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Utilization of Rice Flour and Soy Flour with the Addition of Xanthan Gum for Making Gluten-Free White Bread

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ABSTRACT

Gluten-free white bread formulated with rice and soy flour offers a safe alternative for individuals with celiac disease. Since gluten is absent, xanthan gum is added to improve gas retention and dough structure. This study aimed to identify the optimal formulation of gluten-free white bread by evaluating the physical, chemical, and sensory characteristics of various combinations of rice flour, soy flour, and xanthan gum, as well as analyzing the bread microstructure using Scanning Electron Microscopy (SEM). A Completely Randomized Design (CRD) with two factors- rice flour to soy flour ratios (90:10, 80:20, 70:30) and xanthan gum levels (1%, 2%, 3%)- was performed with three replications. Results showed that the best formula is rice flour to soy flour ratios of 80:20 combined with 3% xanthan gum. The bread had 39.26% water content, 1.26% ash, 10.96% fat, 8.22% protein, and 40.30% carbohydrates. Physically, it had a textural strength of 19.85 N, volume expansion of 82.64%, and porosity of 24.00%. Sensory scores (1-5 scale) were 4.24 (color), 3.92 (aroma), 3.96 (taste), and 4.68 (texture). SEM revealed that the gluten-free bread had larger and less uniform pores. These findings highlight formulation potential to enhance gluten-free bread quality and sensory acceptance.

1. INTRODUCTION

Gluten-free white bread is one of bread products in Indonesia which is increasingly being consumed by locals. The main difference with the conventional white bread is the ingredients used in the production, where white bread commonly used high-protein flour derived from wheat. Unfortunately, Indonesia remains heavily reliant on wheat imports, with volumes reaching up to 11,715 tons in 2024 (BPS, 2025). Aside from that, wheat contains gluten, a protein that cannot be consumed by individuals with celiac disease which is considered as an autoimmune disease that damages the small intestine when gluten is consumed. The variation of the celiac disease symptoms may include diarrhea, gastrointestinal discomfort, and even signs of malnutrition (Ye *et al.*, 2023).

One of some alternatives for individuals with celiac disease is gluten-free white bread, which is produced using non-wheat flours. Rice flour is widely recognized as a suitable base for gluten-free products because of its neutral taste, hypoallergenic, and high starch content, which provides a light texture (Park & Kim, 2023). However, its low protein content and weak viscoelasticity lead to poor gas retention and reduced loaf volume, limiting its use in bread production (Pico *et al.*, 2019). To overcome these limitations, soy flour was selected as a complementary ingredient due to its high protein content and gluten-like function, such as water-binding, gelation, and emulsification (Taghdir *et al.*, 2016). Combining rice flour and soy flour is therefore expected to not only enhance bread quality, but also improve its nutritional profile, addressing both technological and health-related challenges in gluten-free formulations.

A key challenge in the process of developing gluten-free bread from these flours lies in replicating the desirable physical characteristics of conventional bread dough, such as elasticity and volume (Kusnandar *et al.*, 2022). As a matter of fact, in wheat-based bread, gluten plays a critical role in establishing these physical properties by forming a viscoelastic network that traps fermentation-derived CO_2 (Kajzer & Diowksz, 2021). Gluten, in high-protein wheat flour, constitutes at around 80% of its total protein (Ooms & Delcour, 2019). Its absence results in a more fluid dough and structurally weak, which then, leading to a poor dough leavening ability and less optimal texture in the final bread product (Cappelli *et al.*, 2020). To address this issue, additional ingredients such as starches, proteins, and hydrocolloids are often incorporated to improve the structure and quality of gluten-free bread (Samantha, 2017). Amongst these aforementioned ingredients, xanthan gum is one of the most commonly used hydrocolloids, which possesses high fiber content (Saputro *et al.*, 2022) and effectively mimics gluten by imparting viscoelastic properties to the dough, enhancing its volume expansion, improving crumb structure, maintaining water content, and contributing positively to the sensory attributes of gluten-free bread (Chaturvedi *et al.*, 2021).

