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Developing Nutritious Crispy Brownies from Tempe and Purple Sweet Potato Flour for Adolescent Nutritional Needs

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Abstract: *Crispy brownies are a popular snack with potential for nutritional improvement through the addition of tempe flour as a protein source and purple sweet potato flour as a source of fiber and anthocyanins. This study developed four crispy brownie formulas by partially substituting wheat flour with these local ingredients and assessed their hedonic quality and estimated nutritional content. The research was conducted from September to December 2024 at the Nutrition Laboratory of STIKes Cianjur using a Completely Randomized Design with four treatments: F0 (100% wheat flour), F1 (90%:10%), F2 (85%:15%), and F3 (80%:20%). Hedonic evaluation involving 31 panelists using a 1–6 scale was analyzed with One-Way ANOVA ($\alpha = 0.05$) followed by Duncan's test. Substitution significantly affected color and taste ($p < 0.05$), but not aroma or texture. Formula F2 was the most preferred, producing an appealing brownish-purple color and balanced flavor. It also showed increased protein and fiber with reduced energy and fat compared to the control. Based on sensory and nutritional attributes, F2 is the most optimal and has strong potential as a healthy local snack.*
Keywords: *crispy brownies, hedonic quality, nutritional composition, local food ingredients.*

INTRODUCTION

Adolescents are an age group that requires higher energy and nutrient intake due to rapid physical growth and intensive cognitive development (Wicaksono et al., 2023; Reswari & Sudiman, 2024). At this stage, adolescents are highly susceptible to nutritional problems, both deficiencies and excesses, because the rapid physical changes they experience have a direct impact on their health status (Hartanti & Arswinda, 2024). Various health problems frequently occur during adolescence, including iron deficiency anemia, which is characterized by fatigue, pallor, and reduced concentration; stunting or growth impairment that affects height attainment and overall physical development; as well as obesity, which increases the risk of developing non-communicable diseases at an early age (Zahra et al., 2025; Alwi et al., 2022 and Faradisa & Kusumawati, 2025). In addition, adolescents are also vulnerable to body image disturbances, which may affect self-confidence and eating behaviors, the occurrence of acne due to hormonal changes during puberty, as well as eating disorders such as anorexia and bulimia, which are often triggered by unbalanced dietary patterns and social pressures related to physical appearance (Agustin et al., 2019 and Puspita et al., 2024).

According to the World Health Organization (WHO), adolescence (10–19 years) is the period with the fastest growth rate after infancy, characterized by an increase in body mass of up to 50% and a height gain of about 20% of total lifetime growth (Mahardika et al., 2024). To support these processes, adequate protein intake is essential, as this nutrient serves as an energy source, a structural component for tissue building, and a regulator of various metabolic activities in the body (Ristanti et al., 2024). In addition to protein, adolescents require other essential nutrients, such as carbohydrates as the primary source of energy**,** healthy fats to support hormone production and brain function**,** iron to prevent anemia, as well as calcium and vitamin D to promote optimal bone formation (Pantaleon et al., 2025 and Wildayani et al., 2023). In addition, various vitamins and minerals, such as zinc, vitamin A, vitamin C, and folate, also play important roles in maintaining immune function, supporting cellular growth, and promoting cognitive development (Hong, 2025).

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Various surveys reveal that snacking habits among adolescents today are generally dominated by products high in sugar and fat but low in nutritional value (Kencanaputri et al., 2024 and Blum et al., 2019). This situation contributes to various nutritional issues, such as overweight, low fiber intake, and suboptimal protein consumption (Leviana & Agustina, 2024 and Syach & Lestari, 2023). Lifestyle changes, such as increased consumption of high-energy foods and a shift from traditional to modern eating patterns, also have a significant impact on adolescents' nutritional status, with one of the most noticeable trends being the high consumption of snack foods (Amin & Sulaiman, 2025). The "State of Snacking" survey conducted by Mondelez International in 2019 showed that 59% of respondents from 12 countries, including Indonesia, preferred consuming snacks over main meals. In addition, 75% of respondents stated that snacks were more suited to their busy lifestyles (Taula'bi' et al., 2021). However, most modern snacks are generally high in fat, sugar, and calories, making them less supportive of meeting adolescents' nutritional needs (Sulistyadewi & Wasita, 2022). In general, adolescents are recommended to consume snacks 1–2 times per day, contributing approximately 10–15% of their total daily energy intake, while prioritizing options rich in fiber, protein, vitamins, and minerals, and limiting excessive amounts of sugar, salt, and fat in accordance with the principles of balanced nutrition (Delavita et al., 2023).

