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Corresponding Author:

Name : St.Hartini Djaliil
Email : st.hartinidjalil@unhas.ac.id

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Determination of the Nutritional Profile of Rice Flour Substituted with Moringa (*Moringa oleifera*) Leaf Flour as an Intermediate Product

St. Hartini Djaliil^{1*}, Irwan¹, Ariella Ramadhani Putri², Arfina Sukmawati Arifin³, Noor Aliyah Haris³

¹Food Crop Production Technology Study program, Vocational Faculty of Hasanuddin University, Makassar – Indonesia

²Food Agribusiness Study Program, Vocational Faculty of Hasanuddin University, Makassar – Indonesia

³Food Science and Technology Study Program, Faculty of Agricultural Technology of Hasanuddin University, Makassar – Indonesia

Abstract

Rice flour is widely used as an intermediate ingredient in various processed food products; however, it has limitations in terms of protein and micronutrient content. This study employed an experimental laboratory design with a Single-Factor Completely Randomized Design (CRD) to evaluate the nutritional profile of rice flour substituted with moringa (*Moringa oleifera*) leaf flour as an intermediate product for functional food development. The utilization of broken rice as a by-product of rice processing and the substitution of moringa leaf flour are expected to enhance the protein and micronutrient content of rice flour. This study aimed to evaluate the nutritional profile of rice flour substituted with moringa (*Moringa oleifera*) leaf flour as an intermediate product for functional food development. Substitution was conducted at moringa leaf flour concentrations of 0%, 5%, 15%, and 25% based on the total flour weight. Proximate analysis was performed to determine moisture, ash, protein, fat, carbohydrate, and dietary fiber contents. The results showed that increasing the proportion of moringa leaf flour significantly increased moisture, ash, fat, protein, and dietary fiber contents, while carbohydrate content decreased with higher levels of moringa leaf flour substitution. These findings indicate that rice flour substituted with moringa leaf flour has strong potential as a nutrient-enriched intermediate product and may support the development of locally based healthy food products. Further studies are recommended to evaluate the physicochemical, functional, and sensory characteristics of final products derived from this composite flour.

INTRODUCTION

South Sulawesi is the fourth-largest rice-producing region in Indonesia. In addition to being consumed as a staple food, rice is processed into intermediate products, such as rice flour. During the rice milling process, paddy is separated into whole rice as the main product and broken rice, commonly known as *menir*, as a byproduct. Broken rice is generally used as animal feed and is sold at a relatively low price. However, it still has considerable economic potential if further processed into intermediate products, such as rice flour, or used as a raw material for food products (Philips et. al., 2024).

According to Fitriani et al. (2021), the nutritional composition of broken rice is comparable to that of whole rice, containing 8.18% protein and 89.81% carbohydrates. Given this similarity, broken rice can be utilized as a more economical alternative to whole rice flour. However, despite its economic advantages, broken rice flour possesses a significant nutritional

gap, particularly its low protein content (<8%) and a lack of essential dietary fiber and micronutrients, such as Calcium and Iron. These deficiencies are critical to address, as these nutrients are vital for combating stunting and malnutrition in regions like South Sulawesi.

While numerous studies have investigated the fortification of cereal flours with moringa leaves—such as in biscuits (Manggul et al., 2021), bread (Ortiz et al., 2024), and herbal tea (Musa et al., 2022)—there is a significant gap in the literature regarding the synergy between underutilized broken rice and moringa leaf flour as a standardized intermediate composite flour. Most existing research focuses on the final food product rather than the development of a nutrient-dense "ready-to-use" intermediate flour. This study specifically addresses these limitations by using *Moringa oleifera* as a fortificant. The primary goal is protein enhancement and mineral fortification, aiming to transform low-value broken rice into a 'high-protein' or 'high-mineral' intermediate composite flour that meets the criteria for a functional food base.