Xanthan gum plays a key role in forming a cohesive dough matrix by optimizing water and gas retention, which are essential for a well-structured bread (Manik & Nur, 2021). According to Weber *et al.* (2009) xanthan gum contributes its functions through three main mechanisms, such as reducing water mobility within the dough system, inhibiting the retrogradation of amylose and amylopectin, and reinforcing the starch gel matrix. Its interaction with proteins further helps retain water, extend shelf life, and promote a desirable crumb structure in gluten-free bread (Chaturvedi *et al.*, 2021; Furtado *et al.*, 2022). While xanthan gum is typically used at levels between 0.1% and 0.5%, recent research by Lenny *et al.* (2024) found out that additions up to 1.5% yielded optimal results in white bread made from purple yam (*Dioscorea alata* L.) flour. Similarly, Utami *et al.* (2024) stated that xanthan gum outperformed other hydrocolloids in enhancing both the physical and sensory quality of gluten-free white bread. While rice flour has been widely used in gluten-free bread ingredients, there still be limitations on structural and nutritional value (Utarova *et al.*, 2024). Similarly, soybean flour has been studied mainly as a source of protein, much richer in poly-unsaturated fatty acids and phospholipids, which are a good emulsifiers (Messina, 2016). However, only limited research has been done in combining these two flours strategically, supported with xanthan gum, to simultaneously improve the nutritional, structural, and sensory quality of gluten-free bread. This study aims to address that gap.

Based on these findings, the objectives of this research were to address the gap to formulate gluten-free white bread using a combination of rice flour and soybean flour with the addition of xanthan gum, as well as to identify the the impact of varying flour-to-xanthan gum ratios on the bread microstructure, using Scanning Electron Microscopy (SEM) analysis.

2. MATERIALS AND METHODS

2.1. Research Materials and Instruments

Main ingredients included rice flour (Rose Brand), soy flour (from Sopoyono Market, Surabaya), yeast (Fermipan), sugar (Gulaku), table salt, margarine (Forvita), eggs, water (Aqua), and xanthan gum (Fufeng). Chemicals used for analysis included distilled water, K_2SO_4, HgO, H_2SO_4, NaOH, H_3BO_3, methylene blue, methyl red, HCl, and petroleum benzene (Mallinckrodt).

Bread-making equipment included a digital scale (Nagata EK-15000), mixing bowls, measuring cups (Iwaki), aluminum loaf pans, electric oven, spoons, parchment paper, 80-mesh sieve, mixer (Miyako), blender (Philips), cabinet dryer, and gas stove (MASPION S-301). Analytical equipment used were porcelain crucibles, desiccator, Kjeldahl flasks (Iwaki), Erlenmeyer flasks (Pyrex and Iwaki), droppers (Onemed), hot plate (Labinco-L32), filter paper (Whatman), Soxhlet extractor (B-ONE SAHM-6-500), texture analyzer (TVT 6700), Scanning Electron Microscope (SEM, Hitachi SU3600), and electric furnace (600 °C).

2.2. Gluten-Free Bread Preparation

Gluten-free bread preparation followed the no-time dough method, modified from Batubara & Muliyana (2023) and Muthoharoh (2017). At the Mixing Stage I, sugar (20 g), salt (1 g), xanthan gum (1–3% w/w), eggs (50 g), and melted margarine (15 g) were mixed at low speed for approximately 4 min. In Mixing Stage II, the resulting mixture was combined with yeast (1.5 g), water (80 mL), and composite flour (rice flour : soy flour = 90:10, 80:20, 70:30 w/w) and mixed at low speed for approximately 3 min to form a batter-like dough. Prior to use, the flours were analyzed for water content, ash, starch, and amylose content determination, the dough was then poured into paper-lined pans, covered with a clean cloth, and proofed at room temperature (±27 °C) for 30 min. The dough was then baked at 200 °C for 30 min. After baking, the bread was cooled at room temperature (27±2 °C) for 20 min prior to physicochemical characteristics, texture, volume expansion, porosity, and organoleptic attributes (color, aroma, taste, texture).

After cooling to room temperature (±27 °C, 20 min), the bread was analyzed for physicochemical properties such as moisture content (AOAC, 2005, 2023), ash content (Andarwulan *et al.*, 2018), protein content (AOAC, 2023), fat content (AOAC, 2023), amylose content (Yuan *et al.*, 2007), and carbohydrate (Andarwulan *et al.*, 2018), texture profile through tensile strength analysis (Chen *et al.*, 1994), volume expansion (AACC, 2001) and porosity (Surono *et al.*, 2017). Sensory evaluation was conducted with a 25-member panel using a 5-point hedonic scale (BSN, 2024). The best formulation was determined using the effectiveness index method (DeGarmo *et al.*, 1984; Nafi *et al.*, 2015), and the selected sample was further examined for microstructure using SEM.

