contents increased significantly in line with the higher proportion of tofu dregs flour, reaching 3.63% and 21.55% at 40% substitution, respectively. Fat content also showed a marked increase, rising from 9.23% in treatment A to 18.15% in treatment E, reflecting the higher fat content of tofu dregs flour compared to wheat flour. In contrast, total sugar content declined from 36.78% to 22.09% as the substitution level increased, due to the lower carbohydrate content in tofu dregs flour. These results demonstrate that substituting wheat flour with tofu dregs flour not only enhances the nutritional quality of baked brownies, particularly in terms of protein and mineral content, but also alters their proximate balance in ways that could influence texture, taste, and consumer acceptance.

3.1.1. Moisture Content

The analysis of variance revealed that substituting wheat flour with tofu dregs flour in baked brownies had a highly significant impact ($p < 0.01$) on their moisture content. According to the results of the DNMRT test at a significance level of $\alpha = 0.01$, all treatment variations showed notable differences in the moisture content of the baked brownies. The mean values for the moisture content can be seen in Table 1 above, it presents the water levels of baked brownies, which range between 14.10% and 21.93%. The highest moisture content was observed in treatment A (20% substitution of wheat flour with tofu dregs flour), reaching 21.93%, while the lowest was in treatment E (40% substitution), with a value of 14.10%. The DNMRT follow-up test at the 1% significance level indicated that each treatment resulted in a statistically significant difference in moisture content. As the amount of tofu dregs flour increased and wheat flour decreased, the moisture content of the baked brownies tended to decrease.

A recorded the highest water level in baked brownies at 21.93%. This indicates that a lower proportion of tofu dregs flour substitution results in higher moisture content. The reduction in water in this study is attributed to the lower moisture content of tofu dregs flour compared to wheat flour. Wheat flour has a moisture content of 14.50%, while tofu dregs contain 13.75% (Inayah et al., 2025). The decrease in water with increasing tofu dregs flour is due to its inability to form a gel structure, which limits its capacity to retain water and other components (Wati et al., 2024). A lower water level is associated with increased product hardness, which influences shelf life and durability (Aristyarini et al., 2025).

All treatments in this research met the water requirements specified by SNI 01-3840-1995 for sweet bread, which allows a maximum moisture content of 40% (wet basis). Therefore, the moisture content of the baked brownies in this study complied with the established SNI standards. The reference for brownie quality standards follows SNI 01-3840-1995.

The decrease in moisture content in the brownies is because tofu dregs flour has a lower moisture content (13.75%) compared to wheat flour (14.50%). Additionally, the inability of tofu dregs flour to form a gel structure limits its ability to retain water and other components. Therefore, the higher the substitution with tofu dregs flour, the lower the final product's moisture content.

The moisture content of the baked brownies decreased as the amount of tofu dregs flour increased. This is because tofu dregs flour has a lower water content (13.75%) compared to wheat flour (14.50%). The inability of tofu dregs flour to form a gel structure also limits its capacity to retain water, leading to a reduction in moisture as its proportion in the recipe increases. A lower moisture level contributes to a harder product texture and a longer shelf life.

3.1.2. Ash Content

The analysis of variance indicated that variations in the formulation of baked brownies using wheat flour and tofu dregs flour had a highly significant effect ($p < 0.01$) on their ash content. According to the DNMRT test at a 1% significance level ($\alpha = 0.01$), each treatment resulted in a significant difference in the ash levels of the brownies. The average values of ash content across treatments can be seen in Table 1 above, it presents the ash content of baked brownies, which ranges between 1.46% and 3.63%. The highest ash level was observed in treatment E, where 40% of the wheat flour was replaced with tofu dregs flour, reaching 3.63%. Conversely, the lowest ash content was found in treatment A, with a 20% substitution, recorded at 1.46%. The DNMRT follow-up analysis at a 1% significance level revealed that all treatments had significantly different ash contents. As the proportion of tofu dregs flour increased and wheat flour decreased, the ash content also increased.

The highest ash content in baked brownies was observed in treatment E, where 40% of wheat flour was replaced with tofu dregs flour, resulting in an ash content of 3.63%. An increase in tofu dregs flour

substitution and a decrease in wheat flour proportion corresponded with a rise in ash content. This is due to the higher mineral concentration in tofu dregs flour compared to wheat flour. Tofu dregs flour contains 2.37% ash, whereas wheat flour contains only 0.70% (Rahayu et al., 2016). This finding aligns with the statement by Ginting et al., (2024), which suggests that elevated ash levels may result from the addition of tofu dregs flour, which contains substantial inorganic residue. The coarse texture of tofu dregs flour, as opposed to the finer consistency of wheat flour, contributes to the presence of fibrous material in the final product.