The development of healthy snacks made from local food ingredients is a strategic effort to improve the dietary quality of adolescents while strengthening national food diversification initiatives. Brownies, including their variations such as crispy brownies with a thin, sweet, and crunchy texture, are among the most popular snacks and have great potential to be developed into nutritious, innovative food products (Mailisa et al., 2024). Brownies were selected in this study because they are a popular product widely preferred by adolescents, have a formulation that can be easily modified, and possess flexible taste and texture characteristics, allowing the addition or substitution of nutritious ingredients without reducing consumer acceptance (Zukryandry et al., 2025).The use of tempe flour and purple sweet potato flour in such products offers the potential to enhance their nutritional value, as tempe is rich in high-quality protein, fiber, and isoflavones, while purple sweet potatoes contain fiber and anthocyanins that function as antioxidants and provide an appealing color. Quantitatively, tempe contains approximately 18–20 grams of protein per 100 grams and is also rich in iron, calcium, B-complex vitamins, as well as bioactive compounds produced during fermentation that contribute to maintaining digestive health (Azzahra et al., 2025). Meanwhile, purple sweet potato contains complex carbohydrates, dietary fiber, vitamin C, and high levels of anthocyanins, which function as natural antioxidants (Ivane et al., 2024). The combination of these two local ingredients has the potential to produce crispy brownies that are richer in nutrients while still meeting acceptable sensory standards. As affordable and widely available local Indonesian foods, tempe and purple sweet potato have strong cultural and economic value, and their use in innovative products can support food self-sufficiency and increase the value of local commodities.

The partial substitution of wheat flour with tempe flour and purple sweet potato flour in crispy brownies is expected to produce a more nutritious snack without reducing consumer preference or acceptability. The use of these two ingredients requires precise formulation and careful organoleptic assessment to determine the most ideal composition that can provide an optimal balance of color, aroma, taste, and texture. This study aims to design four variations of crispy brownie formulas with different proportions of tempe flour and purple sweet potato flour, and to evaluate their hedonic quality including color, aroma, taste, and texture along with an analysis of the nutritional content of each formula. This study is expected to produce a healthy snack made from local food ingredients that can help meet adolescents' nutritional needs while serving as an innovative option in the development of functional food products.

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METHODS

This study was conducted in the Nutrition Laboratory of the Sekolah Tinggi Ilmu Kesehatan Cianjur (STIKes Cianjur) for the production of crispy brownies using purple sweet potato flour, tempe flour, and added robusta coffee, while the organoleptic testing was carried out in the Nutrition learning room at STIKes Cianjur. This study was conducted over four months, from September to December 2024. The main ingredients used included purple sweet potato flour (Tazza Di Naturale, Bandung, Jawa Barat) and tempe flour (Omah Tepung Organik, Bantul, Yogyakarta). Other additional ingredients included robusta coffee, granulated sugar, eggs, margarine, and cheese, all of which were purchased from a supermarket in Cianjur Regency. The equipment used included stainless bowls, silicone spatulas, pans, pots, whisks, strainers, measuring spoons, an oven, measuring cups, brownie molds, cake scrapers, oven gloves, a scale, a blender, jars, bowls, knives, cutting boards, and spoons. The crispy brownie products were prepared by mixing all main and supporting ingredients according to the formulation, then baking them until fully cooked and allowing them to cool before conducting the organoleptic assessment. The baking process was carried out using an oven at a temperature of approximately 150–160°C for about 20–25 minutes until the product became dry and crispy, consistent with the characteristics of crispy brownies.

Organoleptic testing was carried out using a hedonic test to evaluate color, aroma, taste, and texture, involving 31 semi trained panelists aged 18–27 years, with a scoring range of 1–6, from "dislike very much" to "like very much". The semi-trained panelists referred to in this study were nutrition lecturers who possess competence and experience in sensory evaluation, enabling them to assess the product more objectively and consistently. This study employed a Completely Randomized Design (CRD) with three types of flour as factors (wheat flour, tempe flour, and purple sweet potato flour) and four treatment levels, namely F0 (100% wheat flour), F1 (90% wheat flour : 10% local flour), F2 (85% : 15%), and F3 (80% : 20%). Each treatment was replicated twice, resulting in a total of eight experimental units arranged randomly. The hedonic test data were analyzed using One Way ANOVA with a confidence level of $\alpha = 0.05$ to determine the effect of the treatments on each sensory attribute. If significant differences were found, the analysis was continued with Duncan's test to determine meaningful differences between means. Data processing was carried out using SPSS 16 and Microsoft Excel 2019.