2.3. Experimental Design

This study used a factorial completely randomized design (CRD) with two factors and three replications (Budiharti, 2018), consisting of the ratio of rice flour to soybean flour (90%:10%, 80%:20%, 70%:30% w/w) and Xanthan gum addition (1%, 2%, 3% w/w). This resulted in nine treatment combinations. All samples were prepared and analyzed under the same laboratory conditions, with treatments were randomly assigned to ensure uniformity. In cases where sample preparation was conducted sequentially, strict control of raw materials, equipment settings, and environmental conditions was maintained to minimize potential batch effects, thus preserving the assumptions of a CRD. The obtained data were then statistically investigated using Analysis of Variance (ANOVA) at a 5% significance level. If significant differences were found, Duncan's Multiple Range Test (DMRT) was then conducted (Nisa *et al.*, 2021).

3. RESULTS AND DISCUSSION

3.1. Water Content

The analysis of variance indicated a statistically significant interaction ($p \leq 0.05$) between the ratio of rice flour to soybean flour and the addition of xanthan gum on the water content of gluten-free white bread. According to Table 1, the treatment using a 70:30 rice flour to soy flour ratio and 1% xanthan gum, yielding a water content of 37.18%. Water content ranged from 37.18% to 40.80%, with the highest in 90:10 rice–soy and 3% xanthan (40.80%). All treatments met SNI SNI 01-3840-1995, (BSN, 2000), which allows up to 40%. Water content values ranged from 37.18% to 40.80%, with the lowest value found as shown in Table 1, water content reduced as soybean flour ratios added and xanthan gum reduced. This pattern is linked to the starch content differences: rice flour contains about 71.07% starch, while soy flour contains only about 6.34%. In starch, hydroxyl groups compounds, such as amylose and amylopectin, could be abundantly found and capable of binding water. The higher the starch content, the more hydroxyl groups are available for water absorption (Zhang *et al.*, 2024). Moreover, xanthan gum acts as a hydrocolloid that effectively binds water due to its polar molecular structure, enabling hydrogen bonding with hydroxyl (-OH) groups. It is also reported that xanthan gum can bind up to 32,300 ± 1,100 g of water per 100 g of solid (Tebben & Li, 2019). These results similar to Encina-Zelada *et al.* (2018), confirming that the increasing of xanthan gum addition (1.5–3.5%) in a gluten-free bread, led to an improvement in dough consistency and higher water activity, indicating enhanced water content retention.

Table 1. Effect of flour ratio and xanthan gum addition on the water content of gluten-free white bread.

Rice Flour : Soybean Flour Ratio	Mean Water Content (%) ± SD		
	1% XG	2%XG	3%XG
90 : 10	39.87±0.0564 ^{i}	40.20±0.1409 ^{h}	40.80±0.0302 ^{g}
80 : 20	38.79±0.0599 ^{f}	38.96±0.0480 ^{e}	39.26±0.0397 ^{d}
70 : 30	37.18±0.0989 ^{c}	37.93±0.0603 ^{b}	38.55±0.1015 ^{a}

Note: The average value followed by a different notation indicates a significant difference ($p \leq 0.05$) based on DMRT; XG = Xanthan Gum

3.2. Ash Content

A significant interaction ($p \leq 0.05$) occurred between rice–soy ratios and xanthan gum on ash content (0.62–1.97%). The lowest ash (0.62%) appeared in 90:10 rice–soy with 1% xanthan, while the highest (1.97%) was in 70:30 with 3% xanthan. Only 90:10 treatments met SNI or Indonesian National Standard (SNI 8371-2018) for white bread, which specifies a maximum ash content of ≤1%. Table 2 shows that ash content increased with higher soy flour ratio and greater xanthan gum addition. This is because rice flour typically contains lower ash levels (0.38% to 2.22%) compared to soy flour, which contains up to 4.52% ash (Oppong *et al.*, 2021). Xanthan gum itself also contributes significantly to ash content, ranging from 7% to 12% (Sharma *et al.*, 2014). Ash content reflects the mineral composition of a food product (Ramadhan *et al.*, 2019).