The maximum ash content was recorded at 3.63% in brownies with 40% tofu dregs flour, while the minimum was 1.46% in those with a 20% substitution. On average, the ash levels in this study conformed to the SNI 01-3840-1995 standard for sweet bread, which sets the maximum limit at 3%, except for treatment E.

The increase in ash content is due to the higher concentration of minerals and inorganic residue in tofu dregs flour (2.37% ash) compared to wheat flour, which contains only 0.70% ash. The coarse texture of tofu dregs flour also contributes to the presence of fibrous material in the final product.

The ash content of the baked brownies increased with a higher substitution of tofu dregs flour. This is because tofu dregs flour contains a higher mineral concentration and more inorganic residue (2.37% ash) compared to wheat flour, which has only 0.70% ash. The coarser texture of tofu dregs flour also contributes to the presence of fibrous material in the final product.

3.1.3. Fat level

The variance analysis indicated that substituting wheat flour with tofu dregs flour in baked brownies had a highly significant impact ($p < 0.01$) on the fat content. According to the DNMRT test at a significance level of $\alpha = 0.01$, all treatment groups exhibited notable differences in the fat levels of the baked brownies. The mean fat content for each treatment can be seen in Table 1 above, it presents the fat content of baked brownies, which falls within the range of 9.23% to 18.15%. The highest fat level was recorded in treatment E, where 40% of wheat flour was replaced with tofu dregs flour, resulting in a fat content of 18.15%. In contrast, the lowest fat content, 9.23%, was found in treatment A with a 20% substitution. The DNMRT follow-up test at the 1% significance level revealed that each treatment caused a highly significant variation in fat content. As the proportion of tofu dregs flour increased and wheat flour decreased, the fat content in the brownies rose accordingly.

The highest fat content in baked brownies was observed in treatment E, reaching 18.15%. This result suggests that increasing the proportion of tofu dregs flour leads to a rise in fat content. This occurs because during the pressing process, the fat components from soybean seeds remain in the tofu dregs, as they are not water-soluble. The elevated fat content in the brownies is attributed to the relatively high fat level in tofu dregs flour, which contains 19.69 g of fat per 100 g (Liu et al., 2022), compared to only 0.9 g per 100 g in wheat flour (Kurniasari & Wibisono, 2023). Similar findings were reported by (Aussanasuwannakul et al., 2024), indicating that higher amounts of tofu dregs flour contribute to increased fat content.

The maximum fat content was recorded in the brownies with 40% tofu dregs flour at 18.15%, while the minimum was 9.23% in those containing 20% tofu dregs flour. However, the fat content levels obtained in this study exceeded the SNI 01-3840-1995 standard for sweet bread, which limits fat content to a maximum of 3%.

The fat content rises because tofu dregs flour has a higher fat content (19.69 g per 100 g) compared to wheat flour (0.9 g per 100 g). The fat components from soybeans remain in the tofu dregs during the pressing process because they are not water-soluble.

The fat content of the brownies rose as the proportion of tofu dregs flour increased. This is due to the high fat content in tofu dregs flour (19.69 g per 100 g). During the pressing process to make tofu, the fat components from the soybeans remain in the tofu dregs, as they are not soluble in water. This contrasts with wheat flour, which contains a much lower fat level (0.9 g per 100 g).

3.1.4. Protein Content

The analysis of variance revealed that substituting wheat flour with tofu dregs flour in baked brownies had a highly significant influence ($p < 0.01$) on their protein content. The DNMRT test conducted at a significance level of $\alpha = 0.01$ showed that all treatment variations resulted in significant differences in the protein levels of the brownies. The mean protein content for each treatment can be seen in Table 1 above, it displays the protein levels in baked brownies, which range from 8.49% to 21.55%. The highest protein

content was recorded in treatment E, where 40% of the wheat flour was replaced with tofu dregs flour, resulting in a value of 21.55%. In contrast, the lowest protein level, 8.49%, was observed in treatment A, which used a 20% substitution. According to the DNMRT follow-up test at the 1% significance level, all treatments demonstrated significant differences in protein content. As the proportion of tofu dregs flour increased and wheat flour decreased, the protein content also rose.