According to Iwansyah et al. (2022), moringa leaves contain essential amino acids and vital micronutrients (Vitamins A, C, E, and Calcium), making them an ideal candidate to "plug" the nutritional gaps in broken rice flour. By developing this composite flour, this study does not only offer a nutritional solution but also an upcycling strategy for agricultural waste. While this study focuses on the nutritional enrichment (proximate profile) of the composite flour, the resulting high levels of protein and fiber suggest a strong potential for functional food development. Although further functional assays, such as antioxidant activity and glycemic index testing, are required to fully validate its status as a functional ingredient, this research provides the necessary foundational data. This approach aligns with the current trend in healthy food consumption and contributes to the achievement of Sustainable Development Goal (SDG) 3, focusing on healthy lives and well-being. Therefore, this study aims to evaluate the nutritional profile of this specific composite flour as a foundation for future functional food processing.

RESEARCH METHODS

This study was conducted from Januari to Juni 2025. The first stage involved the production of moringa leaf flour and broken rice flour, which was carried out at the Food Product Processing and Development Laboratory, Vocational Campus of Sidrap. The second stage consisted of proximate analysis, which was performed at the Laboratory of Analytical Chemistry and Food Quality Control, Department of Food Science and Technology, Hasanuddin University, Indonesia. Broken rice was obtained from the PB CV. Menara, Soppeng Regency, while moringa leaves were sourced from a karst area in Maros Regency, South Sulawesi, Indonesia.

Preparation of Moringa Leaf Flour (Modified from Paramita *et al.*, 2021)

The moringa leaves used in this study were young, light green leaves that had been separated from their stalks. The leaves were dried at 40 °C in a blower oven for 16 h. The dried moringa leaves were ground into flour using a blender.

Preparation of Broken Rice Flour (Modified from Fitriani *et al.*, 2021)

The production of broken rice flour began with soaking the broken rice in water for 2 h, followed by draining. The soaked broken rice was milled using a rice milling machine to obtain flour with a particle size of 60 mesh. The resulting broken rice flour was subsequently dried at 60 °C in an oven for 3 h.

Nutritional Profile Analysis (Proximate Analysis)

The nutritional profile of the composite flour was determined using standar proximate analysis procedures according to the Association of Official Analytical Chemists (AOAC, 2019).

- Moisture content was measured using the thermogravimetric (oven-drying) method.
- Ash content was determined by dry ashing in a muffle furnace at 550°C.
- Protein was analyzed using the Kjeldahl method with a conversion factor of 6.25.
- Fat was extracted using the Soxhlet method with n-hexane as the solvent.
- Total carbohydrate was calculated by difference:
$$100\% - (\% \text{moisture} + \% \text{ash} + \% \text{protein} + \% \text{fat}).$$
- Dietary fiber was determined using the enzymatic-gravimetric method.

Experimental Design and Data Analysis

This study employed a Completely Randomized Design (CRD) consisting of five treatments with three replicates. The treatments were formulated based on different ratios of broken rice flour (BRF), moringa leaf flour (MLF), and whole rice flour (WRF) as follows:

T1: 100% BRF

T2: 95% BRF + 5% MLF

T3: 85% BRF + 15% MLF

T4: 75% BRF + 25% MLF

T5: 100% WRF

The observed parameters included moisture, ash, protein, fat, carbohydrate, and dietary fiber content. The collected data were analyzed statistically using One-Way Analysis of Variance (ANOVA) to determine the effects of the treatments. Significant differences between treatment means were further evaluated using Duncan's Multiple Range Test (DMRT) at a significance level of $\alpha=0.05$ ($p<0.05$). All statistical computations were performed using IBM SPSS Statistics version 25.0 software.

RESULTS AND DISCUSSION

Moisture Content of Nutrient-Enriched Rice Flour

Moisture content is a primary quality parameter that determines the microbiological stability, shelf life, flowability, and flour behavior during processing (e.g., lump formation and rehydration). Therefore, measuring the moisture content at each substitution level is essential to evaluate whether the formulation meets quality standards (SNI) and to support the design of appropriate packaging and storage conditions (Jariyah & Vestra, 2023). The moisture content of the nutrient-enriched rice flour is shown in Figure 1.