Table 2. Effect of the rice flour to soybean flour ratio and xanthan gum addition on the ash content of gluten-free white bread

Rice Flour : Soybean Flour Ratio	Mean Ash Content (%)± SD		
	1% XG	2% XG	3% XG
90 : 10	0.62±0.0051 a	0.73±0.0181 b	0.88±0.0107 c
80 : 20	1.06±0.0075 d	1.18±0.0144 e	1.19±0.0011 f
70 : 30	1.68±0.0024 g	1.76±0.0484 h	1.97±0.0185 i

Note: The average value followed by a different notation indicates a significant difference ($p \leq 0.05$) based on DMRT; XG= Xanthan Gum

Soy is a rich source of essential minerals such as calcium, iron, copper, magnesium, and sodium (Messina, 2016), so its increasing proportion naturally elevates the mineral, and thus ash content of the bread (Taghdir *et al.*, 2016). The upward trend in ash content with increasing xanthan gum addition is also supported by (Zarringhalami *et al.*, 2021), who studied gluten-free bread incorporated with roselle seed and egg white powder.

3.3. Nutrient Content

Table 3 presents nutrient content of the gluten-free white bread in term of fat, protein, and carbohydrate contents due to rice-to-soybean flour ratio. Similarly, Table 4 presents nutrient content of the bread due to xanthan gum adition. There was no statistically significant interaction ($p \geq 0.05$) between the ratio of rice flour to soybean flour and xanthan gum addition on the nutrient content of the gluten-free bread, based on the results of the analysis of variance (ANOVA). The nutrient content of the gluten-free bread is significantly affected by ratio of rice flour to soybean flour ($p \leq 0.05$), but not the addition of xanthan gum ($p > 0.05$).

Table 3. Effect of factor treatments (rice-to-soybean flour ratio and xanthan gum addition) on the nutrient content (fat, protein, and carbohydrate) of gluten-free white bread

Factor Treatment	Fat Content (%)	Protein Content (%)	Carbohydrate Content (%)
Rice Flour : Soybean Flour Ratio			
90 : 10	9.81±0.6289 a	7.46±0.1789 a	41.68±0.4376 a
80 : 20	11.16±0.6431 b	8.28±0.1096 b	40.37±0.2846 b
70 : 30	12.35±0.1382 c	9.72±0.0152 c	38.23±1.7685 c
Xanthan Gum Addition	**Fat Content (%)**	**Protein Content (%)**	**Carbohydrate Content (%)**
1%	11.29±2.2601 a	8.52±2.2271 a	40.45±2.8089 a
2%	11.10±2.2453 a	8.51±2.2463 a	40.12±3.4962 a
3%	10.94±2.9485 a	8.43±2.3779 a	39.72±4.2554 a

Note: Mean values followed by different letters in the same column and factor indicate a statistically difference ($p \leq 0.05$) based on DMRT

3.3.1. Fat Content

Rice flour has very low fat (< 1%, 0.3–0.6 g/100 g), with mostly simple triglycerides, offering minimal contribution to dough development and bread quality (Juliano, 2015). In contrast, soy flour contains much more fat (around 47% of its energy), mostly polyunsaturated fatty acids and phospholipids that act as natural emulsifiers (Messina, 2016). These compounds can interact with starch and protein molecules, helping to stabilize air cells, retain moisture (Xia *et al.*, 2022), and contribute to a softer crumb and greater loaf volume, which are particularly beneficial in gluten-free bread with a weakened protein network (Tebben *et al.*, 2022). Because of this, the contribution of soy flour fat becomes much more statistically significant compared to the minimal role of rice flour fat.

As shown in Table 3, a lower ratio of rice flour and a higher ratio of soybean flour resulted in an increase in fat content. This is attributed to the lower fat content of rice flour (0.48%) compared to soybean flour (20.09%). Previous similar studies were reported by Otegbayo *et al.* (2018), where the fat content in composite bread made from wheat and soybean flour increased with higher levels of soybean flour. In contrast, the addition of xanthan gum had no significant effect ($p \geq 0.05$) because xanthan gum itself is fat-free and does not alter overall lipid composition. According to the NutritionValue.org (2025), xanthan gum contains 0% total fat.

3.3.2. Protein Content

As informed in Table 3, decreasing rice flour while increasing soybean flour significantly increased the protein content in the bread. This is due to the higher amount of protein of soybean flour (32.52%) compared to rice flour (6.39%). These findings are aligned with Taghdir *et al.* (2016), who stated that substituting gluten-free flours with soybean flour led to an increase in protein levels. Table 3 reveals that the addition of xanthan gum had no significant effect ($p \geq 0.05$) on protein content. This is affirmed by NutritionValue.org (2025) that xanthan gum contains no protein.

