The Effect of Pre-gelatinized Rice Flour Substitution for Rice Flour on the Characteristics of Gluten-free White Bread

Tuty Anggraini[1], Muhammad Rizky Steval[1], Rina Yenrina[1]

10.18805/ajdfr.DRF-489

ABSTRACT

Background: Gluten-free white bread is made without using wheat or other gluten-containing ingredients, making it safe for consumers who are sensitive to gluten. Physical modifications, such as pre-gelatinization of rice flour, increase viscosity at cold temperatures, helping the dough trap gas produced during fermentation.

Methods: The design used for this research was a completely randomized design with five treatments and three replications. The treatments used in this research are substitutes of pre-gelatinized rice flour to the amount of rice flour where A (control), B (10%), C (20%), D (30) and D (40%).

Result: The results showed that substituting pre-gelatinized rice flour increased the bread's specific volume, porosity, and pore count, although there was a slight decrease when the substitution exceeded 30%. The moisture content of gluten-free white bread increased with the increase in pre-gelatinized rice flour substitution, while the carbohydrate content decreased. No significant differences were found in the ash, protein, or fat content.

Key words: Gluten-free white bread, Porosity, Pre-gelatinized rice flour, Specific volume.

INTRODUCTION

White bread is a food product generally made from wheat flour, fermented with yeast, and baked to produce a hollow structure (Bouhadi *et al*., 2023). Wheat flour contains 70-75% starch, 14% water, 10-12% protein, 2% fat. Most of the proteins contained in flour are glutenin and gliadin, gluten-forming proteins (Goesaert *et al*., 2005). Gluten is a protein formed when glutenin and gliadin are mixed with water, forming a network that provides elasticity (Gibson *et al*., 2018). The elasticity produced by gluten can withstand CO_2 gas produced during fermentation, resulting in good bread volume (Barak *et al*., 2013). However, the gluten found in white bread can cause damage to the small intestine in people with celiac disease.

To produce gluten-free bread that is safe for people living with celiac disease, rice flour is used instead of wheat flour because it does not contain gluten protein (Rodge *et al*., 2024). Apart from not containing gluten protein, rice flour has advantages such as being bland, white, easy to digest, and hypoallergenic (Furlán *et al*., 2015). However, rice flour does not provide good development because it cannot hold CO_2 gas well (Han dan Koh, 2023). The ability to hold CO_2 gas affects the volume of bread as well as the quality and texture of gluten-free white bread (Gallagher *et al*., 2003). To overcome this, physical modification was carried out on rice flour, namely pre-gelatinization, to produce better gluten-free white bread.

Pre-gelatinization allows these products to absorb more water because the damage to the starch granules increases the absorption capacity. Ma *et al*. (2022) stated that physical modifications to flour, such as pre-gelatinization, can increase water absorption and viscosity in cold water. In making white bread, the viscosity of the dough can affect the characteristics of the resulting white bread.

In the pre-research, the researchers examined three treatments of gluten-free white bread made from rice flour with different levels of substitution of pre-gelatinized rice flour for rice flour, namely 0% substitution of pre-gelatinized rice flour for rice flour (control), 10% substitution of rice flour. Pre-gelatinization of rice flour, and 25% substitution of pre-gelatinization of rice flour for rice flour. In the pre-gelatinized flour substitution treatment of 10%, the results were bread with bread edges that were not hard and had smaller pores and thinner pore walls. With 25% pre-gelatinized flour substitution, bread results were obtained with bread pores that were more evenly distributed and thinner pore walls than in treatments with lower substitution levels. Based on the description above, researchers want to conduct research entitled "The Effect of Pre-Gelatinized Rice Flour Substitution for Rice Flour on the Characteristics of Gluten-Free White Bread".

[1]Department of Food Technology and Agricultural Products, Faculty of Agricultural Technology, Kampus Limau Manis Padang, West Sumatra-25163, Indonesia.

Corresponding Author: Tuty Anggraini, Department of Food Technology and Agricultural Products, Faculty of Agricultural Technology, Kampus Limau Manis Padang, West Sumatra-25163, Indonesia. Email: tuty@ae.unand.ac.id

How to cite this article: Anggraini, T., Steval, M.R. and Yenrina, R. (2025). The Effect of Pre-gelatinized Rice Flour Substitution for Rice Flour on the Characteristics of Gluten-free White Bread. *Asian Journal of Dairy and Food Research*. **44 (Special Issue):** 46-53. doi: 10.18805/ajdfr.DRF-489.

