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Effect of Modified Kimpul Flour Substitution and Glycerol Monostearate Concentration on the Physicochemical and Sensory Properties of Sweet Bread

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Abstract

Wheat flour is the primary ingredient in sweet bread production, yet its import-dependent supply in countries like Indonesia prompts the need for alternative local ingredients. Kimpul tuber (*Xanthosoma sagittifolium*), rich in carbohydrates, presents a promising substitute, though its native starch properties are less suitable for baking. This study aimed to evaluate the effect of substituting wheat flour with heat moisture treated (HMT) kimpul flour and the addition of glycerol monostearate (GMS) on the physicochemical and sensory properties of sweet bread. A factorial completely randomized design was applied using three wheat-to-kimpul flour ratios (3:1, 1:1, and 1:3) and three GMS concentrations (2%, 3%, and 4%). Results showed that higher kimpul flour substitution increased moisture and carbohydrate content but reduced protein and fat levels. Textural properties such as hardness and adhesiveness also increased with kimpul content, but these were mitigated by the addition of GMS, particularly at 3%. The optimal formulation 1:1 wheat-to-kimpul ratio with 3% GMS produced sweet bread with the best overall sensory acceptance. The findings suggest that HMT-modified kimpul flour combined with GMS can serve as a functional and acceptable alternative to wheat flour in bread production. This supports food diversification strategies and promotes utilization of local tuber flours in bakery applications.

Keywords: glycerol monostearate; modified kimpul flour; physicochemical properties; sensory evaluation; sweet bread.

INTRODUCTION

Sweet bread is a widely consumed product and serves as an essential source of energy due to its high carbohydrate content. Conventionally, sweet bread is produced using refined wheat flour, which contains gluten an important protein that contributes to dough elasticity and volume expansion during fermentation and baking (Irmawati et al., 2024; H. Li et al., 2024; Setiyoko & Sari, 2024). However, the reliance on wheat flour presents a challenge for countries like Indonesia that are dependent on imported wheat, prompting efforts to diversify food sources by utilizing locally available ingredients (Al Ubaidilah et al., 2025; Fetriyuna et al., 2024; Ramadhanty, 2025). One such alternative is kimpul tuber (*Xanthosoma sagittifolium*), a tropical plant rich in carbohydrates and native to Indonesia. The high starch content of kimpul makes it a viable candidate for flour production, although its native starch properties tend to result in poor processing characteristics, such as high gelatinization temperature, limited swelling power, and low resistance to acid and shear during baking (Budiarti et al., 2022, 2023; Rosida et al., 2024).

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In addition to starch modification, the incorporation of food additives such as glycerol monostearate (GMS) offers another opportunity to improve bread quality. GMS is a non-toxic emulsifier commonly used in baked goods to stabilize air bubbles, improve dough handling, and extend product shelf life (Chen et al., 2024; Karthik et al., 2024; Setiarto et al., 2024). It can interact with gluten and starch components to create a more cohesive matrix within the dough, thereby enhancing the volume, softness, and uniformity of bread texture (Ibrahim et al., 2025; Setiawan et al., 2024). The application of GMS in composite flour bread formulations could potentially mitigate the textural drawbacks associated with gluten-free or low-gluten products (Amelia et al., 2024; Azid et al., 2025).

Although various studies have examined the impact of either modified starch or emulsifiers on bakery products, there remains limited research on the combined effect of HMT-modified kimpul flour and GMS in sweet bread. Particularly, how the flour substitution ratio and emulsifier concentration affect the physicochemical and sensory characteristics of sweet bread is not yet fully understood (Febriani & Sumarto, 2021; Yahya & Hashim, 2023). Understanding this relationship is essential for developing bakery products with desirable qualities while promoting the use of local, underutilized tubers as sustainable food sources.

This study aims to examine the effect of HMT-modified kimpul flour substitution and varying GMS concentrations on the physicochemical and sensory properties of sweet bread. This study is expected to contribute to the development of high-quality bread products that utilize local ingredients, support food diversification, and reduce dependence on imported wheat flour.

MATERIALS AND METHODS

Materials

The main raw material used in this study was kimpul tuber (*Xanthosoma sagittifolium*), which was harvested at 6–8 months of age and obtained from local farmers in Salatiga, Central Java. In addition to kimpul tubers, other ingredients used in the preparation of sweet bread included wheat flour, granulated sugar, salt, margarine, powdered milk, yeast, eggs, and glycerol monostearate (GMS) as an emulsifier. For the modification process of the kimpul flour, supporting materials included aquadest, sodium chloride (NaCl), and various packaging materials such as HDPE plastic and aluminum foil. Analytical grade chemicals, including sodium hydroxide (NaOH), concentrated sulfuric acid (H_2SO_4), boric acid, hydrochloric acid (HCl), hexane, and Kjeldahl tablets, were used for the proximate and physicochemical analyses (Diana et al., 2024).

