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The Effect of Tempe Flour Substitution on the Chemical and Organoleptic Quality of Mud Cake Based on Wheat Flour

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Abstract
This study addresses the need to enhance the nutritional quality of traditional Indonesian foods, particularly *kue lumpur*, which is widely consumed but generally low in protein due to its reliance on wheat flour. As a locally available and protein-rich ingredient, tempeh flour offers potential as a functional substitute to improve both nutritional value and food diversification. Therefore, this research aims to evaluate the effect of tempeh flour substitution on the chemical and organoleptic quality of wheat-based *kue lumpur*. The study employed an experimental method using a Completely Randomized Design (CRD) with a single factor, namely the level of tempeh flour substitution (0%, 25%, 50%, 75%, and 100%), with three replications. Chemical properties were analyzed using Analysis of Variance (ANOVA), while organoleptic data were assessed using the Kruskal-Wallis test. The effectiveness of each formulation was determined using the De Garmo index. The results indicate that tempeh flour substitution significantly increases protein and fat content while reducing carbohydrate levels. However, it shows no significant effect on moisture content, color, taste, and texture, but significantly affects aroma. The optimal formulation was identified at 75% substitution, achieving a balanced improvement in both nutritional and sensory qualities. In conclusion, tempeh flour is a viable alternative ingredient to enhance the nutritional value of traditional *kue lumpur* while maintaining acceptable consumer preferences.

INTRODUCTION

Kue lumpur is a popular Indonesian traditional snack, widely enjoyed for its soft texture and distinct flavor. The primary ingredients typically include wheat flour, coconut milk, eggs, and sweeteners. Despite its popularity, *kue lumpur* is generally low in protein due to the dominance of wheat flour, which is nutritionally higher in carbohydrates than in protein (Sari et al., 2020). Various studies have attempted to modify its composition to enhance its nutritional value, such as incorporating pumpkin flour (Putri, 2019), utilizing local flours like taro and cassava as wheat alternatives (Sari & Lestari, 2020), and applying mung bean flour to boost protein content and organoleptic quality (Sari, Lestari, & Hidayat, 2022). These findings suggest that raw material innovation holds significant potential for improving both the nutritional quality and consumer acceptance of *kue lumpur* (Kenang et al., 2022; Pramitasari et al., 2011).

Another ingredient capable of enhancing the nutritional profile of *kue lumpur* is tempeh flour, which contains a high protein content of approximately 39 grams (per 100g). As a

fermented soybean product, tempeh has long been recognized as an affordable and beneficial source of plant-based protein. Its high protein content, along with the presence of bioactive compounds resulting from fermentation, makes it a potential functional food ingredient for improving the nutritional value of processed products (Astawan, 2010). The innovation of tempeh in flour form allows for its use as a substitute in various food formulations, including bakery products and traditional cakes. With its high protein content and functional properties that support nutritional enhancement, tempeh flour is well-suited as an additive for *kue lumpur*. It has been successfully applied in the production of cakes (Pratiwi, 2017), *kue pukis* (Asih, 2022), *kue basah* (Murni, 2013), and *kue semprong* (Fadhila, Nurhayati, & Lestari, 2025), showing positive results in terms of nutritional quality and consumer preference. A study on the addition of tempeh flour in *kue basah* (traditional moist cake) regarding consumer acceptance through organoleptic testing found that *nagasari* made with a 10% substitution of tempeh flour for rice flour was the most preferred by consumers (Murni, 2013).

Although previous research has utilized tempeh flour as a wheat substitute in various traditional moist cakes, its application specifically in *kue lumpur* has not yet been conducted (Inggriyanita et al., 2023; Ningrumsari, 2021). Therefore, this study was carried out to examine the effect of tempeh flour substitution on the chemical and organoleptic qualities of wheat-based *kue lumpur*. This effort is part of an innovation in utilizing high-nutrition local raw materials while supporting the quality improvement of traditional foods to better meet the needs of modern consumers who are increasingly health-conscious and attentive to nutritional content (Niu et al., 2024; Pramitasari et al., 2011; Zheng et al., 2020).

Despite these findings, the specific application of tempeh flour in *kue lumpur* remains underexplored. Most prior studies have focused on other moist cakes or bakery products, while *kue lumpur* has different formulation characteristics, including high moisture, soft texture, and a strong sensory profile from coconut milk, eggs, and butter. This creates a research gap regarding how different levels of tempeh flour substitution influence both chemical quality and organoleptic acceptance in wheat-based *kue lumpur*.