Submitted: 23-12-2024 **Accepted:** 05-05-2025 **Online:** 11-06-2025

MATERIALS AND METHODS

The experiment was conducted from October until November 2024 in the Laboratory of Instrumentation, Faculty of Agricultural Technology, Andalas University, West Sumatra, Indonesia. The tools used in this research are a rice cooker, food dehydrator, mixer, rapid visco analyzer, scanning electron microscope, oven, and proximate analysis glassware. The ingredients used in this research were rice, Fermipan yeast, Blue Band margarine, mineral water, sugar, and salt. The chemicals used for analysis are distilled water, 30% NaOH solution, 0.02N HCl, methyl red indicator (mm); methyl blue (MB), H_2SO_4, selenium catalyst, nonpolar organic solvents, alcohol, filter paper, and other chemicals used for analysis.

The design used for this research was a completely randomized design with five treatments and three replications. The data obtained were analyzed statistically with the F test, and if significantly different, they were continued with Duncan's new multiple range test (DNMRT) at the 5% level. The treatments used in this research are substitutes of pre-gelatinized rice flour to the amount of rice flour where A (control), B (10%), C (20%), D(30) and D(40%).

Research procedure

Making rice flour

Making rice flour is done by drying rice at a temperature of 80°C for 4 hours in a food dehydrator. After drying, the rice is reduced using a grinder and sifted using an 80-mesh sieve.

Making pre-gelatinized rice flour

Pre-gelatinized rice flour is made by cooking or gelatinizing the rice using water in a ratio of 1:1, cooked using a rice cooker at a temperature of 70°C for 30 minutes. Then, it dried at a temperature of 80°C for 4 hours in a food dehydrator; after drying, it was reduced in size using a grinder and sieved using an 80 mesh sieve.

Making gluten-free bread

Making gluten-free white bread begins by mixing rice flour, pre-gelatinized rice flour, sugar, salt, and yeast. Next, add water slowly while stirring using a mixer. Then, add margarine to the mixture while stirring it with a mixer. After the mixture has been mixed, the mixture is fermented for 30 minutes. The fermented dough is transferred into a mold and proofed for 40 minutes. The oven is preheated before the dough is baked to a temperature of 180°C. When the oven temperature has reached 180°C, the proofed dough is baked at 180°C for 30 minutes. After that, baking was continued at 200°C for 20 minutes. The formulation of the ingredients used in making gluten-free white bread can be seen in Table 1.

Microstructural analysis of starch granules (Qin *et al*., 2021)

Sample photomicrographs were taken using a Scanning Electron Microscope (SEM). Samples of 1-5 mg that had been dried were then coated with gold and observed at a magnification of 100x-1000x. The gold coating was carried out on non-conductive samples to produce clear images.

Fourier transform infraRed (FTIR) analysis

FTIR analysis is conducted using the method from (Bhuiyan *et al*., 2024). The sample FTIR analyzed was rice flour with different carrier materials. Fifteen milligrams of the sample are prepared and ground with 300 mg of dry KBr (p.a.) in a mortar until homogeneous. The mixture is then placed into a KBr die. A pressure of 10 × 10,000 kg (equivalent to 10 tons) is applied to form a pellet. The sample is then analyzed by FTIR over a wave number range of 400-4500 cm^{-1} and compared with literature data.

Analysis of pasting properties

The pasting properties of the samples were observed using a Rapid ViscoAnalyzer starting from 45°C for 1 minute, then increasing the temperature to 95°C (with a heating speed of 12°C/minute) within 3 minutes and 42 seconds, maintained for 2 minutes and 30 seconds. Cooled to 45°C in 3 minutes and 48 seconds and the process was terminated in 13 minutes. The results obtained are in the form of a graph of viscosity values for each temperature change.

Specific volume analysis

The specific bread volume analysis is determined from the ratio between the volume and weight of the bread. Bread volume was measured using the displacement method, where rice was used as the measuring medium. The volume of rice without bread is compared with the volume of the container containing bread to obtain the bread volume through the difference.

Bread pore analysis

In bread pore analysis, the number of bread pores and bread porosity is calculated by analyzing bread images using the Image J application. Bread porosity is the ratio of the amount of space in the bread, which can be calculated in 2 or 3 dimensions. Porosity is calculated in 2 dimensions from the ratio of the total pore area of the bread to the

Table 1: Formulation of gluten-free white bread ingredients.