The highest protein level in baked brownies was found in treatment E (ratio 60:40), reaching 21.55%. This indicates that increasing the proportion of tofu dregs flour leads to a higher protein content. This occurs because tofu dregs flour contains more protein than wheat flour. As stated by Aristyarini et al. (2025), higher protein levels in food ingredients can influence the texture of the final product, with increased protein often reducing the product's ability to rise. This is supported by (Ginting et al., 2024), who reported that tofu dregs flour contains 23.55% protein, significantly more than wheat flour, which has only 8.90%.

The protein content of baked brownies with various levels of wheat flour substituted by tofu dregs flour ranged from 8.49% to 21.55%. Therefore, all protein values obtained in this study meet the minimum requirement set by SNI 01-3840-1995 for sweet bread, which is at least 8%.

The protein content increases significantly because tofu dregs flour has a much higher protein content (23.55%) than wheat flour (8.90%).

The protein content in the brownies increased as the amount of tofu dregs flour substitution rose. Tofu dregs flour contains a significantly higher amount of protein (23.55%) compared to wheat flour (8.90%). This higher protein level in the tofu dregs flour is the primary reason for the increase in the final product's protein content.

3.1.5. Total Sugar Content

The variance analysis results demonstrated that substituting wheat flour with tofu dregs flour in baked brownies had a highly significant effect ($p < 0.01$) on the total sugar content. According to the DNMRT test at a significance level of $\alpha = 0.01$, each treatment produced significantly different total sugar levels. The average values of total sugar content in the baked brownies can be seen in Table 1 above, it presents the total sugar content of baked brownies, ranging between 22.09% and 36.78%. The highest sugar level was recorded in treatment A, where 20% of the wheat flour was replaced with tofu dregs flour, reaching 36.78%. On the other hand, the lowest sugar content, 22.09%, was observed in treatment E, which used a 40% substitution. The DNMRT follow-up test at a 1% significance level revealed that each treatment showed a statistically significant difference in total sugar content. As the proportion of tofu dregs flour increased and wheat flour decreased, the total sugar content declined.

The highest total sugar content in baked brownies was found in treatment A (20% tofu dregs flour substitution), with a value of 36.78%. In contrast, the lowest sugar level was observed in treatment E (40% substitution), at 22.09%. As the proportion of tofu dregs flour increases and the wheat flour portion decreases, the total sugar content tends to decline. This is because wheat flour and several other brownie ingredients naturally contain higher amounts of sugar. Since wheat flour has a greater carbohydrate content compared to tofu dregs, its increased use leads to higher total sugar levels in the final product (Mointi et al., 2023).

The elevated sugar content is also influenced by the high sugar levels present in ingredients such as wheat flour, granulated sugar, and chocolate bars. The sugar levels identified in this study exceeded the sweet bread standard set by SNI 01-3840-1995, which limits total sugar to a maximum of 8% (Inayah et al., 2025).

The total sugar content decreases as the amount of tofu dregs flour increases and the amount of wheat flour decreases. This is because wheat flour naturally contains more carbohydrates and sugar compared to tofu dregs. Substituting wheat flour with tofu dregs flour, which has a lower sugar content, leads to a reduction in the overall sugar content of the final product.

The total sugar content of the brownies decreased as the proportion of tofu dregs flour increased and the amount of wheat flour decreased. This is because wheat flour naturally contains more carbohydrates and sugar compared to tofu dregs. Other ingredients like granulated sugar and chocolate bars also contribute to the high sugar levels. Therefore, substituting the lower-sugar tofu dregs flour for wheat flour leads to a reduction in the overall sugar content of the brownies.

These findings indicate that the utilization of tofu dregs flour has potential in bakery applications, particularly for enhancing protein and ash content while maintaining acceptable sensory quality. Although

previous studies have explored the use of tofu dregs in different food matrices, our research highlights the unique role of cinnamon (*Cinnamomum burmannii*) in masking undesirable aroma compounds typically associated with tofu dregs, thereby improving consumer acceptance of baked brownies. This formulation aspect has not been previously reported, and thus contributes novelty to the existing literature. Nevertheless, we acknowledge that the present study is still preliminary in nature. Further validation is required, including shelf-life determination, microbiological safety testing, evaluation of antioxidant activity, and consumer acceptance studies involving a larger and more diverse population, in order to establish the industrial feasibility of tofu dregs flour substitution in baked products.

