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Nutrification of Moringa Leaf Flour (Moringa oleifera) in Wet Noodle Production and Its Effect on Macronutrient Content

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Abstract

In this study, we analyzed the effects of different concentrations of Moringa oleifera leaf flour on the carbohydrate, protein, and fat content of wet noodles. We conducted an experimental study using a Completely Randomized Design (CRD) and analyzed the data through ANOVA and LSD tests using SPSS 21 software. The results showed that fortifying wet noodles with Moringa leaf flour significantly altered their macronutrient composition. The carbohydrate content decreased from 28.286% in treatment 2 to 27.350% in treatment 3 and 25.677% in treatment 4. In contrast, the protein content increased from 5.289% in treatment 2 to 5.905% in treatment 3 and 6.345% in treatment 4. Similarly, the fat content rose from 0.439% in treatment 2 to 0.554% in treatment 3 and 0.645% in treatment 4. These findings suggest that increasing concentrations of Moringa leaf flour can improve the nutritional profile of wet noodles, particularly by enhancing their protein and fat content while reducing carbohydrate levels.

Keywords: Functional food; Macronutrient content; Nutrification; Wet noodles

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INTRODUCTION

Noodles are among the most widely consumed staple foods across the globe, particularly in Asia, due to their low cost, versatility in culinary applications, long shelf-life (in dried forms), and ease of preparation (Visalakshmi et al., 2022). In countries such as China, Indonesia, Japan, and Vietnam, wet noodles a type of fresh, non-dried noodle made from wheat or rice flour form a significant part of the daily diet and are often consumed in various traditional dishes including soups, stir-fries, and salads (Abujazar et al., 2022; Benalia et al., 2023). These noodles serve as a major source of caloric intake, primarily due to their high carbohydrate content derived from refined flour. However, conventional wet noodles tend to be nutritionally limited, as they are predominantly composed of starch and lack adequate levels of other essential macronutrients, particularly proteins and lipids. For example, 100 grams of standard wet noodles typically contain over 20–30 grams of carbohydrates but provide only minimal amounts of protein (5–6 grams) and negligible fat content (<1 gram) (Alhassan et al., 2022). This nutrient imbalance becomes a critical concern in communities where noodles constitute a substantial portion of the diet and where access to protein-rich foods such as meat, dairy, or legumes is economically or geographically constrained (Anoop et al., 2023). Long-term dependence on such carbohydrate-dominant foods without adequate macronutrient diversity may contribute to protein-energy malnutrition, reduced immune function, and other diet-related health issues.

To address the nutritional limitations of conventional carbohydrate-rich foods like wet noodles, food scientists and nutritionists have increasingly turned their attention to the development of functional food products those designed not only to satisfy basic dietary needs but also to deliver health-promoting benefits. One promising approach involves the incorporation of plant-based ingredients that are naturally rich in essential nutrients and bioactive compounds. Among these, *Moringa oleifera* commonly known as the "miracle tree" has gained significant attention due to its impressive nutritional profile and adaptability across various food systems (Kaur et al., 2023). *Moringa oleifera* leaves are particularly notable for their high-quality plant protein, which includes a complete set of essential amino acids, a feature uncommon in many plant sources. Additionally, Moringa leaves are rich in micronutrients, including fat-soluble vitamins such as vitamin A (β-carotene), water-soluble vitamins like vitamin C and B-complex, and important minerals such as calcium, potassium, magnesium, and iron (Kong et al., 2022; Kaur et al., 2023). Furthermore, Moringa exhibits antioxidant, anti-inflammatory, and antimicrobial properties, making it highly suitable for use in health-oriented food formulations. A growing body of research has confirmed the applicability of Moringa leaf flour as a functional ingredient in various food products. Studies have demonstrated improvements in the protein, mineral, and antioxidant content of bakery items (e.g., bread, muffins), cereal-based snacks, and dry pasta when fortified with Moringa powder (Manu et al., 2022; Paul et al., 2024). However, a critical review of this literature reveals that the majority of these applications focus on dry, baked, or extruded products, which have relatively low moisture content and longer shelf life. In contrast, wet noodles characterized by their high moisture content, softer texture, and shorter shelf stability present distinct formulation challenges. These include potential interactions between added plant materials and the starch-gluten matrix, changes in textural properties, cooking loss, and consumer acceptability. Despite the cultural and economic significance of wet noodles in many parts of the world, especially in Southeast Asia, scientific investigations into the incorporation of Moringa leaf flour into wet noodle formulations remain limited (Shahzad et al., 2022).