Ingredients	Treatments				
	A	B	C	D	E
Rice flour (g)	300	270	240	210	180
Pre-gellatinisation rice flour (g)	0	30	60	90	120
Water (ml)	360	360	360	360	360
Sugar (g)	25	25	25	25	25
Margarine (g)	12	12	12	12	12
Yeast (g)	9	9	9	9	9
Salt (g)	4	4	4	4	4

Note: The concentration of pre-gelatinized rice flour is calculated based on the level of substitution for rice flour, namely 0%, 10%, 20%, 30% and 40%.

bread area obtained after analyzing the image in the Image J version 1.54 k application.

Proximate analysis

Proximate analysis is carried out to determine water, ash, protein, fat and carbohydrate content. Water content was analyzed using the gravimetric method by measuring the weight loss after drying at a temperature of 105°C to constant weight. Ash content is also determined gravimetrically by burning the sample at a temperature of 600°C until white ash remains. Protein content was calculated using the Kjeldahl method through digestion, distillation and titration, while fat content was measured using the Soxhlet method using hexane solvent. The carbohydrate content is calculated by the difference from 100% to the total water, ash, fat and protein content.

RESULTS AND DISCUSSION

Analysis of raw material

Microstructural analysis of starch granules

The results of observing starch granules using SEM in Fig 1a show that the structure of the starch granules in rice flour is polyhedral in shape. This shape is a general characteristic of starch granules in rice. According to Zhang *et al*. (2023), different types of rice still have the same starch granule shape, namely polyhedral.

Meanwhile, Fig 1b shows that the structure of the starch granules in pre-gelatinized rice flour is damaged, loses its polyhedral shape, and forms an irregular matrix. Damage to the starch granule structure occurs due to the gelatinization process in the pre-gelatinized flour. When the gelatinization process of starch granules is heated in water, the starch granules swell and then burst at higher temperatures, resulting in changes in the structure of the starch granules, which provide different water absorption properties (Gopadile *et al*., 2024). The irregular structure (crystalline) of starch granules that have been damaged makes the shape of the starch granules irregular, making it easier for water to penetrate the starch granules, thereby increasing the absorption capacity of the starch granules (Jia *et al*., 2023).

The changes that occur in the starch granules in pre-gelatinized flour, which can be seen in Fig 1b, occur due to the damage to the starch granule structure; the amylose molecules interact with each other to form a gel and can no longer return to their original granule form (Richardson *et al*., 2004). Pre-gelatinized rice flour has irregular starch granules, making it easier to hydrate. This allows rice flour to absorb water at cold temperatures. Starch granules' high hydration level increases absorbency and viscosity (Cornejo-Ramírez *et al*., 2018).

FTIR analysis

FTIR was used to analyze rice flour compounds before and after pre-gelatinization treatment, as seen in Fig 2. The same peak was detected in both samples at 3000-3500 cm^{-1} and 1500-2000 cm^{-1}, indicating no significant difference in chemical composition between regular rice flour and pre-gelatinized rice flour. At 3000-3500 cm^{-1}, the broad peak reflects the stretching vibration of the O-H groups, related to the presence of hydroxyl groups and hydrogen bonds in starch. This shows that even though the gelatinization process occurs, the basic chemical structure of the hydroxyl groups in the starch molecules does not change.

At waves of 1500-2000 cm^{-1}, the peaks that appear are associated with the vibration of minor functional groups, such as proteins and lipids (Kong and Yu, 2007). The peak positions and intensities in these bands were similar for both samples, indicating that pre-gelatinization treatment did not significantly change the primary or secondary structure of the protein. The similarity in these waves confirms that the pre-gelatinization process does not cause the formation of new chemical groups or significant molecular changes in rice flour. This suggests that pre-gelatinization influences physical properties, such as granule structure and hydration, more than the basic chemical structure of the flour.

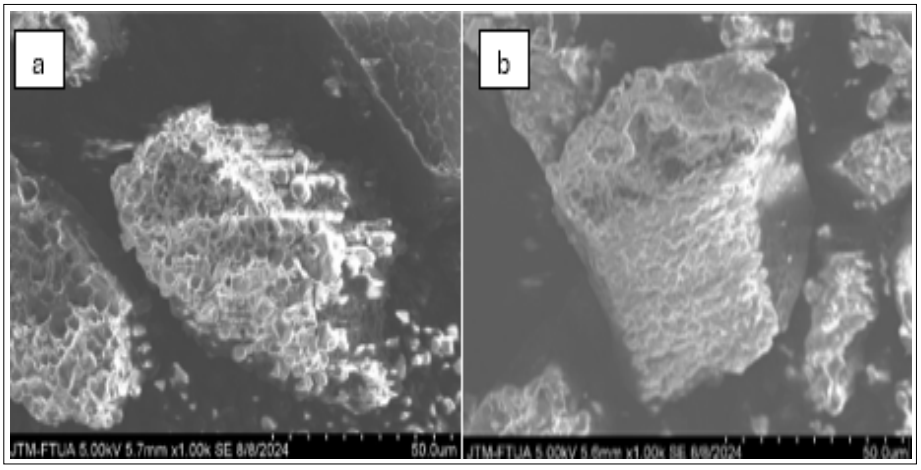


Fig 1: a) Rice flour starch granules, b) Pre-gelatinized rice flour starch granules at 1000× magnification.