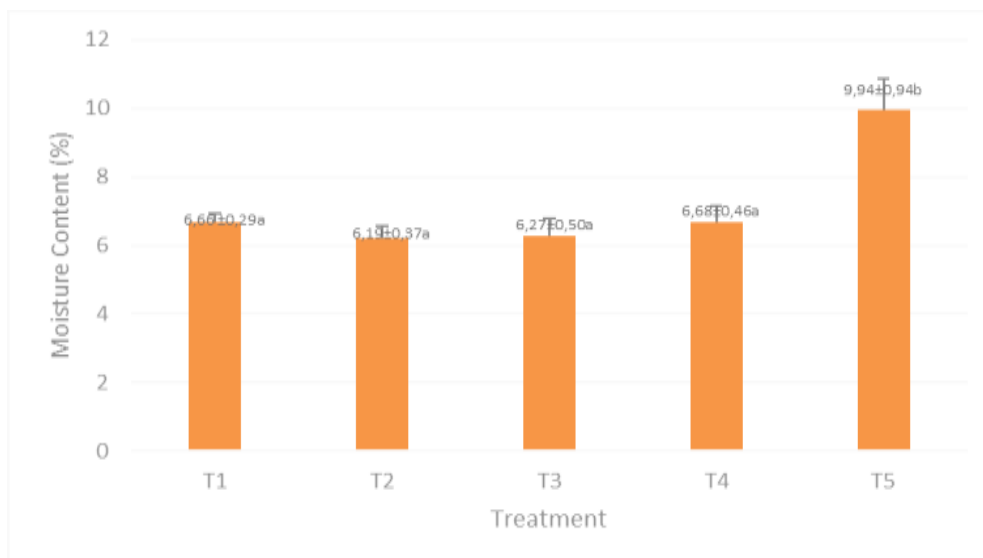


Figure 1. Average moisture content of rice flour with moringa leaf flour at different substitution levels (T1–T5).

The moisture content of rice flour samples subjected to five treatments (T1–T5) was evaluated using the oven-drying method at 105 ± 2 °C. The average moisture content obtained from triplicate measurements for each treatment is presented in Figure 1. The type of rice flour and the level of moringa leaf flour substitution significantly affected the moisture content. The highest moisture content was observed in T5 (100% whole rice flour), reaching 9.94%, whereas the lowest value was recorded in T2 (95% broken rice flour + 5% moringa leaf flour) at 6.19%. The remaining treatments exhibited moisture content ranging from 6.27% to 6.68%. These differences can be attributed to variations in the flour composition and structure. Whole rice flour retains the aleurone layer, bran, and germ, which are rich in lipids and dietary fiber with a high water-holding capacity, resulting in a higher moisture content. In contrast, broken rice flour loses part of these layers during milling, leading to lower moisture retention values (Genevois *et al.*, 2020). All treatments (T1–T5) complied with the Indonesian National Standard for rice flour (SNI 3549:2009), which stipulates a maximum moisture content of 13%. This indicates that the produced flour meets the quality requirements for commercial distribution.

The addition of 5% moringa leaf flour reduced the moisture content, as the fine fibers of moringa leaves rapidly absorb and release water during the drying process (Adeoti & Hawumba, 2020). However, higher substitution levels (15–25%) resulted in increased moisture content due to the presence of insoluble fiber and protein, which promoted water retention within the flour matrix (Dossa *et al.*, 2024). The relatively low moisture content observed in treatments T1–T4 (approximately 6%) suggests a potential for good storage stability, as moisture levels below 10% are generally associated with reduced microbial activity (Hapsari *et al.*, 2023). While water activity (a_w) was not directly measured, the low moisture content achieved in this study is a positive indicator for extending shelf life and enhancing the potential of broken rice–moringa leaf flour blends as intermediate products.

Ash Content of nutrient-enriched rice flour

Ash content reflects the total inorganic mineral content of a sample; therefore, substitution with moringa leaf flour, which is rich in minerals, commonly leads to an increase in ash content. An increase in ash content serves as an indicator that the substitution provides natural mineral fortification (e.g., Ca, Fe, and Mg), thereby enhancing the nutritional value of the nutrient-enriched rice flour. From a physicochemical perspective, however, increased

mineral content may also influence product characteristics, such as color (darker appearance), taste, and processing behavior, including gelatinization properties (Zaddana *et al.*, 2022). The ash content of the nutrient-enriched rice flour is shown in Figure 2.