Experimental Design and Setup

This study employed a completely randomized factorial design (RAL faktorial) with two treatment factors: the ratio of wheat flour to modified kimpul flour (3:1, 1:1, and 1:3), and the concentration of glycerol monostearate (2%, 3%, and 4%). Each treatment was carried out in triplicate. Laboratory equipment used included a cabinet dryer, convection oven, digital balance, sieves (60 mesh), baking molds, and standard glassware. The baking was conducted under consistent conditions, and evaluations were carried out in a food analysis laboratory using a texture analyzer and colorimeter to measure physical characteristics (Nurislaminingsih et al., 2024).

Preparation of Modified Kimpul Flour and Sweet Bread

Kimpul tubers were first washed, peeled, and sliced into thin chips, then soaked in a sodium chloride solution to reduce calcium oxalate content. The chips were drained and dried in a cabinet dryer at 50°C for 24 hours. Once dried, they were ground and sieved using a 60-mesh sieve to obtain fine flour. The heat moisture treatment (HMT) process was carried out by adjusting the flour's moisture content to 28% through spraying with distilled water. The moistened flour was then equilibrated in a refrigerator for 24 hours before being placed in a covered tray and heated in an oven at 105°C for 5 hours, with stirring every 2 hours. After heating, the flour was dried again at 50°C for 4 hours, then ground and sieved (Jiang et al., 2024).

Sweet bread preparation involved mixing the dry ingredients (wheat flour, modified kimpul flour according to treatment ratios, powdered milk, salt, sugar, and yeast) before gradually adding eggs, margarine, water, and GMS based on the assigned concentration. The dough was kneaded until smooth and elastic, fermented for a specific period, shaped into molds, and baked. All preparation steps were standardized across treatments to ensure comparability.

Data Collection and Analytical Methods

Physicochemical characteristics of the modified kimpul flour were measured, including moisture content, swelling power, solubility, water absorption capacity, and color parameters (L*, a*, b*). The results showed that the modified flour had a moisture content of 5.70%, swelling power of 0.41 g/g, solubility of 14.19%, water absorption of 4.55 g/g, and color values of L* = 83.84, a* = 1.67, and b* = 10.35. These measurements indicate that the HMT process successfully enhanced the functional properties of the flour.

Subsequently, the sweet bread produced from each treatment was analyzed for its proximate composition (moisture, ash, fat, protein, and carbohydrate), physical color (L*, a*, b*), texture (hardness, cohesiveness, adhesiveness), and volume expansion. Sensory evaluation was also conducted using descriptive tests that assessed aroma, sweetness, softness, stickiness, and crust color, following standardized food sensory protocols.

Statistical Analysis

All data collected from physicochemical, textural, and sensory evaluations were statistically analyzed using one-way analysis of variance (ANOVA). When significant differences were detected ($p < 0.05$), Duncan's Multiple Range Test (DMRT) was employed for post hoc comparisons. The statistical software used for this analysis was SPSS version 26. Results were presented as mean values accompanied by standard deviations to illustrate data consistency across replicates.

RESULTS AND DISCUSSION

Result

Proximate Composition of Sweet Bread

The proximate analysis of sweet bread showed significant variations depending on the ratio of wheat flour to HMT-modified kimpul flour and the concentration of glycerol monostearate (GMS). As shown in Table 1, the moisture content increased with higher substitution of kimpul flour. The treatment using a 1:3 (wheat:kimpul) ratio with 3% GMS recorded the highest moisture level (29.48%), while the lowest (27.32%) was observed in the 3:1 ratio with 2% GMS. In terms of ash content, a steady increase was also observed with higher levels of kimpul flour substitution. Conversely, protein and fat content decreased as kimpul flour levels rose. The highest protein content (10.24%) occurred at the lowest kimpul substitution (3:1 with 2% GMS), while the lowest (8.40%) was at 1:3 with 3% GMS. Carbohydrate content increased alongside kimpul flour substitution, peaking at 43.61%.

Table 1. Proximate Composition of Sweet Bread.

Treatment (Wheat:Kimpul + GMS%)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
3:1 + 2%	27.32	1.21	10.35	10.24	40.88
1:1 + 3%	28.64	1.30	9.71	9.51	40.84
1:3 + 3%	29.48	1.41	9.10	8.40	43.61

Physical Texture of Bread

Bread texture, measured by hardness, adhesiveness, and cohesiveness, was significantly influenced by both kimpul flour levels and GMS concentration. The bread sample with the 1:3 substitution ratio and 2% GMS displayed the highest hardness (440.83 g), while the 3:1 substitution ratio with 4% GMS resulted in the softest texture (127.50 g). Adhesiveness followed a similar trend, with higher values occurring at higher kimpul levels. Cohesiveness remained relatively stable across treatments. The Hardness Values of Sweet Bread Samples are shown in Figure 1.