3.2. Organoleptic Test

Organoleptic evaluation was carried out to determine the acceptance level of baked brownies substituted with tofu dregs flour at different proportions. Sensory attributes assessed included aroma, color, flavor, and texture, since these characteristics are directly related to consumer preference and play a decisive role in product acceptability. Aroma is important in masking or enhancing the characteristic odor of tofu dregs, color serves as the first impression of product quality, flavor is the most influential attribute for overall liking, and texture determines mouthfeel and eating quality. The evaluation was conducted using a hedonic scale with 30 untrained panelists. To provide a comprehensive overview, the average values of all sensory attributes were combined in one table, as shown in Table 2.

Table 2. Organoleptic Scores of Baked Brownies Substituted with Tofu Dregs Flour.

Treatment	Aroma	Color	Taste	Texture	Overall Acceptability
A (20%)	4.52	5.11	4.38	4.90	4.72
B (25%)	4.65	5.15	5.00	5.16	4.99
C (30%)	5.20	5.18	5.55	5.26	5.29
D (35%)	4.70	4.84	4.68	4.96	4.79
E (40%)	4.57	4.52	4.66	4.52	4.56

Description: Organoleptic test used a 9-point hedonic scale, where 1 = strongly dislike, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely.

As shown in Table 2, the substitution of wheat flour with tofu dregs flour produced notable differences in the organoleptic characteristics of baked brownies. Aroma scores ranged between 4.52 and 5.20, with the highest rating obtained in treatment C (30% substitution). This indicates that a moderate level of tofu dregs flour combined with cinnamon powder was effective in reducing the beany odor typically associated with tofu dregs, thereby producing a more acceptable aroma. At higher substitution levels (35–40%), the aroma scores slightly declined, which may be attributed to the stronger presence of soy-based volatile compounds that could not be fully masked by cinnamon.

Color scores were relatively consistent across treatments, ranging from 4.52 to 5.18. The highest score was again observed in treatment C, suggesting that panelists preferred brownies with a balanced brown appearance, resulting from the interaction between cocoa, wheat flour, and tofu dregs flour. At the 40% substitution level, the color score decreased, likely due to the darker and less uniform crumb appearance influenced by the coarser texture and natural pigmentation of tofu dregs flour.

Flavor was the most decisive attribute, with scores ranging from 4.38 to 5.55. Panelists rated treatment C as the most favorable in terms of flavor, reflecting the synergy between chocolate and cinnamon in masking undesirable flavors while enhancing overall taste. Lower scores in treatments A (20% substitution) and E (40% substitution) suggest that too little or too much tofu dregs flour results in imbalanced flavors, either because of insufficient nutritional enrichment or the dominance of undesirable notes.

Texture evaluation revealed scores between 4.52 and 5.26, with the best score again recorded at 30% substitution. Brownies with this formulation exhibited a moist yet firm crumb structure, which was appreciated by panelists. At the highest substitution level (40%), texture acceptability declined, likely due to the higher fiber content of tofu dregs flour, which resulted in a rougher and denser crumb.

Overall, treatment C (30% substitution) achieved the highest average score (5.29), outperforming other formulations in all attributes. This suggests that a 30% substitution level offers the best balance between improved nutritional quality and consumer acceptability. These findings demonstrate the potential of tofu dregs flour in bakery applications while also emphasizing the importance of determining an optimal substitution level that satisfies both sensory and functional qualities.

The brownies produced in this study showed a characteristic brown crust formed through caramelization and Maillard reactions during baking, with the surface appearing uniform and visually appealing. The crumb color was darker and consistent, reflecting the influence of cocoa powder, wheat flour, and the incorporation of tofu dregs in the formulation. In terms of structure, the brownies exhibited moderate height and volume, indicating adequate aeration and expansion during baking. Overall, the products displayed a balanced rise without collapse, a firm crust, and a moist crumb, which together demonstrated acceptable physical quality across treatments.

In organoleptic test, it plays a crucial role in assessing product quality and consumer acceptance. This evaluation helps determine the panelists' level of preference for the baked brownies by examining attributes such as aroma, color, texture, and taste, as judged by 30 untrained panelists. The assessment was conducted using a hedonic scale ranging from 1 to 9, where 1 = strongly dislike, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely.

During the testing process, panelists were instructed to score each sample based on their individual preference. The organoleptic evaluation focused on the sensory characteristics of baked brownies made with varying levels of tofu dregs flour substitution.