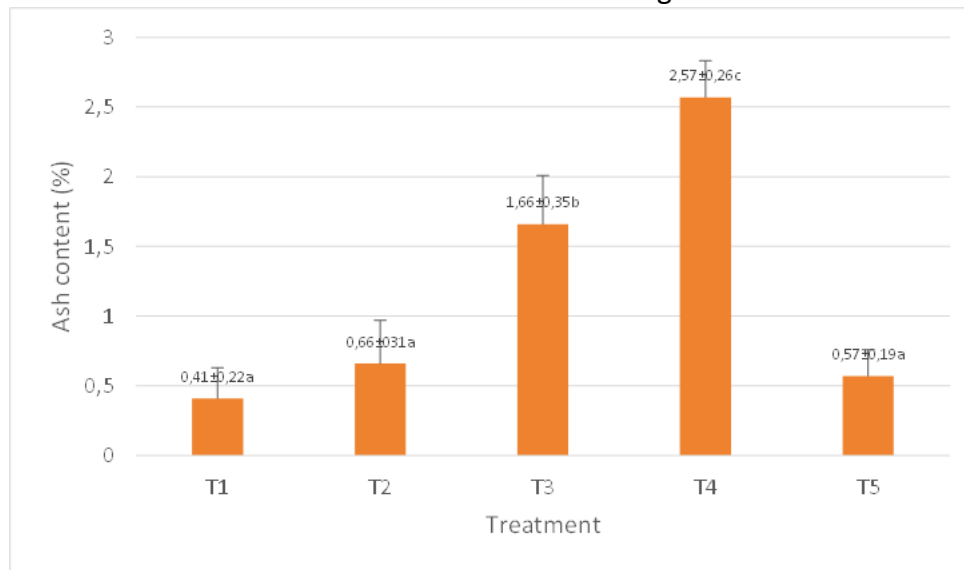


Figure 2. Average ash content of rice flour with moringa leaf flour at different substitution levels (T1-T5). Ash content was determined by incineration in a muffle furnace at 550°C until constant weight

Increasing levels of moringa leaf flour substitution significantly affected the ash content of the nutrient-enriched rice flour. The lowest ash content was observed in treatment T1 (100% broken rice flour), with a value of 0.41%, whereas the highest ash content was recorded in T4 (75% broken rice flour + 25% moringa leaf flour) at 2.57%. The progressive increase in ash content with higher moringa leaf flour substitution levels of MLF can be attributed to the high mineral content of moringa leaves, particularly calcium, potassium, magnesium, and iron (Masitlha *et al.*, 2024; Ntshambiwa *et al.*, 2023).

According to Sibanda *et al.* (2024), moringa leaves are characterized by a relatively high ash content of approximately 6–8%, reflecting substantial concentrations of macro- and micronutrients. Consequently, increasing the proportion of moringa leaf flour in the nutrient-enriched rice flour formulation directly elevated the total mineral content, which was positively correlated with the observed increase in ash content. The elevated ash content indicates that the incorporation of moringa leaf flour enhances the nutritional quality of rice flour by enriching it with essential minerals beneficial to human health, such as iron for red blood cell formation (erythropoiesis) in the bone marrow, calcium for bone health, and magnesium for enzymatic activity (Masitlha *et al.*, 2024; Sibanda *et al.*, 2024).

Protein Content of Nutrient-Enriched Rice Flour

One of the primary objectives of substituting rice flour with moringa leaf flour is to enhance the protein content. Protein analysis results demonstrated a consistent increase in protein content with increasing proportions of moringa leaf flour. The highest protein content was observed in treatment T4 (25% substitution) at 9.73%, while the lowest was in T5 (100% whole rice flour) at 3.55% (Figure 3). This substantial increase is attributed to the high protein density of Moringa leaves, which ranges from 25% to 30% on a dry-weight basis (Masitlha *et al.*, 2024).