RESULTS AND DISCUSSION

The crispy brownies formulation was designed with various flour proportions to obtain the most optimal product characteristics. The control treatment (F0) used 100% wheat flour, while F1, F2, and F3 were formulated by partially substituting wheat flour with purple sweet potato flour and tempe flour at different proportions. All formulations used the same supporting ingredients, including robusta coffee, granulated sugar, chocolate bars, eggs, margarine, and cheese, so that variations in product characteristics were primarily influenced by differences in the flour composition used. Theoretically, the use of tempe flour and purple sweet potato flour in controlled proportions does not interfere with the absorption of other nutrients. The fermentation process in tempe can enhance the bioavailability of protein and minerals, while the fiber and bioactive compounds in purple sweet potato remain within safe levels and continue to support balanced nutrient intake (Azzahra et al., 2025 and Monoarfa et al., 2026). The addition of robusta coffee in relatively small amounts also does not meaningfully affect nutrient absorption. Although coffee contains tannins and polyphenols, which theoretically may reduce the absorption of non-heme iron, the proportion used in this formulation remains within safe limits and does not affect the overall nutritional quality of the product. The following table presents the detailed formulation for each treatment.

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Table 1. Ingredient Composition of Various Crispy Brownie Formulations

Ingredients	Treatment			
	F0 (100%)	F1 (72% : 8% : 20%)	F2 (68% : 12% : 20%)	F3 (64% : 16% : 20%)
Purple sweet potato flour	-	36 g	34 g	32 g
Tempeh flour	-	4 g	6 g	8 g
Medium protein wheat flour	50 g	10 g	10 g	10 g
Robusta coffee	6 g	6 g	6 g	6 g
Sugar	30 g	30 g	30 g	30 g
Chocolate bar	55 g	55 g	55 g	55 g
Egg	40 g	40 g	40 g	40 g
Margarine	30 g	30 g	30 g	30 g
Cheese	2 g	2 g	2 g	2 g

The formulation in the table 1, shows that the variation among treatments is primarily determined by the differences in the proportions of purple yam flour and tempeh flour, while the amount of wheat flour in F1, F2, and F3 remains consistent at 10 grams each. This arrangement allows for more controlled experimental conditions in evaluating the effects of local flour substitution on the characteristics of crispy brownies. The addition of purple yam flour and tempeh flour in each treatment has the potential to produce variations in color, aroma, and nutritional value, given that purple yam flour is rich in anthocyanins and tempeh flour contains plant-based protein and fermentation-derived compounds. The use of other ingredients such as sugar, chocolate bars, eggs, margarine, and robusta coffee, kept constant, ensures that variations in texture, taste, and color are primarily attributable to differences in the flour composition used.

The Duncan test was applied to identify significant differences between crispy brownie formulas for each sensory parameter evaluated by the panelists. The parameters analyzed include color, aroma, sweetness level, bitterness, and texture, allowing for a more detailed comparison of each organoleptic quality aspect between formulas F0, F1, F2, and F3. In this test, different letters in the mean values indicate significant differences between formulas, whereas the same letters suggest that the panelists' preference levels for those formulas do not differ significantly. The complete findings from the analysis are presented in Table 2, which provides a comparison of the mean hedonic values for each parameter along with significance markers based on the results of the Duncan test.

Table 2. Average Hedonic Scores of Crispy Brownies in Various Treatments

Treatmen t	Specification				
	Color	Fragrance	Sweet Taste	Bitter Taste	Texture
F0	$1{,}46^{a}$	$2{,}09^{b}$	$3{,}24^{b}$	$3{,}11^{b}$	$4{,}17^{b}$
F1	$1{,}66^{b}$	$2{,}03^{ab}$	$2{,}95^{a}$	$2{,}72^{a}$	$4{,}01^{ab}$
F2	$1{,}67^{b}$	$1{,}96^{ab}$	$2{,}95^{a}$	$2{,}74^{a}$	$4{,}09^{ab}$
F3	$1{,}71^{b}$	$1{,}90^{a}$	$3{,}14^{b}$	$2{,}74^{a}$	$3{,}96^{a}$

Note: Different superscript values in each column indicate significant differences (< 0.05).