3.3.3. Carbohydrate Content

The results of the variance analysis indicated no significant interaction ($p \geq 0.05$) between the ratio of rice flour to soybean flour and xanthan gum addition on the carbohydrate content of the gluten-free white bread. This is due to the considerably higher starch content in rice flour (71.07%) compared to soybean flour (6.34%). This observation aligns with findings from Riyansah *et al.* (2019), who noted that a reduction in starch content was directly associated with a decrease in carbohydrate levels in bread formulations. Table 3 confirms that the added xanthan gum had no significant effect to carbohydrate content. This result is consistent with NutritionValue.org (2025).

3.4. Bread Volume Expansion

Analysis of variance indicated a significant interaction ($p \leq 0.05$) between the ratio of rice flour to soybean flour and xanthan gum addition on gluten-free white bread volume expansion. Bread volume expansion ranged from 76.05% to 83.32%, with the lowest observed in the 70:30 flour ratio combined with 1% xanthan gum, and the highest in the 90:10 of rice flour to soybean flour ratio with 3% xanthan gum. As presented in Table 4, reducing the ratio of rice flour, increasing soybean flour, and using lower xanthan gum decreased the bread's expansion. This can be attributed to the low starch content of soybean flour (6.34%) compared to rice flour (71.07%).

Starch, particularly amylose, plays a key role in gelatinization and water absorption during baking. Bread rises throughthe interaction of starch, protein, water, and heat. Starch releases amylose to thicken dough, while gluten traps gases. Water hydrates and produces steam for oven spring. Balanced amylose and protein, with proper heat, ensure good volume, gas retention, and crumb texture (Rosida, 2021). Apart from that, Xanthan gum improves gas retention during fermentation, boosting dough expansion, while low levels reduce volume (Chaturvedi *et al.*, 2021).

Table 4. Relationship between flour ratio and xanthan gum on the volume expansion

Rice Flour : Soybean Flour Ratio	Mean Volume Expansion (%) ± SD		
	1%XG	2%XG	3%XG
90:10	79.50±0.1786 [d]	80.29±0.1333 [e]	83.32±0.0098 [h]
80:20	78.76±0.1786 [c]	80.29±0.1386 [e]	82.64±0.0966 [g]
70:30	76.05±0.2053 [a]	77.89±0.1558 [b]	80.94±0.2568 [f]

Note: The average value followed by a different notation indicates a significant difference ($p \leq 0.05$) based on DMRT. XG = Xanthan Gum

3.5. Texture

Results of analysis of variance showed a significant interaction ($p \leq 0.05$) among flour ratio and the addition xanthan gum on bread texture, ranging from 19.25 N to 21.05 N (Table 5). The softest texture (19.25 N) was observed in the

90:10 ratio with 3% xanthan gum, while the firmest (21.05 N) occurred in the 70:30 ratio with 1% xanthan gum. Table 10 illustrates that increasing soybean flour ratio and decreasing rice flour ratio, along with lower xanthan gum levels, led to higher firmness. This is due to the higher fiber content in soybean flour (7.60%) versus rice flour (2.4%), which inhibits starch gelatinization and limits expansion, resulting in a denser texture (Rosiana *et al.*, 2023). Moreover, lower xanthan gum addition impair gas retention during proofing, reducing loaf expansion and increasing firmness. Xanthan gum acts as a gel-forming agent, improving dough gas retention, softness, and the bread overall attribute (Salehi, 2019).

Table 5. Effect of factor treatments (rice-to-soybean flour ratio and xanthan gum addition) on the physical texture of gluten-free white bread

Rice Flour : Soybean Flour Ratio	Mean Texture ± SD		
	1%XG	2%XG	3%XG
90:10	19.80±0.0000 [c]	19.45±0.0707 [b]	19.25±0.0707 [a]
80:20	20.80±0.0707 [e]	20.15±0.0000 [d]	19.85±0.0707 [c]
70:30	21.05±0.0707 [f]	20.90±0.0000 [e]	20.75±0.0707 [e]

Note: The average value followed by a different notation indicates a significant difference ($p \leq 0.05$) based on DMRT