Analysis of pasting properties

Table 2 show the pasting properties of rice flour. Rice flour has a peak viscosity value of 4712 cP with a peak time of 9.47 minutes. The rice flour pasting properties graph in Fig 3 shows several stages: peak viscosity, breakdown viscosity, and final viscosity. This is similar to the results obtained by Copeland *et al.* (2022) on the pasting properties graph for rice flour, which has peak viscosity, breakdown viscosity and final viscosity. The pattern formed from this graph shows the process of swelling of starch granules, increasing viscosity.

On the other hand, pre-gelatinized rice flour produces a different graphic pattern, as seen in Table 2. In this graph, pre-gelatinized rice flour shows no peak or breakdown viscosity. The viscosity is already formed at cold temperatures and increases gradually without decreasing. This phenomenon can be explained by the gelatinization process, which changes the structure of starch granules. When the temperature increases, the starch granule structure breaks down, resulting in a decrease in viscosity (breakdown viscosity). However, in pre-gelatinized rice flour, the previous gelatinization process has caused permanent damage to the starch granules. This damage allows pre-gelatinized rice flour to absorb water and form viscosity at cold temperatures without experiencing viscosity breakdown because no longer intact granules can break. The damage to starch granules during the gelatinization process carried out on pre-gelatinized rice flour gives pre-gelatinized rice flour the characteristics of absorbing water and producing viscosity at cold temperatures (Nakorn *et al*., 2009).

The characteristic of pre-gelatinized rice flour, which can form viscosity at cold temperatures, provides benefits in making white bread, especially in helping trap gas produced during fermentation So that it can produce better characteristics of white bread. However, a too-high viscosity results in the dough being too thick, making the dough stiff so that gas during fermentation is challenging to trap. Dough that is too stiff can reduce the volume of the bread because it loses the ability to trap gas effectively (Waziiroh *et al*., 2021).

Analysis product

Specific volume analysis

Based on Fig 3, it can be seen that as the substitution of pre-gelatinized rice flour for rice flour increases, the specific volume of gluten-free white bread increases. The increase in specific volume shows that the density of gluten-free white bread decreases, which indicates that gluten-free white bread is more hollow and lighter. This decrease in density occurs because gluten-free white bread traps more air, which increases the bread's volume. The substitution of pre-gelatinized rice flour, which can absorb cold water, contributes to the viscosity of the dough, which plays an important role in increasing the ability of the dough to trap gases produced during fermentation.

When the pre-gelatinized flour substitution exceeded 20%, a specific volume decreased, indicating an increase in the density of gluten-free white bread. This decrease is caused by the dough's viscosity being too high so that the dough becomes too thick and less elastic, inhibiting the dough from expanding during fermentation. As a result, the dough's ability to trap gas decreases, which makes the bread volume smaller. On the other hand, a viscosity that is too low can also cause a dense bread structure because the dough loses the ability to hold gas, which ultimately reduces the volume of the bread (Waziiroh *et al*., 2021).

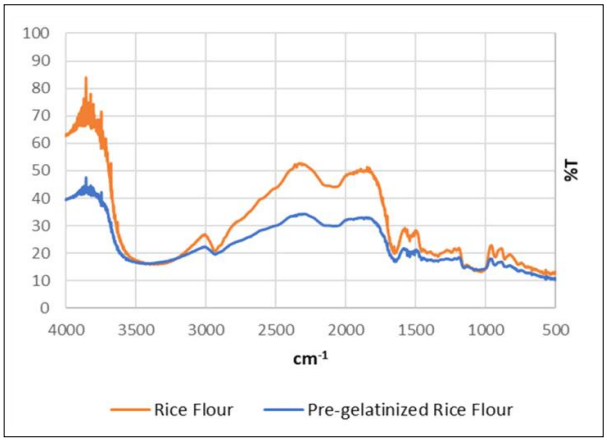


Fig 2: FTIR graph of rice flour and pregelatinzed rice flour.