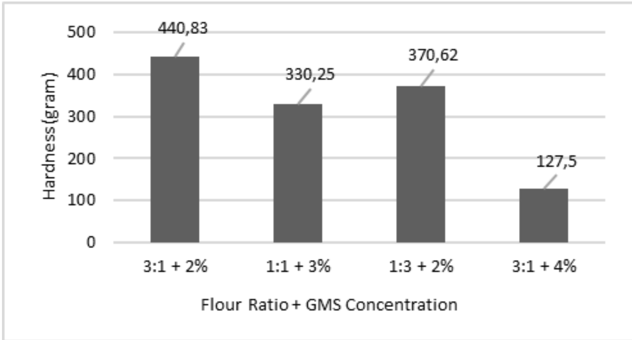

Figure 1. Hardness Values of Sweet Bread Samples.

Sensory Evaluation of Sweet Bread

The sensory quality of sweet bread was evaluated based on five parameters: softness, sweetness, aroma, crust color, and overall acceptance. As shown in Table 2, the 1:1 flour ratio with 3% GMS received the highest scores across most attributes, especially softness (4.6) and overall acceptance (4.5). In contrast, the 1:3 ratio with 2% GMS scored lowest across all categories.

Table 2. Sensory Evaluation Scores of Sweet Bread

Treatment	Softness	Sweetness	Aroma	Crust Color	Overall Acceptance
3:1 + 2% GMS	4.2	3.8	3.9	3.7	3.9
1:1 + 3% GMS	4.6	4.4	4.5	4.3	4.5
1:3 + 2% GMS	3.6	3.2	3.3	3.4	3.3

Color and Volume Expansion

The L*, a*, and b* color values demonstrated that higher levels of kimpul flour substitution led to slightly darker bread. Bread samples with higher GMS concentrations appeared lighter and more uniform in color. Meanwhile, volume expansion decreased as more kimpul flour was used, with the lowest volume expansion in the 1:3 ratio and the highest in the 3:1 ratio. Volume Expansion of Sweet Bread Based on Flour Ratio is shown in Figure 2.

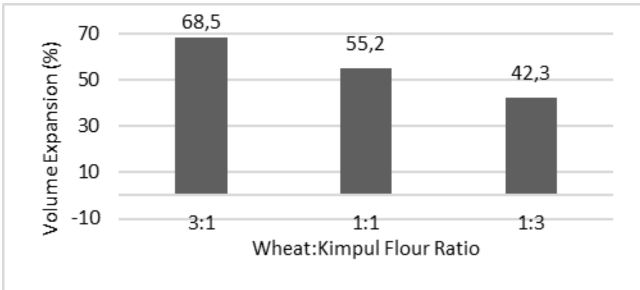

Figure 2. Volume Expansion of Sweet Bread Based on Flour Ratio.

Discussion

The overall results indicate that the substitution of wheat flour with HMT-modified kimpul flour significantly affects both the nutritional content and physical characteristics of sweet bread. The increase in moisture and carbohydrate content, alongside the decrease in protein and fat, suggests that kimpul flour contributes to softer crumb and longer moisture retention, though at the expense of nutritional density. From a texture standpoint, the absence of gluten in kimpul flour was associated with increased hardness and reduced elasticity. However, the addition of glycerol monostearate successfully mitigated this effect by improving softness and cohesiveness, especially at the 3% concentration. This confirms the emulsifying role of GMS in stabilizing air bubbles and enhancing crumb softness. The sensory evaluation results support the instrumental data: the combination of a 1:1 wheat to kimpul ratio with 3% GMS provided the most acceptable bread in terms of texture, appearance, and flavor. It achieved a good balance between desirable sensory quality and increased local ingredient utilization. Color changes and reduced volume expansion were expected due to the intrinsic properties of kimpul starch, which lacks gluten's gas-holding capacity. Although volume decreased, consumer acceptability remained relatively high in the optimal treatment. While the findings are promising, limitations include the use of only one modification method and the lack of detailed microstructural analysis of dough and crumb. Future studies should consider comparing different modification techniques and including shelf-life testing and consumer-scale panels for wider validation. In conclusion, HMT-modified kimpul flour can be effectively used to partially substitute wheat flour in sweet bread production, especially when combined with 3% GMS. This formulation enhances moisture retention and sensory appeal while promoting local food utilization.

CONCLUSIONS

This study concludes that substituting wheat flour with HMT-modified kimpul flour, particularly at a 1:1 ratio combined with 3% glycerol monostearate (GMS), improves the physicochemical and sensory qualities of sweet bread. The modified kimpul flour increased moisture and carbohydrate content, while GMS enhanced texture and overall acceptability, indicating a successful synergy between local starch sources and functional additives. These findings highlight the potential of utilizing underutilized local tubers like kimpul in bakery products to support food diversification and reduce wheat import dependency. It is recommended that food producers adopt up to 50% kimpul flour substitution with 3% GMS in sweet bread formulations. Further research should explore additional starch modification methods, structural and shelf-life characteristics, and broader sensory evaluations to support product development and commercialization.

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