The statistical analysis results indicate that the different proportions of purple sweet potato flour and tempeh flour have a significant effect on the color of crispy brownies, as evidenced by a significance value of 0.022 (< 0.05). The evaluation from 31 panelists showed that the preference level for color ranged from 4.40 to 4.59 (somewhat like to like). The lowest score was obtained by F0 (100% wheat flour), while the highest score was achieved by F3 with a composition of 64% purple sweet potato flour, 16% tempeh flour, and 20% wheat flour. The Duncan test showed that F0 was significantly different compared to F1, F2, and F3. Although all samples maintained a strong brown color, the addition of purple sweet potato flour resulted in a dark purplish-brown hue that was more preferred by the panelists.

In theory, color is one of the main aspects that influence consumer acceptance (Sylvia et al., 2025). In purple sweet potato-based products, the appearance of color is influenced by the anthocyanin

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pigment content and the Maillard reaction process that occurs during baking (Muhammad et al., 2022). Anthocyanins function as natural purple colorants, while the presence of lysine in tempeh flour enhances the intensity of non-enzymatic browning reactions, resulting in a darker brown color (Priska et al., 2018 and Lestari et al., 2024). Previous research also supports this finding, where an increase in the use of purple sweet potato flour has been shown to produce a darker color in baked goods (Tuhumury et al., 2018). Thus, the combination of purple sweet potato flour and tempeh flour has proven to enhance the color intensity of crispy brownies while also increasing the panelists' preference for the product.

The results of the statistical analysis indicate that varying the proportions of purple sweet potato flour and tempeh flour does not have a significant impact on the aroma of crispy brownies, with significance values of 0.180 and 0.074 respectively (> 0.05). The results of the organoleptic test conducted by 31 panelists indicated that the preference level for the aroma of crispy brownies ranged from 3.79 to 4.00, which falls into the category of slightly dislike to slightly like. The lowest score was obtained from the F0 formula (100% wheat flour), while the highest scores were recorded in the F2 and F3 formulas. The lowest score was obtained from the F0 formula (100% wheat flour), while the highest scores were recorded in the F2 and F3 formulas, which likely included varying combinations of purple sweet potato flour and tempeh flour. The Duncan's multiple range test results showed that the aroma of the F0 formula did not significantly differ from F1 and F2, but was significantly different from F3.

The aroma of food is formed by volatile compounds that can be detected by the olfactory system. These compounds play a crucial role in the perception of flavor and overall sensory experience of food (Huseynli et al., 2025). In this study, the addition of purple sweet potato flour and tempeh flour did not cause a significant change in the aroma of crispy brownies. This is because the proportion of tempeh flour used was relatively low (8–16%), which did not impart the typical beany aroma of tempeh flour. These findings are consistent with previous reports stating that the addition of 5–20% tempeh flour can reduce the occurrence of a beany aroma in cookie products (Malau et al., 2022). The beany aroma in tempeh flour is caused by the activity of the enzyme lipoxygenase, which breaks down polyunsaturated fatty acids into volatile compounds responsible for the distinctive aroma, such as ethyl phenyl ketone (Astawan et al., 2016). Therefore, the addition of purple sweet potato flour and tempeh flour to crispy brownies did not cause a significant change in aroma and was still acceptable to the panelists.

Statistical analysis showed that variations in the proportion of purple sweet potato flour and tempeh flour had a significant effect on the taste of crispy brownies ($p = 0.000$). The panelists' preference ranged from 3.59 to 4.27, with the lowest score for F0 (100% wheat flour) and the highest for F2 (68% purple sweet potato flour, 12% tempeh flour, 20% wheat flour). This indicates that the intermediate flour proportion in F2 resulted in the most balanced taste favored by the panelists. For the sweet taste attribute, there was a significant difference ($p = 0.000$), with scores ranging from 2.94 to 3.24. An increase in the proportion of tempeh flour in F3 reduced the perception of sweetness due to a bitter aftertaste. Bitterness also showed a significant difference ($p = 0.006$), with F0 exhibiting the highest bitterness, possibly due to bitter compounds in robusta coffee and the hydrolysis of amino acids from tempeh flour (Budi et al., 2020). Overall, the combination of purple sweet potato flour and tempeh flour affected the flavor balance of crispy brownies. The F2 formulation produced the best flavor profile, with a not too bitter taste, balanced sweetness, and was the most preferred by the panelists compared to other formulations.