Table 2: Pasting properties of flour.

Sample	Pasting temperature (°C)	PT (minutes)	PV (Cp)	FV (Cp)	BV (Cp)	SV (Cp)
TB	82.9	9.47	4712	5759	2137	3184
TBP	0	-	-	468	-	154

Description: Rice flour (TB), Pre-gelatinized rice flour (TBP), Peak time (PT), Peak viscosity (PV), Final viscosity (FV), Breakdown viscosity (BV), Setback viscosity (SV).

Although the specific volume of gluten-free white bread obtained increased, this result differs significantly from the specific volume of white bread made from wheat flour. Based on research by Pham *et al*. (2005) and Iacovino *et al*. (2024), white bread made with wheat flour has a specific volume ranging from 2 to 4 ml/g.

Bread pore analysis

The analysis results show that the bread porosity obtained ranges from 17.65-28.05%, as seen in Fig 4. Bread porosity increases with increasing substitution of pre-gelatinized rice flour from 0% to 20%.

This decrease is caused by too much pre-gelatinized flour, causing excessive water absorption and making the dough too thick and less flexible. The number of bread pores also showed significant changes along with increasing substitution of pre-gelatinized rice flour, as seen in Fig 5, with pores ranging from 63.33-484.33. The number of pores increased at rice flour substitution levels of up to 30%. This increase can occur due to adequate viscosity for good gas-trapping power, which supports effective gas distribution and trapping during fermentation.

Proximate analysis

As seen in Table 3, pre-gelatinized rice flour can absorb water better in cold conditions because hydrogen bonds in starch molecules are broken during the gelatinization process, damaging the structure of starch granules. The gelatinization process causes the starch to swell. It causes damage to the starch granules, making their structure irregular and providing access for water to bind with the starch, thereby increasing water absorption (Jia *et al*., 2023). As a result, more water molecules bind to the starch granules, making it more difficult for the water in the bread to evaporate during the baking process.

Rice, as the flour used in gluten-free white bread, contains minerals such as magnesium, zinc, iron, potassium, calcium, manganese and copper, which can be found in rice (Summpunn *et al*., 2023). Lack of mineral intake such as magnesium, zinc, copper and iron can reduce the

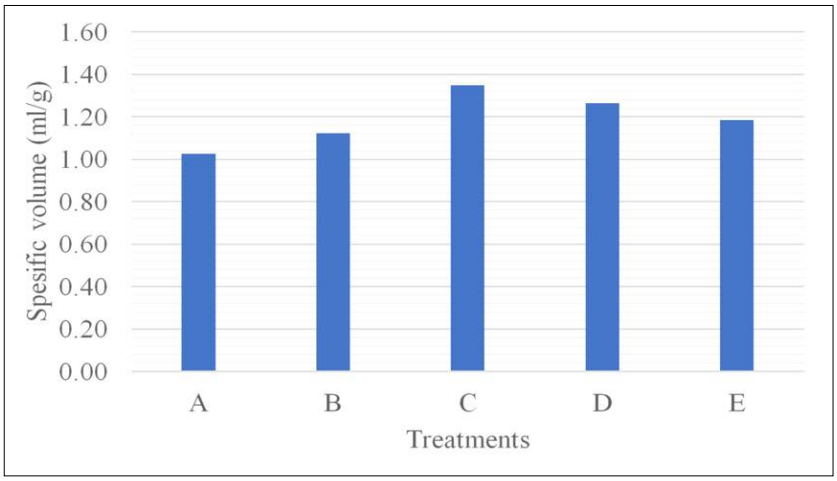


Fig 3: Specific volume of gluten-free white bread with different levels of pre-gelatinized rice flour substitution.