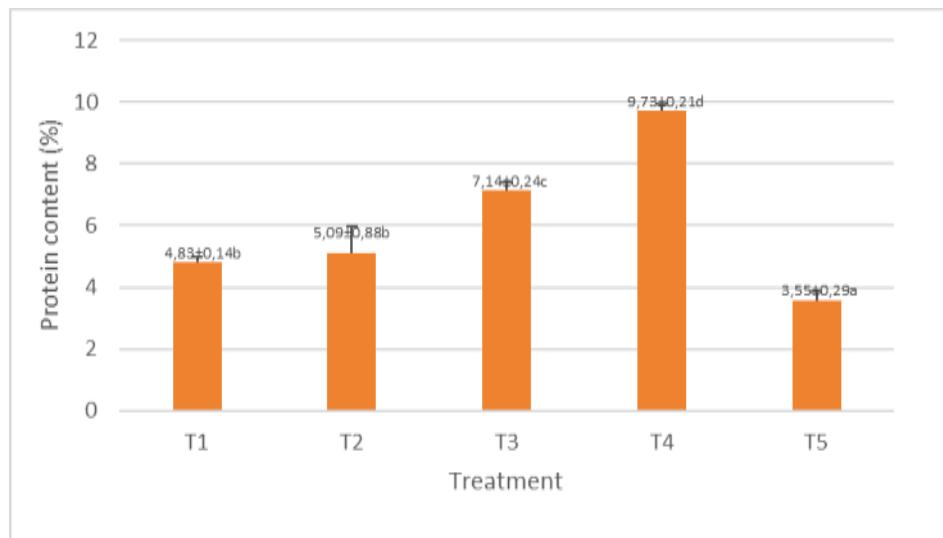


Figure 3. Average protein content of rice flour with moringa leaf flour at different substitution levels (T1–T5). Protein was analyzed using the Kjeldahl method, with total nitrogen converted to protein using a conversion factor of 6.25.

Beyond the quantitative increase, the incorporation of moringa leaf flour creates a significant nutritional synergy through a complementary amino acid profile. Rice protein is typically deficient in lysine, an essential amino acid, but relatively rich in sulfur-containing amino acids like methionine and cysteine. Conversely, *Moringa oleifera* leaves are exceptionally high in lysine, leucine, and valine (Agba et al., 2024; Peñalver et al., 2022). By blending these two sources, the amino acid gaps in rice flour are bridged, resulting in a more balanced protein quality with a higher biological value than either component alone. This synergy enhances the overall protein quality score (Chemical Score) of the final blend, making it a more complete nutritional source for human consumption.

Furthermore, the increased protein content—particularly the globulin and albumin fractions found in *Moringa*—contributes positively to the functional properties of the flour. These proteins enhance emulsifying and water absorption capacities (Fatima et al., 2023). However, it is noted that at high concentrations, this enrichment may influence the flour matrix's viscosity and sensory acceptance, specifically regarding color and 'beany' aftertaste (Pratiwi et al., 2024)

Fat Content of Nutrient-Enriched Rice Flour

Pure rice flour is generally low in fat, whereas moringa leaf flour contains a relatively higher fat content; therefore, substituting moringa leaf flour may increase the fat content in nutrient-enriched rice flour formulations. An increase in fat content influences the energy value, texture (e.g., chewiness in final products), oxidative stability, and emulsifying properties of food dough systems. Consequently, fat analysis is particularly recommended for formulations with high substitution levels to ensure an acceptable shelf life and sensory quality (Yunita et al., 2022). The fat content of the nutrient-enriched rice flour is shown in Figure 4.