The urgency of this study lies in the need to develop traditional foods that are more nutritious, locally based, and acceptable to consumers. Replacing part of wheat flour with tempeh flour can reduce reliance on wheat-based ingredients while increasing the use of Indonesian local food resources. This is important because product innovation in traditional snacks can support food diversification, improve protein intake, and strengthen the value of local commodities such as tempeh.

The novelty of this research is its focus on evaluating tempeh flour substitution in *kue lumpur* using both chemical and organoleptic parameters. Unlike studies that only examine nutritional composition or consumer preference separately, this study combines proximate analysis, hedonic testing, and the De Garmo effectiveness index to identify the most balanced formulation. The manuscript reports five treatment levels, namely 0%, 25%, 50%, 75%, and 100% tempeh flour substitution, allowing a more comprehensive comparison of formulation effects.

Therefore, this study aims to examine the effect of tempeh flour substitution on the chemical and organoleptic quality of wheat-based *kue lumpur*. The contribution of this research is expected to enrich food technology literature, especially in the development of protein-enriched traditional foods using local ingredients. Practically, the results may benefit food

producers, culinary entrepreneurs, and nutrition-oriented consumers by providing an alternative formulation for *kue lumpur* that maintains sensory acceptance while improving nutritional quality.

METHOD

The primary materials used in this study included fresh tempeh for the production of tempeh flour, medium-protein wheat flour, chicken eggs, granulated sugar, liquid milk, butter, and vanilla. Chemical reagents for proximate analysis included sulfuric acid, selenium catalyst, sodium hydroxide, boric acid, hydrochloric acid, and n-hexane solvent. The equipment utilized consisted of baking tools such as mixers, ovens, and *kue lumpur* molds, as well as laboratory apparatus for chemical analysis, including the Kjeldahl distillation unit, Soxhlet extraction apparatus, and a muffle furnace for ash determination.

This study followed an experimental design using a single-factor Completely Randomized Design (CRD), consisting of five levels of tempeh flour substitution for wheat flour: 0%, 25%, 50%, 75%, and 100%, with each treatment performed in triplicate. The research procedure began with the preparation of tempeh flour, where fresh tempeh was dried at 60°C for 6–8 hours, then ground and sieved. Subsequently, the *kue lumpur* was prepared by whisking eggs and sugar until aerated, incorporating liquid milk and melted butter, and gradually adding wheat flour and tempeh flour according to the treatment proportions until a homogenous batter was formed before baking.

The observed variables included chemical quality analysis, covering protein, fat, moisture, ash, and carbohydrate content, as well as organoleptic quality analysis through hedonic testing for color, aroma, flavor, and texture. Data from chemical testing were analyzed using Analysis of Variance (ANOVA) at a 95% confidence level, followed by post-hoc tests if significant effects were found. Meanwhile, organoleptic data were analyzed using the Kruskal-Wallis test. The determination of the optimal formulation among all treatments was established using the De Garmo effectiveness index method.

RESULT AND DISCUSSION

Chemical Quality

The Analysis of Variance (ANOVA) results indicated that the substitution of tempeh flour had no significant effect on the moisture content ($p=0.064$). However, it had a highly significant effect ($p<0.001$) on the ash, protein, fat, and carbohydrate content of the *kue lumpur*. These findings demonstrate that there were significant differences between treatments across nearly all chemical parameters tested, with the exception of the moisture component. The mean chemical quality values of the *kue lumpur* are presented in Table 1.

Table 1. Recapitulation of Chemical Test Results of Tempeh Flour Mud Cake

Treatment	Air (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrates (%)
A1 (0%)	40.93 ± 2.61^{a}	3.40 ± 0.01^{a}	4.63 ± 0.98^{a}	3.41 ± 0.41^{a}	49.01 ± 2.06^{a}
A2 (25%)	43.74 ± 0.60^{a}	3.57 ± 0.11^{a}	33.96 ± 1.78^{b}	6.42 ± 1.00^{b}	13.87 ± 2.89^{b}
A3 (50%)	43.49 ± 0.53^{a}	3.27 ± 0.16^{a}	36.54 ± 0.57^{bc}	7.34 ± 0.09^{b}	10.79 ± 0.63^{b}
A4 (75%)	40.47 ± 1.64^{a}	2.17 ± 0.20^{b}	37.62 ± 0.03^{c}	7.44 ± 0.19^{b}	13.19 ± 1.32^{b}
A5 (100%)	42.32 ± 0.92^{a}	2.46 ± 0.40^{b}	42.48 ± 0.44^{d}	4.84 ± 0.59^{a}	9.95 ± 1.56^{c}