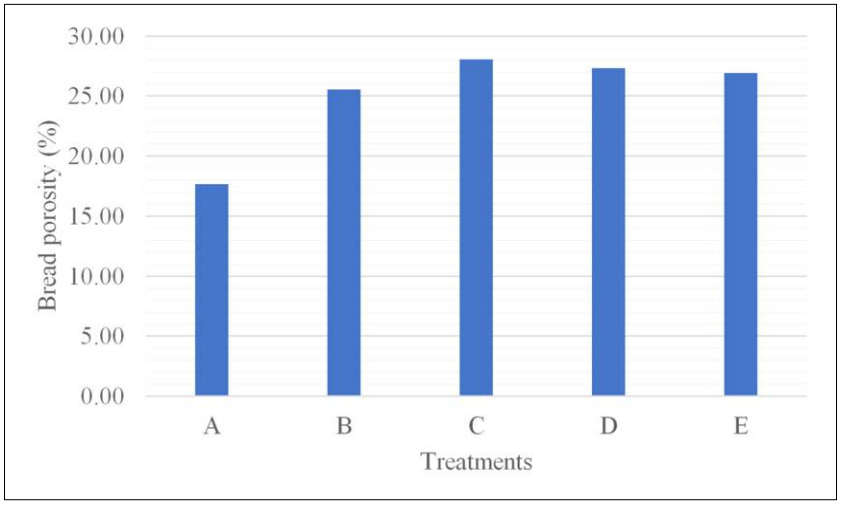


Fig 4: Bread porosity in gluten-free white bread with different levels of pre-gelatinized rice flour substitution.

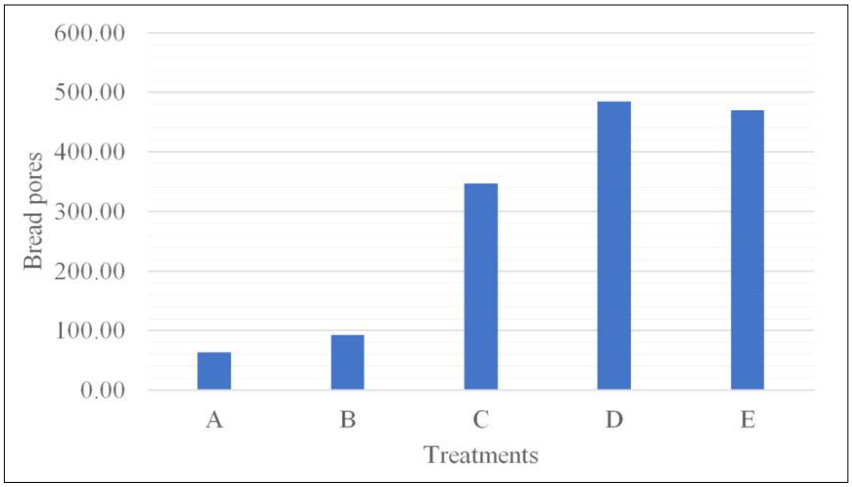


Fig 5: Number of bread pores in gluten-free bread with different levels of pre-gelatinized rice flour substitution.

Table 3: Results of proximate analysis of gluten-free white bread at different levels of pre-gelatinized rice flour substitution.

Treatment (Pre-gelatinized rice flour substitution)	Moisture content (%)	Ash content (%)	Content Protein (%)	Fat content (%)	Carbohydrate content (%)
A (0%)	38.23±0.31^{a}	0.65±0.33	2.96±0.41	0.71±0.15	57.46±0.45^{a}
B (10%)	40.72±0.29^{b}	0.66±0.14	3.22±0.80	0.92±0.11	54.48±0.76^{b}
C (20%)	41.49±0.49^{c}	0.64±0.02	2.95±0.46	0.94±0.26	53.98±0.95^{bc}
D (30%)	42.79±0.30^{d}	0.69±0.19	2.66±0.89	0.62±0.11	53.24±0.79^{c}
E (40%)	43.67±0.71^{e}	0.63±0.02	2.49±0.84	0.79±0.17	52.41±1.30^{d}

ability of the immune system or even interfere with controlling inflammation throughout the body (Weyh *et al*., 2022).

The proteins in rice flour are divided based on their solubility: around 4-6% albumin, 6-13% globulin, 79-83% glutelin and 2-7% prolamin (Jayaprakash *et al*., 2022). Even though rice flour has a relatively low protein content, rice flour is the primary source of protein content in this gluten-free white bread. Protein levels measured in various treatments of gluten-free white bread showed that there were no significant differences between treatments, as seen in Table 3, with protein content values ranging from 2.49-3.22%.

In the fat content analysis, the main source of fat content in gluten-free white bread comes from additional ingredients such as margarine and rice flour. As the main source of fat content in white bread, Margarine plays a role in the stability of the gas bubbles produced in white bread dough during fermentation (Renzyaeva, 2013). It can be seen in Table 3 that the results of the analysis of fat content in gluten-free white bread show that there is no significant difference between various levels of pre-gelatinized rice flour substitution with fat content values ranging from 0.62-0.92%.