3.2.1. Aroma

A food's aroma plays a key role in influencing its perceived deliciousness. Evaluating aroma primarily involves the sense of smell, which operates independently from other senses such as sight, hearing, and touch. The scents detected by the nose and interpreted by the brain typically consist of a combination of four basic odor types: fragrant, sour, rancid, and burnt (Aristyarini et al., 2025). The panelists' evaluations of the aroma of baked brownies can be seen Table 2, it indicates that the highest aroma score for baked brownies was achieved in treatment C (30% substitution of wheat flour with tofu dregs flour), with a value of 5.20. In contrast, the lowest aroma rating was recorded in treatment A (20% substitution), at 4.52. This is because aroma plays a critical role in determining how appealing a food product is, often being more complex and influential than taste itself (Aristyarini et al., 2025).

Variations in the proportion of tofu dregs flour substitution led to differences in how the aroma was perceived by panelists. Among the treatments, treatment C was the most favored in terms of aroma. This is likely due to the presence of lipoxygenase enzymes in tofu dregs flour, which are known to produce an unpleasant odor. When the amount of tofu dregs flour is too high, it can negatively impact the aroma of the final baked product. Conversely, using a smaller proportion of tofu dregs flour and a higher amount of wheat flour tends to lessen the negative aromatic impact. As stated by (Nurasyifa et al., 2024; Tridtitanakiat et al., 2023), tofu dregs flour contains a distinct, often undesirable odor due to lipoxygenase enzymes in soybeans.

The aroma of the baked brownies originates from volatile compounds in key ingredients such as tofu dregs flour, wheat flour, sugar, and cocoa, which serve as aroma precursors. During baking, reactions between amine and carboxyl groups in these ingredients lead to the development of the characteristic aroma. The uniform use of chocolate bars and cocoa powder across treatments also contributed to the aroma consistency (Lubis et al., 2021).

3.2.2. Color

Color is the first sensory attribute perceived visually by panelists. The evaluation of color is done through direct observation using the panelists' sense of sight. While food quality is influenced by multiple aspects, color is typically the initial indicator used to judge a product's quality before other characteristics are considered (Aristyarini et al., 2025). The outcomes of the panelists' evaluation of the color of baked brownies made with varying levels of tofu dregs flour substitution can be seen Table 2, it shows that the highest score for the color of baked brownies was observed in one of the treatments, reaching 5.18. In contrast, the lowest color rating was recorded in treatment E, with a value of 4.52. This difference is likely due to panelists' preference for brownies with a lighter brown hue. The appearance of the brownies is affected by the presence of tofu dregs during processing. The final color is influenced by the combination of ingredients such as flour, chocolate, and liquids used in the batter (Nurasyifa et al., 2024).

The color development in baked brownies results from the Maillard reaction, which occurs when carbohydrates in the flour interact with sugars and cocoa during baking, producing a dark brown or blackish hue. This process, explained by (Aristyarini et al., 2025), involves a chemical reaction between sugars and starches, leading to browning and color enhancement.

3.2.3. Taste

Taste is a key element that greatly influences consumer preference for a food product. It results from a combination of taste detected by the tongue, aroma sensed by smell, and prior experiences with similar foods (Aristyarini et al., 2025). The panelists' evaluations of the taste of baked brownies can be seen Table 2, it reveals that the highest taste score for baked brownies was achieved in treatment C, where 30% of the wheat flour was replaced with tofu dregs flour, receiving a rating of 5.55. In contrast, the lowest rating was given to treatment A, with a 20% substitution level, scoring 4.38. These differences in ratings are influenced by the varying levels of tofu dregs flour used, which affected how panelists perceived the taste of the brownies. Individual variations in sensory experience can be attributed to differences in sensitivity of taste receptors or limited familiarity with certain flavors (Nurasyifa et al., 2024).

Based on the panelists' evaluations, it can be concluded that the use of tofu dregs flour as a substitute for wheat flour was well received. This suggests that the panelists appreciated the flavor of the baked brownies. This finding is in line with research by Fatimah, which notes that the dominant chocolate taste plays a key role in the overall flavor of brownies as reflected in organoleptic testing (Lestari et al., 2019).

3.2.4. Texture

The texture of a food product is primarily influenced by its water, fat, protein, and carbohydrate content (Yuliani & Mardesci, 2017). The visual appearance of a product also plays a significant role in whether it is accepted or rejected by consumers. The panelists' evaluation of the texture of baked brownies can be seen Table 2, it indicates that the highest texture score for baked brownies was found in treatment C (30% tofu dregs flour substitution), with a value of 5.26. In contrast, the lowest texture rating was recorded in treatment E (40% substitution), at 4.52. The reduced preference for treatment E may be due to the higher fiber content in tofu dregs flour, which resulted in a rougher, less desirable brownie texture.