Source: Primary Data Processed (2025)

The absence of significant differences in moisture content across treatments is presumably due to the characteristics of the raw materials, specifically the low moisture content of tempeh flour at 6% (FI, 2024) and wheat flour at 10% (FI, 2024). The relatively similar moisture levels between these two flours helped maintain a uniform final moisture content in the product, despite the variations in the amount of tempeh flour added. This finding is consistent with a report by Putri (2019) on the addition of pumpkin flour in *kue basah*, which also showed that moisture content did not change significantly despite flour substitution. Furthermore, Sari and Lestari (2020), who utilized taro and cassava flour in similar food products, also reported stable moisture levels with no significant differences. Likewise, the utilization of mung bean flour by Sari, Lestari, and Hidayat (2022) confirms that substituting flour with alternative raw materials does not always result in significant changes in moisture content. Consequently, the lack of significant variance in the moisture content of *kue lumpur* across different substitution levels is likely due to the moisture balance between the main ingredients, which keeps the physical properties of the product consistent. Table 1 further shows that the moisture content of the tempeh flour-substituted *kue lumpur* ranges from 40.47% to 43.74%. These high values indicate that *kue lumpur* is classified as a *kue basah* (traditional moist cake). According to the Indonesian National Standard (SNI 01-4309-1996), moist cakes typically have a maximum moisture content of 40%. Due to this high moisture level, *kue lumpur* is susceptible to quality degradation during storage. According to Indrawati (2020), high moisture content in moist cakes generally leads to a reduction in shelf-life, as it facilitates microbial growth and oxidation processes.

The ash content of the *kue lumpur* ranged from 2.17% to 3.57%. No significant differences were observed in treatments A1 through A3, whereas treatments A4 and A5 showed a significant variance in ash levels. Tempeh flour contains an ash content of approximately 5% per 100 grams, while medium-protein wheat flour contains only 0.5% to 1% (FI, 2024). Theoretically, a higher proportion of tempeh flour in the formulation should alter the ash content of the final product, as tempeh flour has a higher mineral content than wheat flour. However, the study results indicate that the ash content of the final product at substitution levels exceeding 50% showed values that differed from the raw material proportions. According to Nurjanah (2018), variations in the final ash content of a product can be attributed to changes in ingredient composition as well as the distribution of dry matter and minerals detected during chemical analysis. According to SNI 01-4309-1996 regarding *kue basah*, the maximum allowable ash content is 3% based on dry matter. While treatments A1, A2, and A3 had ash levels that approached or slightly exceeded this threshold, A4 and A5 remained below the maximum limit, ensuring that all treatments generally met quality standards. Consequently, the substitution of tempeh flours up to 100% in *kue lumpur* still yields a product that is acceptable for consumption in terms of ash content, in accordance with SNI regulations.

The protein content of the *kue lumpur* increased significantly in correlation with the rising percentage of tempeh flour substitution for wheat flour. Treatment A1 exhibited the lowest protein content at 4.63%, while treatment A5 reached the highest level at 42.48%. This significant increase is consistent with the high protein profile of tempeh flour, which contains approximately 39% protein per 100 grams (FI, 2024) substantially higher than wheat flour, which contains only about 10.33% protein (FI, 2024). It can be concluded that the elevation of

protein levels in the final product is heavily influenced by the increased proportion of tempeh flour in the *kue lumpur* formulation. These findings align with research by Wulandari and Prasetyo (2018), which reported that utilizing tempeh flour as a substitution material can significantly boost the protein content of processed food products. Consequently, substituting tempeh flour in the production of *kue lumpur* serves as an effective alternative to enhance the product's nutritional profile without compromising its overall quality.

A significant increase in fat content was observed in treatments with 25% to 75% tempeh flour substitution (A2, A3, and A4) compared to treatments A1 and A5. The lowest fat content was found in treatment A1 at 3.41%, while the highest was recorded in A4 at 7.44%. These results indicate that the moderate addition of tempeh flour tends to elevate the fat levels in *kue lumpur*. However, it is important to note that according to SNI 01-4309-1996, the maximum allowable fat content for *kue basah* is 3% based on dry matter. All treatments exceeded this threshold, including the control group (A1) without tempeh flour substitution. Therefore, while variations in tempeh flour substitution significantly influence fat levels, the overall fat content of *kue lumpur* requires specific attention, particularly regarding product quality and safety aspects such as storage stability and shelf-life. Consequently, while substituting wheat flour with tempeh flour can increase the fat content of *kue lumpur*, careful control of fat levels is necessary to ensure the product remains within quality standards and is safe for consumption.