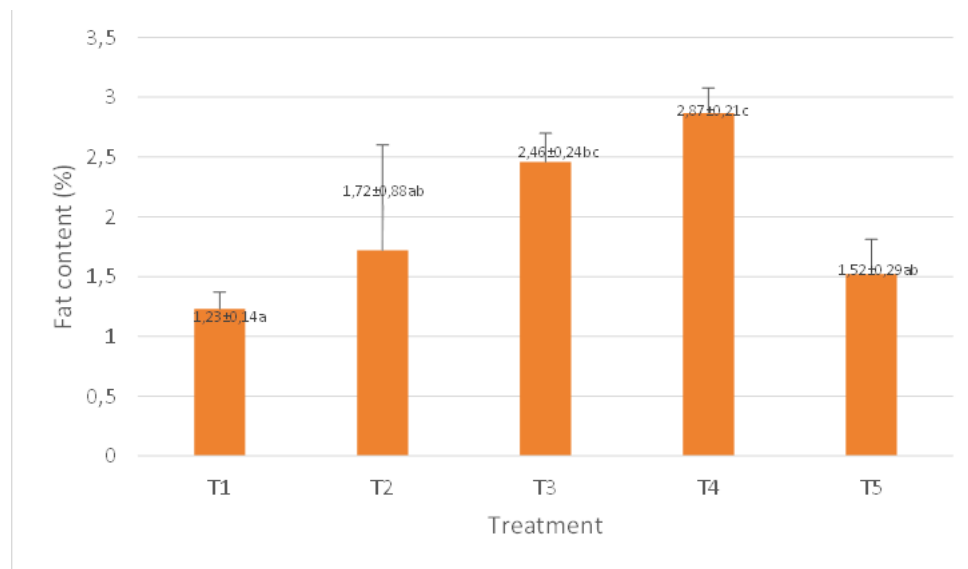


Figure 4. Average fat content of rice flour with moringa leaf flour at different substitution levels (T1-T5). Fat was determined using the soxhlet extraction method with a suitable organic solvent.

The fat content of nutrient-enriched rice flour (Figure 4) varied depending on the base flour type and moringa leaf flour substitution level. The addition of moringa leaf flour tended to increase the total fat content, as moringa leaves contain natural lipids ranging from 2% to 7%, primarily composed of unsaturated fatty acids such as oleic, linoleic, and palmitic acids (Sibanda et al., 2024; Pareek et al., 2023; Fejer et al., 2019).

The increased fat content in these formulations may contribute positively to the flavor and softness of the final products. However, the presence of unsaturated fatty acids from moringa leaves presents a potential challenge for long-term storage. While this study did not directly measure oxidative stability indicators, such as Peroxide Value (PV) or p-Anisidine Value, it is important to note that higher fat levels—especially those rich in unsaturated fractions—could potentially accelerate lipid oxidation if not stored under optimal conditions. High fat content in flour-based materials may promote rancidity due to lipase activity and oxygen exposure (Riaz & Wahab, 2021).

Therefore, while formulations with up to 25% substitution enhance the nutritional profile, further research focusing on oxidative stability and peroxide value during storage is necessary to determine the exact shelf life. Maintaining moderate substitution levels and utilizing opaque, airtight packaging are recommended strategies to mitigate potential oxidative degradation in these nutrient-enriched flours (Getachew & Admassu, 2022).

Carbohydrate Content of Nutrient-Enriched Rice Flour

Carbohydrates are the main component of rice flour, consisting primarily of starch in the form of amylose and amylopectin, along with small amounts of simple sugars and soluble and insoluble dietary fiber. In broken rice flour, the carbohydrate content typically accounts for more than 75–80% of the dry weight. Substituting wheat flour with Moringa leaf flour, which is richer in protein, minerals, and fiber, partially replaces starch with protein, fat, fiber, and minerals derived from Moringa leaves. Consequently, this substitution directly reduces the total carbohydrate content of nutritionally enriched flour blends. Therefore, any change in raw material composition has a substantial impact on the energy content and functional properties

of the flour (Jariyah & Vestra, 2023). The carbohydrate content of nutrient-enriched rice flour is presented in Figure 5.

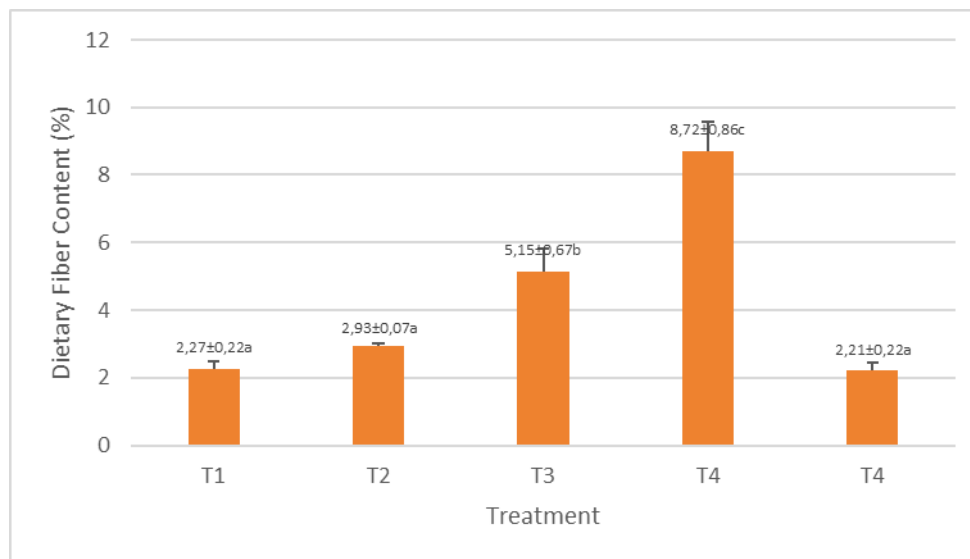


Figure 5. Average carbohydrate content of rice flour with moringa leaf flour at different substitution levels (T1–T5). Carbohydrate levels were calculated by difference, subtracting moisture, ash, protein, and fat contents from the total sample weight.