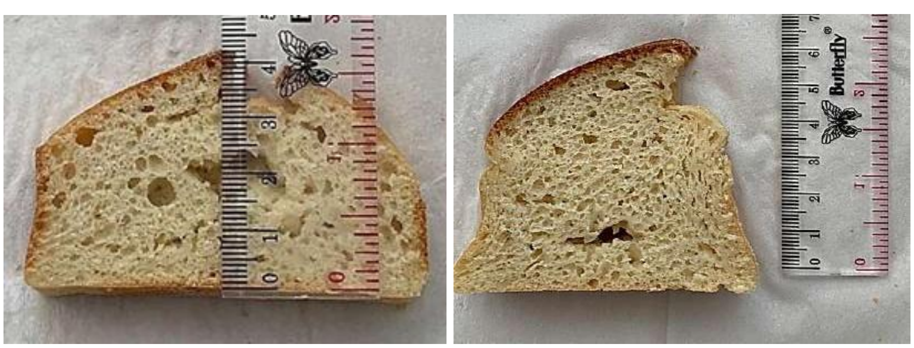
Table 6. Effect of ratio of rice flour to soybean flour and xanthan gum addition on the porosity of gluten-free white bread

Rice Flour : Soybean Flour Ratio	Mean Porosity ± SD		
	1%XG	2%XG	3%XG
90:10	15.63±0.1786 [c]	19.13±0.1768 [e]	27.25±0.3536 [h]
80:20	15.25±0.0000 [c]	17.13±0.1768 [e]	24.00±0.0000 [g]
70:30	9.88±0.1768 [a]	14.25±0.0000 [b]	22.88±0.1768 [f]

Note: The average value followed by a different notation indicates a significant difference ($p \leq 0.05$) based on DMRT

3.6. Porosity

A significant interaction ($p \leq 0.05$) was found between the ratio of rice flour to soybean flour and xanthan gum addition on bread porosity, with values ranging from 9.88% to 27.25%. It means that Bread porosity results from gas production, retention, and structural stability during fernentation. Yeast CO_2 expands air cells, gluten holds gases, and xanthan gum aids weak networks. Baking fixes pores through starch gelatinization and protein setting, with moisture and matrix balance shaping final crumb texture. Table 6 shows that increased soybean flour ratio and reduced xanthan gum ratio led to lower porosity. This is due to lower starch levels in soybean flour, which limit gelatinization and gas entrapment. Additionally, xanthan gum contributes to the formation of porous starch matrices that retain water content during heating, enhancing porosity (Parwiyanti *et al.*, 2018).



(a) (b)

Figure 1. Porosity characteristics of the gluten-free white bread: (a) least firm made with a 70:30 rice flour to soybean flour ratio and 1% xanthan gum, (b) most firm made with a 90:10 rice flour to soybean flour ratio and 3%

As shown in Figures 1a and 1b, porosity in gluten-free bread was generally large and uneven, correlating with poor volume development. Figure 1a shows that the loaf expansion is lower than that of the Figure 1b. According to Cappelli *et al.* (2020), gelatinization influences gluten-free bread expansion, while Surono *et al.* (2017) note that lower loaf volume results in smaller and less uniform crumb cavities. On this occasion, a fine, uniform, and moderately porous crumb is recommended as this structure ensures an optimal balance of texture, shelf life, and acceptability from the consumers. Therefore, Figure 1b shows better characteristic of porosity, compared to that of Figure 1a.

3.7. Sensory Evaluation (Color, Aroma, Taste, and Texture)

The sensory evaluation revealed significant differences ($p \leq 0.05$) among treatments in terms of color, taste, and texture, but not aroma (Table 7). Color ranged from light brown to dark brown (score: 3.84–4.92). The lightest bread (3.84) came from the 90:10 ratio with 1% xanthan gum, while the darkest (4.92) came from the 70:30 ratio with 3% xanthan gum. A higher soybean proportion increased browning due to the Maillard reaction which occurs between amino acids and reducing sugars, such as lysine from soy proteins (Hustiany, 2016; Otegbayo *et al.*, 2018; Sepehr *et al.*, 2025). Apart from that, aroma is also considered as an important indicator of consumer acceptance and overall product quality (Rodriguez Gamboa *et al.*, 2019). The softest texture was found in the 90:10 ratio with 2% xanthan gum, while the firmest came from the 70:30 ratio with 2% xanthan gum. Texture is influenced by fat and water content, whereby higher fat increases softness, while lower water content yields a denser crumb (Taghdir *et al.*, 2016).