The carbohydrate content of the *kue lumpur* varied between 9.95% and 49.01%. Treatment A1 recorded the highest carbohydrate content at 49.01%, while the tempeh flour substitution treatments of 25%, 50%, and 75% (A2, A3, and A4) showed no significant differences, ranging from 10.79% to 13.87%. Meanwhile, treatment A5 (100% tempeh flour) exhibited the lowest carbohydrate content at 9.95%, which was significantly different from the other treatments. This variation in carbohydrate levels is consistent with the characteristics of the raw materials; tempeh flour contains approximately 34% carbohydrate per 100 grams, which is substantially lower than wheat flour's carbohydrate content of approximately 77% (FI, 2024). Therefore, increasing the proportion of tempeh flour as a wheat substitute leads to a marked decrease in the carbohydrate content of the final product. This is in line with the food composition principles stated by Nurjanah (2018), which posit that changes in raw material composition directly impact the nutritional content of the resulting product. According to SNI 01-4309-1996 for *kue basah*, the minimum required carbohydrate content is 8%. Based on the data, all treatments in this study met the standard, confirming that the tempeh flour-substituted *kue lumpur* is acceptable for consumption in terms of its carbohydrate levels.

Mutu Organoleptic

The results of the organoleptic evaluation using the Kruskal-Wallis test indicated that tempeh flour substitution had no significant effect on the parameters of colour ($p=0.746$), flavour ($p=0.358$), and texture ($p=0.138$) of the *kue lumpur*. However, a significant difference was observed in the aroma parameter ($p=0.035$) across the different tempeh flour substitution treatments. The median values for all organoleptic parameters are presented in Table 2.

Table 2. Organoleptic Test Results of Tempeh Flour Mud Cake

Treatment	Color	Taste	Texture	Aroma
A1 (0%)	4 ± 0.55^{a}	4 ± 0.91^{a}	4 ± 0.77^{a}	4 ± 0.68^{a}
A2 (25%)	4 ± 0.56^{a}	3 ± 0.84^{a}	4 ± 0.72^{a}	4 ± 0.77^{ab}
A3 (50%)	4 ± 0.57^{a}	4 ± 0.68^{a}	4 ± 0.61^{a}	3 ± 0.85^{b}
A4 (75%)	4 ± 0.86^{a}	3 ± 0.85^{a}	$4 \pm 0.72_{a}$	3 ± 0.82^{b}

Source: Primary Data Processed (2025)

The absence of significant differences in the color of the *kue lumpur* with tempeh flour substitution is attributed to the color characteristics of tempeh flour, which are similar to those of wheat flour. Tempeh flour possesses a natural yellowish hue that does not differ substantially from wheat flour; consequently, varying the proportions of these two ingredients in the batter does not significantly alter the product's color (Rachmawati, 2019). As shown in Table 2, the median score for color remained stable at 4 across all tempeh flour substitution treatments. This indicates that the substitution of tempeh flour does not adversely affect the visual appearance of the product. Therefore, the color of the *kue lumpur* remains consistent and shows no significant variance between treatments, as both tempeh flour and wheat flour contribute a similar chromatic effect to the final product.

The absence of significant differences in the flavor perception of *kue lumpur* across various tempeh flour substitution levels is likely due to the dominance of the primary ingredients' flavor profiles, which remain relatively stable within the formulation. According to Nugraheni and Widyaningsih (2019), although tempeh flour possesses a distinct fermented aroma and taste, these characteristics are not dominant enough to significantly alter the final product's flavor within the substitution limits applied. These results align with research by Pratiwi (2017), which states that substituting wheat flour with tempeh flour does not necessarily affect the product's flavor as long as the composition of other ingredients is maintained. Consequently, tempeh flour substitution up to 100% has no significant impact on the flavor parameters of *kue lumpur*, ensuring that consumer acceptance regarding the product's taste remains consistent.

The substitution of tempeh flour had no significant effect on the texture of the *kue lumpur*, as evidenced by the uniform median scores across nearly all treatments. According to Handayani (2011), the texture of *kue lumpur* is primarily influenced by the gluten protein content of wheat flour and the balance of moisture within the batter. Furthermore, Nugraheni (2019) suggests that because tempeh flour is processed into a relatively fine powder, it is capable of maintaining a product texture similar to that of wheat flour when used as a substitute. Consequently, substituting up to 100% of the wheat flour with tempeh flour does not significantly alter the texture of the *kue lumpur*, ensuring that the textural quality remains consistent and acceptable to consumers.