In the carbohydrate analysis, it can be seen in Table 3 that the results of the carbohydrate content analysis show a decrease in carbohydrate content along with increasing substitution of pre-gelatinized rice flour with carbohydrate content values ranging from 52.41-57.46%. The gelatinization that pre-gelatinized flour has undergone causes the granule structure to be damaged, which changes the shape of the starch granules to become irregular and increases their surface area, causing the absorption capacity to increase (Liu *et al*., 2017) in line with the statement of Jia *et al*. (2023), which states that gelatinization destroys the crystalline (ordered) structure of starch granules, turning them into irregular structures and providing more free hydroxyls that can bind with water. This means that the starch can retain more water molecules so that the water content increases as pre-gelatinization rice flour increases, as seen in Table 3.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that increasing the substitution of pre-gelatinized rice flour has a real influence on the specific volume, bread porosity, number of bread pores, water content and carbohydrate content in gluten-free white bread. The pre-gelatinized rice flour substitution level of 30% is gluten-free white bread with the most optimal characteristics, with a specific volume of 1.26 cm^3/g, porosity of 27.32% and a number of bread pores of 484.33.

ACKNOWLEDGEMENT

The present study was supported by the Faculty of Agricultural Technology, Andalas University number 01J/PL/PN- UNAND/FATETA-2024.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of our affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

No animal testing in this research.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Barak, S., Mudgil, D. and Khatkar, B.S. (2013). Relationship of gliadin and glutenin proteins with dough rheology, flour pasting and bread making performance of wheat varieties. *LWT - Food Science and Technology*. **51(1):** 211-217. https://doi.org/10.1016/J.LWT.2012.09.011.

Bouhadi, D., Belkhodja, H. and Benattouche, Z. (2023). Rheological properties of soft wheat flour and sensory characteristics of bread added with bean flour (*Vicia faba*. L). *Asian Journal of Dairy and Food Research*. **43(2):** 253-260. doi: 10.18805/ajdfr.DRF-319.

Bhuiyan, M.H.R., Liu, L., Samaranayaka, A. and Ngadi, M. (2024). Prediction of pea composites physicochemical traits and techno-functionalities using FTIR spectroscopy. *LWT*. **208:** 116667. https://doi.org/10.1016/j.lwt.2024.116667.

Copeland, L., Blazek, J., Salman, H. and Tang, M.C. (2022). Form and functionality of starch. *Food Hydrocolloids*. **23(6):** 1527-1534. https://doi.org/10.1016/j.foodhyd.2008.09.016.

Cornejo-Ramírez, Y.I., Martínez-Cruz, O., Del Toro-Sánchez, C.L., Wong-Corral, F.J., Borboa-Flores, J. and Cinco-Moroyoqui, F.J. (2018). The structural characteristics of starches and their functional properties. *CYTA - Journal of Food*. **16(1):** 1003-1017. https://doi.org/10.1080/19476337. 2018.1518343.

Furlán, L.T.R. ., Padilla, A.P. and Campderrós, M.E. (2015). Improvement of Gluten-free bread properties by the incorporation of bovine plasma proteins and different saccharides into the matrix. *Food Chemistry*. **170:** 257-264. https://doi.org/10.1016/J.FOODCHEM.2014.08.033.

Gallagher, E., Gormley, T.R. and Arendt, E.K. (2003). Crust and crumb characteristics of gluten free breads. *Journal of Food Engineering*. **56(2-3):** 153-161. https://doi.org/10.1016/S0260-8774(02)00244-3.

Gibson, M. and Newsham, P. (2018). Bread. In Food Science and the Culinary Arts. Academic Press. https://doi.org/10.1016/B978-0-12-811816-0.00010-5. pp. 121-131.

Goesaert, H., Brijs, K., Veraverbeke, W.S., Courtin, C.M., Gebruers, K. and Delcour, J.A. (2005). Wheat flour constituents: How they impact bread quality and how to impact their functionality. *Trends in Food Science and Technology.* **16(1-3):** 12-30. https://doi.org/10.1016/j.tifs.2004.02.011.

Gopadile, O.D., Kobue-Lekalake, R., Mokobi, B. and Bultosa, G. (2024). Physicochemical, cooking quality and sensory acceptability of three cowpea varieties grown in botswana. *Asian Journal of Dairy and Food Research*. **44(1):** 52-59. doi: 10.18805/ajdfr.DRF-356.

Han, H.M. and Koh, B.K. (2023). Gel properties of rice Varieties in relation to bread baking potential. *International Journal of Food Properties*. **26(1):** 833-841. https://doi.org/10.1080/10942912.2023.2185179.