The results showed that the carbohydrate content in nutrient-enriched rice flour decreased progressively with increasing levels of moringa leaf flour substitution. Treatment T1 (100% broken rice flour) exhibited the highest carbohydrate content (86.86%), whereas treatment T4 (75% broken rice flour + 25% moringa leaf flour) showed a reduced carbohydrate content (78.15%). This decline was attributed to the replacement of the carbohydrate-rich rice flour matrix with Moringa leaf flour, which contains relatively lower carbohydrate levels and higher amounts of protein, fat, minerals, and dietary fiber. Peñalver et al. (2022) reported that moringa leaf flour has a lower carbohydrate content than cereal flours because a substantial portion of its carbohydrates consists of dietary fiber that is not converted into simple sugars.

From a functional perspective, the reduction in carbohydrate content is advantageous, as rice flour substituted with Moringa leaf flour may serve as a lower-carbohydrate alternative suitable for functional food formulations or for consumers seeking reduced carbohydrate intake compared to conventional rice flour (Agba et al., 2024).

Dietary Fiber Content of Nutrient-Enriched Rice Flour

The results of dietary fiber analysis showed that the addition of moringa leaf flour had MLF significantly increased the fiber content of the composite flour. The 100 percent broken rice flour exhibited the lowest fiber content (2.07%), which was even lower than that of the whole rice flour (3.89%). This finding is expected, as broken rice consists of rice fragments that have typically undergone extensive milling, resulting in the removal of most of the aleurone layer, bran, and fiber-rich components. However, with increasing levels of moringa leaf flour substitution, the dietary fiber content increased markedly. The fiber content of the blend containing 95% broken rice flour and 5% moringa leaf flour was 2.93%, which increased to 5.15% at 85% broken rice flour and 15% moringa leaf flour, and reached 8.72% at 75% broken rice flour and 25% moringa leaf flour. This substantial increase in fiber content indicates that Moringa leaves are a rich source of dietary fiber and can effectively enrich the nutritional composition of cereal-based flours.

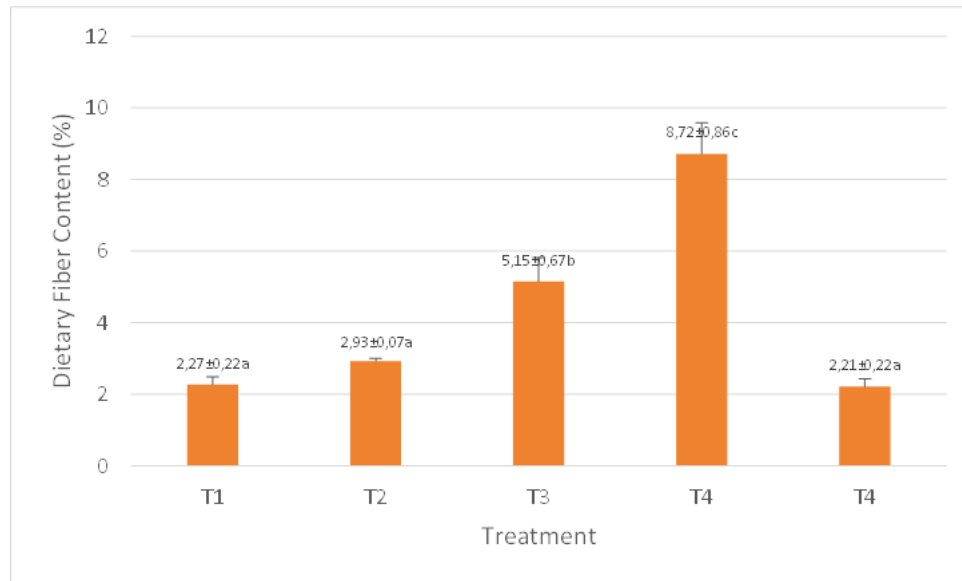


Figure 6. Average dietary fiber content of rice flour with moringa leaf flour at different substitution levels (T1-T5). Fiver content was determined using an enzymatic-gravimetric method.