From these findings, it can be inferred that increasing the proportion of wheat flour leads to a softer product texture and greater acceptance among panelists. This aligns with the explanation by (Yulneriwarni, 2024), which states that food texture is greatly affected by water, fat, and the composition and type of carbohydrates and proteins present.

3.2.5. Recapitulation of organoleptic values

Overall, the summary of the organoleptic evaluations by 30 untrained panelists showed responses ranging from "like" to "somewhat like" toward the baked brownies. The detailed results can be seen Table 2, it summarizes the panelists' evaluations of the baked brownie samples. The data shows that the highest scores given by the panelists were for aroma (5.52), color (5.18), taste (5.55), and texture (5.29). These results indicate that treatment C, which involved substituting 30% of wheat flour with tofu dregs flour, received the best overall average in the organoleptic test. This finding aligns with the explanation provided by Irigoytia et al. (2024), which states that acceptance or preference testing reflects an individual's level of approval toward certain characteristics or qualities of a product, ultimately influencing whether they like it.

4. Conclusions

This study demonstrated that substituting wheat flour with tofu dregs flour significantly influenced the chemical and sensory characteristics of baked brownies. Increasing the substitution level led to higher protein, ash, and fat contents while reducing moisture and total sugar levels, with the 40 percent substitution producing the highest protein and ash values. Sensory evaluation showed that the 30 percent substitution produced the most acceptable brownies because this level provided the best balance of aroma, color, taste, texture, and overall liking. The addition of cinnamon successfully improved the sensory quality of the product by masking the beany odor of tofu dregs. These findings indicate that tofu dregs flour can serve as a functional ingredient that enhances the nutritional value of brownies while maintaining consumer acceptability. Further research is recommended to evaluate antioxidant activity, dietary fiber content, shelf life, and microbial stability to support broader application in bakery products.

Future research is recommended to optimize formulation stability during storage, investigate antioxidant and dietary fiber profiles, and evaluate large-scale production feasibility. Limitations of this study include the restricted sensory panel size and absence of shelf-life and microbiological analyses, which should be addressed in subsequent work to strengthen product validation.

Author Contributions

Based on the provided manuscript, the author contributions are distributed among the research team to cover all aspects of the study's execution and documentation. I.K.B. took the lead on the project, handling the initial conceptualization, designing the research methodology, performing the formal analysis of the data, and writing the first draft of the paper. R.A.S. was responsible for the hands-on investigation and systematic data curation throughout the experiment. I.S. focused on the validation of the results and the visual representation of the findings, while E.A.F. managed the necessary software and resources required for the study. M.K.S. contributed through the critical process of writing, specifically in reviewing and editing the final manuscript, and A.L. provided overall supervision and project administration to ensure the research met the necessary academic standards. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Since this study involved human participants in the form of 30 untrained panelists for sensory evaluation, an ethical statement is required. Based on the manuscript's guidelines, the statement is as follows: The study was conducted according to the guidelines of the Declaration of Helsinki. Ethical review and approval were waived for this study because the research involved standard sensory evaluation of food products using non-invasive methods with a small group of participants, posing no risk to their health or well-being.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study. Before the sensory evaluation began, each of the 30 panelists was briefed on the nature of the research, the ingredients used in the brownies (including tofu dregs flour and cinnamon), and the evaluation process. Participants took part voluntarily and were informed that they could withdraw at any time. All data collected from the taste tests were recorded anonymously to ensure the privacy and confidentiality of the individuals involved.

Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy considerations regarding the individual sensory evaluation scores of the participants and to maintain the confidentiality of the specific raw laboratory datasets until further research phases are completed.

Conflicts of Interest

The authors declare that there are no financial or personal relationships with other people or organizations that could inappropriately influence or bias the findings of this research. The study was conducted independently, and the results are presented objectively to contribute to the scientific understanding of tofu dregs flour substitution in bakery products.

Use of AI and AI-Assisted Technologies

The authors used AI-assisted technologies, specifically language models, during the preparation of this manuscript to improve the grammatical accuracy, structural organization, and ensuring adherence to academic writing standards. After using these technologies, the authors reviewed and edited the content to ensure the scientific accuracy of the findings and the integrity of the data presented. The authors remain fully responsible for the final content of the article and its overall scholarly merit.

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