Iacovino, S., Quiquero, M., Arcangelis, E. De, Cuomo, F., Carmela, M., Cristina, M. and Marconi, E. (2024). Physico-chemical and nutritional properties of different high-amylose wheat breads. *Journal of Cereal Science*. 117. https://doi.org/10.1016/j.jcs.2024.10391.9.

Jayaprakash, G., Bains, A., Chawla, P., Fogarasi, M. and Fogarasi, S. (2022). A narrative review on rice proteins: Current scenario and food industrial application. *Polymers.* **14(15).** https://doi.org/10.3390/POLYM14153003.

Jia, R., Cui, C., Gao, L., Qin, Y., Ji, N., Dai, L., Wang, Y., Xiong, L., Shi, R. and Sun, Q. (2023). A review of starch swelling behavior: Its mechanism, determination methods, influencing factors and influence on food quality. *Carbohydrate Polymers*. 321. https://doi.org/10.1016/J.CARBPOL.2023.121260.

Kong, J. and Yu, S. (2007). Fourier transform infrared spectroscopic analysis of protein secondary structures protein. *FTIR data analysis and band assign*. **39(20745001):** 549-559. https://doi.org/10.1111/j.1745-7270.2007.00320.x.

Liu, Y., Chen, J., Luo, S., Li, C., Ye, J., Liu, C. and Gilbert, R.G. (2017). Physicochemical and structural properties of pregelatinized starch prepared by improved extrusion cooking technology. *Carbohydrate Polymers.* **175:** 265-272. https://doi.org/10.1016/J.CARBPOL.2017.07.084.

Ma, H., Liu, M., Liang, Y., Zheng, X., Sun, L., Dang, W., Li, J., Li, L. and Liu, C. (2022). Research progress on properties of pre-gelatinized starch and Its application in wheat flour products. *Grain and Oil Science and Technology*. **5(2):** 87-97. https://doi.org/10.1016/J.GAOST.2022.01.001.

Nakorn, K., Karilla, T. and Sirivongpaisal, P. (2009). Crystallinity and rheological properties of pregelatinized rice starches differing in amylose content crystallinity and rheological properties of pregelatinized rice starches differing in amylose content. Starch/Staerke. 61(August). https://doi.org/10.1002/star.200800008.

Pham, V.H., Yamamori, M. and Morita, N. (2005). Formation of Enzyme-resistant starch in bread as affected by high-amylose wheat flour substitutions. *Cereal Chemistry*. **82(6):** 690-694. https://doi.org/10.1094/CC-82-0690.

Qin, W., Lin, Z., Wang, A., Chen, Z., He, Y., Wang, L., Liu, L., Wang, F. and Tong, L.T. (2021). Influence of particle size on the properties of rice flour and quality of gluten-free rice bread. *LWT*. 151. https://doi.org/10.1016/J.LWT.2021.112236.

Renzyaeva, T.V. (2013). On the role of fats in baked flour goods. *Foods and Raw Materials*. **1(1):** 19-25. https://doi.org/10.12737/1513.

Richardson, G., Kidman, S., Langton, M. and Hermansson, A.M. (2004). Differences in mylose aggregation and starch gel formation with emulsifiers. *Carbohydrate Polymers*. **58(1):** 7-13.

Rodge, S.M., Devkatte, A.N., Shere, P.D. and Pawar, G.S. (2024). Development and effectual evaluation of gluten free multi millet pasta based on nutritional, sensory and colour characteristics. *Asian Journal of Dairy and Food Research*. **43(3):** 478-484. doi: 10.18805/ajdfr.DR-2206.

Summpunn, P., Deh-ae, N., Panpipat, W., Manurakchinakorn, S., Bhoopong, P., Donlao, N., Rawdkuen, S., Shetty, K. and Chaijan, M. (2023). Nutritional profiles of yoom noon rice from royal initiative of southern Thailand: A comparison of white rice, brown rice and germinated brown rice. *Foods*. **12(15):** 2952. doi: 10.3390/foods12152952.

Waziiroh, E., Bender, D., Saric, A., Jaeger, H. and Schoenlechner, R. (2021). Ohmic baking of gluten-free bread/: Role of starch and flour on batter properties. *Applied Sciences*. **11(14):** 6567.

Weyh, C., Peeling, P. and Castell, L. (2022). The role of minerals in the optimal functioning of the Immune System. *Nutrients*. **14(3):** 644. doi: 10.3390/nu14030644.

Zhang, C., Xue, W., Li, T. and Wang, L. (2023). Understanding the relationship between the molecular structure and physicochemical properties of soft rice starch. *Foods*. **12(19):** 3611. doi: 10.3390/foods12193611.