Statistical analysis results indicate that the texture of crispy brownies did not differ significantly between formulas ($p = 0.832 > 0.05$), meaning that variations in the proportions of purple sweet potato flour and tempeh flour did not affect the panelists' preference for texture. The texture preference scores ranged from 4.79 to 4.88 (categorized as 'liked'), with the highest score for formula F1 and the lowest for F0 and F3. This suggests that all formulas produced a crispy brownie texture that was well accepted by the panelists. Although the differences were not significant, there was a tendency for an increased proportion of purple sweet potato flour to result in a crispier texture, due to its high starch content being able to absorb water and form crispy pores after baking (Munfarida, 2023). In addition, the protein content in tempeh flour contributes to increasing water evaporation, resulting in a more brittle structure

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(Astawan et al., 2016). Overall, all formulas exhibited the distinctive crunchy texture of crispy brownies, which remained favored by the panelists.

The estimated nutritional content of the various crispy brownie formulas is presented in Table 3, including energy, protein, fat, carbohydrates, and fiber. A comparison between the control formula (F0) and those supplemented with tempeh flour and purple sweet potato flour (F1, F2, F3) provides an overview of the changes in nutritional values. This data serves as a basis for assessing the improvement in the product's nutritional quality and the potential of each formula to produce more nutritious crispy brownies.

Table 3. Estimated Nutritional Content of Crispy Brownies Based on Variations

Nutritional Content	Treatment			
	F0	F1	F2	F3
Energy (kkal)	482,75	444,17	447,5	450,5
Protein (g)	8,6	13,11	13,95	13,78
Fat (g)	26,38	23,96	23,77	24
Carbohydrates (g)	37,8	34	34,6	35,11
Fiber (g)	3,07	8,24	9,1	7,73

The estimated nutritional content based on DKBM, TKPI, and nutrition facts indicates that substituting wheat flour with tempeh flour and purple sweet potato flour significantly alters the nutritional profile of crispy brownies. Formulas F1, F2, and F3 have lower energy content compared to F0, suggesting that the addition of these two ingredients can reduce the energy density of the product. Protein content increased significantly in all substitution formulas, particularly in F2, which reached 13.95 g, aligning with the high protein content in tempeh flour. Conversely, the fat content in F1–F3 tends to be lower than in F0, indicating that the addition of alternative ingredients can reduce the total fat content of the product.

The carbohydrate content in the substitution formulas is slightly lower compared to the control, consistent with the characteristic of tempeh flour having a lower carbohydrate content (Talitha et al., 2025). Additionally, there is a significant increase in fiber content, with F2 showing the highest value (9.1 g), attributed to the high fiber content in purple sweet potato flour and tempeh flour (Legowo et al., 2022 and Mozin et al., 2019). Overall, formulas F1–F3 demonstrate a better nutritional profile compared to F0, particularly in terms of protein and fiber content, making the substituted crispy brownies a potentially more nutritious snack. When related to the recommended nutritional requirements for adolescents in the snack category, which account for approximately 10–15% of total daily energy intake, the composition of energy, protein, and fiber in the substituted formulations provides a balanced contribution (Delavita et al., 2023). These nutrients particularly contribute to supporting adolescents' daily protein and fiber intake, positioning the product as a healthier snack option that aligns with the development objectives of this study.

CONCLUSION

The results of this study indicate that partially replacing wheat flour with purple sweet potato flour and tempeh flour can enhance the sensory quality and nutritional content of crispy brownies. The formulation differences had a significant impact on color and taste, with F2 (68% purple sweet potato flour and 12% tempeh flour) being the most preferred formula due to its appealing purplish-brown color, balanced flavor, and maintained crisp texture. There were no significant differences in aroma between formulas, indicating that the addition of tempeh and purple sweet potato flour did not produce any off-flavors. In terms of nutritional content, the substitution formulas (F1–F3) have higher levels of protein and fiber and lower energy and fat content compared to the control (F0), with F2 showing the most optimal nutritional improvement. When related to the recommended nutritional requirements for adolescents in the snack category, which account for approximately 10–15% of total daily energy intake, the energy, protein, and fiber content in formula F2 provides an appropriate contribution, thereby

supporting the fulfillment of a portion of adolescents' daily nutrient requirements. Overall, F2 is the most optimal formula as it provides the best balance between sensory quality and nutritional content, making it a potential healthy snack while supporting the utilization of local food ingredients.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest, either financial or non-financial, that could affect the results or interpretation of this study.

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