Table 2 illustrates a significant difference in the aroma parameters of the *kue lumpur* between the 0% and 25% tempeh flour substitution levels and the 50% to 100% levels. The median aroma scores for the 0% and 25% substitutions remained at 4, whereas for substitutions of 50% and above, the median score decreased to 3. This variation in median aroma scores at substitution levels exceeding 50% is influenced by the distinct aromatic profile of tempeh flour, which differs substantially from that of wheat flour (Nugraheni, 2019). This distinction impacts the panelists' perception of the final product's aroma, particularly at higher substitution

concentrations. Consequently, substituting tempeh flour at levels greater than 50% leads to a significant difference in aroma parameters, while lower substitution levels (0%–25%) show no significant variance, thereby maintaining the relative aromatic quality of the product.

Effectiveness Test

Based on the calculation results, treatment A4 (75% tempeh flour substitution) achieved the highest effectiveness value of 0.807. This indicates that formulation A4 is the most optimal, as it successfully balances various quality parameters holistically, including protein, moisture, ash, carbohydrate, and fat content, as well as organoleptic aspects such as flavor, color, aroma, and texture. Although treatment A5 exhibited the highest protein content (protein NH contribution = 0.18), its total effectiveness value of 0.679 was lower than that of A4. This suggests that an increase in protein content alone does not guarantee overall product quality. Other parameters in A5, such as moisture, fat, and texture, provided lower contributions, while organoleptic parameters like aroma and texture were also sub-optimal (aroma and texture NH values = 0). In contrast, treatment A4 demonstrated an optimal balance with high contributions from protein (0.157), fat (0.10), and moisture content (0.16). Its organoleptic parameters were also relatively favorable; although some aspects like flavor and aroma had zero values in the index, the overall composition remained superior to the other treatments. Therefore, a 75% tempeh flour substitution (treatment A4) is recommended as the best formulation for *kue lumpur* production. This formulation provides a balanced and comprehensive improvement in product quality, bridging nutritional and sensory aspects to produce a snack that is not only highly nutritious but also possesses the best physical and flavor characteristics. The results of the effectiveness test calculations are presented in Table 3.

Table 3. Effectiveness Test Calculation Results

Parameter	Weight	Weight Score	NH (A1)	NH (A2)	NH (A3)	NH (A4)	NH (A5)
Protein	9	0.18	0	0.139	0.151	0.157	0.18
Moisture	8	0.16	0.138	0	0.013	0.16	0.069
Ash	7	0.14	0	0	0.031	0.14	0.115
Carbohydrate	6	0.12	0	0.108	0.118	0.11	0.12
Fat	5	0.1	0	0.075	0.098	0.1	0.035
Flavour	4	0.08	0.08	0	0.08	0	0.08
Color	4	0.08	0.08	0.08	0.08	0.08	0.08
Aroma	4	0.08	0.08	0.08	0	0	0
Texture	3	0.06	0.06	0.06	0.06	0.06	0
TOTAL	**50**	**1**	**0.538**	**0.542**	**0.673**	**0.807**	**0.679**

Source: Primary Data Processed (2025)

***NH = Result Velue**

CONCLUSION

The findings of this study demonstrate that the substitution of tempeh flour in wheat-based *kue lumpur* significantly influences its chemical composition while maintaining acceptable organoleptic properties. Increasing the proportion of tempeh flour was proven to enhance protein and fat content, while reducing carbohydrate levels, indicating its effectiveness in improving the nutritional quality of the product. However, the substitution showed no significant effect on moisture content, colour, taste, and texture, although it significantly

affected aroma due to the characteristic beany flavor of tempeh. Based on the De Garmo effectiveness index, the optimal formulation was identified at 75% tempeh flour substitution, as it provides the best balance between nutritional improvement and sensory acceptability. This result confirms that tempeh flour can be utilized as a functional local ingredient to enrich traditional foods without compromising consumer acceptance. Despite these promising findings, this study has several limitations that open opportunities for further research. Future studies are recommended to explore shelf-life stability and microbial quality, considering the high moisture content of *kue lumpur* which may affect product durability. In addition, more advanced sensory evaluation involving a larger and more diverse panel of respondents is needed to obtain more generalizable results. Further research could also investigate the application of tempeh flour in combination with other local ingredients or different food products to expand its utilization. Moreover, economic feasibility and consumer market acceptance studies are necessary to support the commercialization potential of tempeh flour-based products in the food industry.

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