The observed increase in dietary fiber content is consistent with the high fiber content of Moringa leaves, which contain both soluble and insoluble dietary fibers. A high dietary fiber intake is associated with significant health benefits, including improved digestive function, regulation of blood glucose levels, and reduced risk of degenerative diseases, such as diabetes and cardiovascular disorders. Therefore, fortification of broken rice flour with moringa leaf flour not only enhances the mineral content, as reflected by increased ash values, but also improves the functional value of the product through its high dietary fiber content.

Compared to whole rice flour, which contains 3.89% dietary fiber, the broken rice–Moringa leaf flour blends with $\geq 15\%$ Moringa leaf flour clearly exceeded the natural fiber content of rice. The increase in dietary fiber content observed in the enriched rice flour blends is consistent with previous findings that substitution with Moringa leaf flour significantly elevates fiber levels in cereal-based products (Wahyuningsih et al., 2023; Amin et al., 2025). The high intrinsic fiber content of Moringa leaf flour, as reported by Yunita et al. (2022), supports its role as a potent source of dietary fiber in functional food formulations. This finding demonstrates that the composite flour formulation has strong potential as an alternative raw material for healthier food products with higher nutritional value than conventional whole rice flour. The increase in dietary fiber resulting from Moringa oleifera leaf flour (MLF) substitution contributes to both nutrient enrichment and functional modifications within the rice flour matrix. Dietary fibers—particularly viscous soluble fibers—influence carbohydrate digestion by increasing chyme viscosity, thereby delaying gastric emptying and slowing glucose absorption, which leads to a moderated glycemic response (Giuntini et al., 2022). Furthermore, moringa leaves exhibit anti-hyperglycemic effects mediated by the inhibition of carbohydrate digesting enzymes and fiber glucose interactions, supporting their potential as functional ingredients for metabolic health (Azad et al., 2017). This mechanistic evidence suggests that incorporating MLF into broken rice flour not only elevates dietary fiber content but also confers benefits related to glycemic regulation, enhancing the flour’s functional quality without compromising its utility as a staple food ingredient.

CONCLUSION

The increasing proportion of Moringa leaf flour significantly enhanced the moisture, ash, fat, and protein content of the rice flour formulation. The rise in protein and fat levels indicates that Moringa leaf flour substantially contributes to the nutritional value of the final product. Conversely, the reduction in carbohydrate content corresponds to the increased proportions of protein and fat, reflecting a fundamental shift in the overall nutrient composition. These findings demonstrate that rice flour substituted with Moringa leaf flour has strong potential as a nutrient-rich intermediate product and may support the development of locally based functional food products.

However, this study is subject to several limitations. The current evaluation was focused primarily on proximate analysis; therefore, a formal bioactivity evaluation and mineral profiling were not conducted. Furthermore, the functional properties of the flour essential for determining its behavior during food processing remain to be investigated. Future research addressing these parameters will provide a more comprehensive understanding of the material's potential applications in the food industry.

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DECLARATIONS

Author Contributions

S.H.D formulated the core research concept, designed the study framework, and provided overarching supervision. I and A. R. P orchestrated the experimental workflow and resource management. A. S. A and N.A. H executed the primary data collection and conducted the experimental trials. Analytical interpretation, manuscript drafting, and critical intellectual revisions were performed collaboratively by all authors. The final manuscript has been reviewed and approved by all contributors.

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Ethical Statement

As this study was conducted in an *in vitro* setting and did not involve human participants or animal subjects, formal ethical approval from an Institutional Review Board was not required. All experimental procedures were performed in strict accordance with the standard laboratory safety protocols and institutional biosafety guidelines. The researchers ensured the integrity of

the data and the responsible management of all biological and chemical materials used throughout the study.

Declaration of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The funding body (LPPM Unhas) had no role in the study design, data collection, analysis, interpretation of data, or the writing of the manuscript.

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