Table 7. Sensory test results for gluten-free bread in different flour ratios and xanthan gum addition

Treatment		Color	Aroma	Taste	Texture
A	B				
90%:10%	1%	3.84±0.3918	3.96±0.1040	3.92±0.1325	3.84±0.5194
	2%	3.84±0.3828	3.88±0.1066	3.84±0.1396	3.44±0.5477
	3%	3.92±0.3593	3.88±0.1140	4.00±0.1487	4.88±0.5365
80%:20%	1%	4.08±0.3269	3.92±0.1231	4.04±0.1508	4.08±0.4674
	2%	4.16±0.3018	3.92±0.1329	3.88±0.1376	4.20±0.5093
	3%	4.24±0.2567	3.92±0.1452	3.96±0.1496	4.68±0.5523
70%:30%	1%	4.64±0.1146	3.92±0.1611	4.56±0.1359	4.12±0.3597
	2%	4.80±0.0600	3.96±0.1800	3.80±0.0400	4.92±0.0400
	3%	4.92±0.0000	3.60±0.0000	3.88±0.0000	4.84±0.0000

Note: Values are expressed as means ± standard deviation. A = ratio of rice flour to soybean flour B = xanthan gum addition

Table 8. Selected optimal formulation of gluten-free bread

Treatment		Physico-Chemical Properties								Sensory Properties			
A	B	MC	AC	FC	PC	CC	Text	VE	Por	Color	Aroma	Taste	Texture
90%:10%	1%	39.87	0.62	10.06	7.53	41.93	19.80	79.50	15.63	3.84	3.92	3.92	3.84
	2%	40.20	0.73	9.93	7.50	41.63	19.45	80.29	19.13	3.84	3.88	3.84	3.44
	3%	40.80	0.88	9.46	7.36	41.50	19.25	83.32	27.25	3.92	3.88	4.00	4.88
80%:20%	1%	38.79	1.06	11.54	8.33	40.29	20.80	78.76	15.25	4.08	3.92	4.04	4.08
	2%	38.96	1.19	11.01	8.30	40.54	20.15	80.29	17.13	4.16	3.92	3.88	4.20
	3%	39.26	1.26	10.96	8.22	40.30	19.85	82.64	24.00	**4.24**	**3.92**	3.96	**4.68**
70%:30%	1%	37.18	1.68	12.28	9.73	39.13	21.05	76.05	9.88	4.64	3.92	3.56	3.12
	2%	37.93	1.76	12.38	9.72	38.21	20.90	77.89	14.25	4.80	3.96	3.80	3.92
	3%	38.55	1.97	12.41	9.71	37.36	20.75	80.94	22.88	4.92	3.60	3.88	3.84

Note: A = Rice to soybean flour ratio; B = Xanthan gum addition (%); MC = Water content (%); AC = Ash content (%); FC = Fat content (%); PC = Protein content (%); CC = Carbohydrate content (%); Text = Physical texture; VE = Volume Expansion (%); Por = Porosity.

3.8. Decision Analysis for Best Formulation

Decision analysis is a method for identifying the optimal outcome based on known criteria and information (Hariwan *et al.*, 2022). In this study, the effectiveness test method by DeGarmo *et al.* (1984) and Nafi *et al.* (2015) was used to determine the best formulation. This method was used because it provides a systematic design and analysis framework to evaluate the effects of multiple factors and their interactions efficiently, which helps identifying the most suitable gluten-free bread formulation. The treatment using a proportion of 80% rice flour and 20% soybean flour with the addition of 3% xanthan gum produced the most balanced gluten-free bread in terms of physical, chemical, and sensory characteristics. The protein (8.22%) and fat (10.96%) contents indicate that soybean flour contributed to nutritional improvement without compromising texture quality. The moisture content of 39.26% and texture value of 19.85 N show a soft yet compact crumb, while the expansion volume (82.64%) and porosity (24%) reflect good gas-holding capacity due to the binding effect of xanthan gum. Moreover, the sensory evaluation revealed high panelist acceptance, particularly in texture (4.68) and color (4.24), indicating a well-balanced formulation and consumer acceptability. Overall, this combination produced the best-quality gluten-free bread compared to other treatments. Besides, xanthan gum (1 to 3%) improves dough structure while supporting gut health and moderating postprandial glycemia (Tanaka *et al.*, 2018), and can act as a probiotics (Saputro *et al.*, 2022), which make it safe and well tolerated, with minimal risk of adverse effects.

3.9. Scanning Electron Microscopy (SEM) Analysis of the Best Treatment

The best treatment which is 80% rice flour, 20% soybean flour with 3% xanthan gum was further examined using Scanning Electron Microscopy (SEM) to understand the microstructural characteristics. Figure 3 reveals starch granules (a) coated by a xanthan gum film (b) and visible CO_2 gas pockets (c) from fermentation. Compared to wheat-based bread (Figure 4), gluten-free bread had larger and more uneven pores but its crumb structure was still capable of capturing gas bubbles effectively. According to Quinte *et al.* (2025) xanthan gum forms a biocontinuous matrix with starch, which helps trap CO_2 manage water content distribution and prevent syneresis. This contributes to a more stable and uniform pore structure in gluten-free bread.

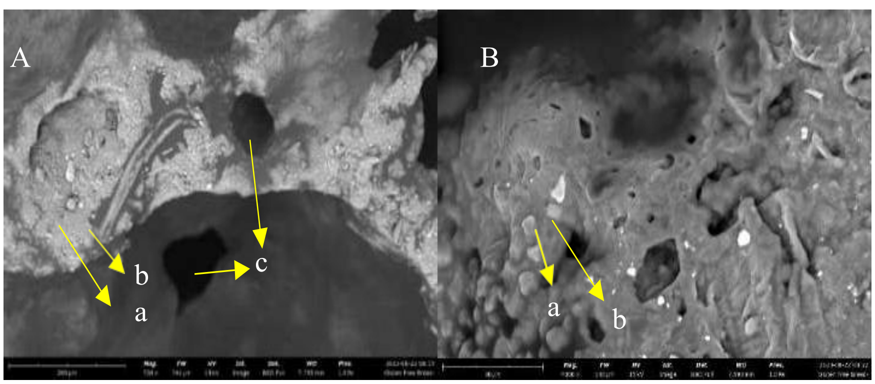


Figure 3. SEM images of gluten-free white bread made with a rice flour to soybean flour ratio of 80:20 and 3% xanthan gum addition. (A) Microstructure at 700× magnification; (B) Microstructure at 4000× magnification. Annotations: (a) starch granules; (b) xanthan gum film layer; (c) CO_2 gas cells formed during fermentation

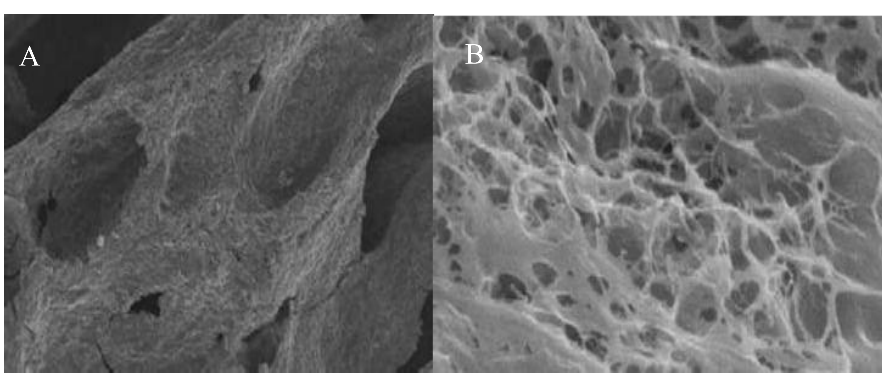


Figure 4. SEM images of white bread made of wheat flour with magnification: (A) 50x, (B) 10.000x

4. CONCLUSION

To sum up, this study formulated gluten-free white bread using rice–soybean flour blends with xanthan gum, and evaluated the effects on quality. The 80:20 rice–soybean flour ratio with 3% xanthan gum produced the most favorable outcomes, achieving balanced nutritional composition, desirable texture, good loaf expansion, and high consumer acceptability. SEM analysis confirmed that xanthan gum contributed to improved but still less uniform crumb structures compared to wheat bread due to the lack of gluten. Based on these findings, the formulation of 80% rice flour, 20% soybean flour, and 3% xanthan gum is recommended as the optimal combination for producing gluten-free white bread with enhanced structural integrity, acceptable sensory qualities, and potential market viability.

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