To bridge this gap, the present study evaluates the quantitative gradient effect of Moringa oleifera leaf flour supplementation on the macronutrient composition of wet noodles, specifically carbohydrates, proteins, and fats. Previous studies have primarily focused on the use of Moringa oleifera as a nutritional enhancer in various food products such as bread, biscuits, and instant noodles (Sudha et al., 2014; Leone et al., 2015; Gopalakrishnan et al., 2016; Shi et al., 2021). However, most of these studies employed a limited range of concentrations or single-dose supplementation, and often lacked a comprehensive, concentration-dependent analysis of its impact on macronutrient profiles (Abdullah et al., 2021; Mugode et al., 2014). Moreover, investigations into its application in wet noodles remain limited, despite the product's popularity in many Asian and African countries and its potential as a carrier for dietary improvements (Nuraini et al., 2020). The novelty of this research lies in its detailed, concentration-dependent analysis of Moringa influence, providing granular data on how varying supplementation levels affect the nutritional quality of wet noodles. By addressing the limitations in previous work such as narrow concentration ranges, insufficient macronutrient breakdown, and lack of focus on wet noodle formulations this study contributes actionable data for improving staple food formulations. This research not only informs functional food development, but also supports broader goals in food security and nutrition policy, particularly in low- and middle-income regions where cost-effective strategies for dietary improvement are critically needed (WHO, 2021; FAO, 2022).

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We hypothesize that increasing the concentration of Moringa leaf flour in wet noodle formulations will lead to a proportional decrease in carbohydrate content, while enhancing protein and fat levels. This hypothesis is grounded in Moringa's known nutritional profile and reflects a growing need for alternative food systems that promote macronutrient diversity and health resilience, particularly among populations at risk of protein energy malnutrition. Accordingly, this study aims to analyze how different concentrations of Moringa leaf flour affect the macronutrient composition carbohydrates, proteins, and fats of wet noodles, and to offer insights into its practical application in food product development.

METHOD

This research was conducted using an experimental approach with a Completely Randomized Design (CRD) to assess the effect of Moringa leaf flour (*Moringa oleifera*) nutrification on the macronutrient content of wet noodles (Shi et al., 2021). The research was carried out at the Biology Laboratory, Tadulako University over a period of three months, from June to September 2024.

The population of this study consisted of all formulations of wet noodles enriched with varying concentrations of Moringa leaf flour. The sample used in this research comprised four groups of noodle formulations: one control group without Moringa flour addition and three treatment groups with different concentrations of Moringa leaf flour (specifically, 2%, 3%, and 4% based on the total flour weight) (Shweta et al., 2023). Samples were prepared by first producing wet noodles following a standardized noodle-making process. The ingredients included wheat flour, Moringa leaf flour, salt, water, and eggs. The wheat flour used was commercial all-purpose flour, while Moringa leaf flour was obtained by drying fresh Moringa leaves at 45–50°C and grinding them into a fine powder using a mechanical grinder. The noodle dough was mixed, sheeted, and cut into strands using a noodle machine. All equipment used, including mixers, noodle sheeters, and drying ovens, was standardized and calibrated prior to use to ensure consistent results (Singh et al., 2020; Tian et al., 2021).

Sampling was conducted systematically, ensuring homogeneity in sample preparation. Each noodle sample was stored under controlled conditions until analysis. Instrumentation development involved standard proximate analysis methods to measure macronutrient contents. Carbohydrate content was determined by difference method, protein content was measured using the Kjeldahl method, and fat content was determined using Soxhlet extraction with petroleum ether as the solvent. All analyses were performed following the protocols of the Association of Official Analytical Chemists (AOAC).

Data analysis was performed using the Analysis of Variance (ANOVA) to identify significant differences among the treatment groups, followed by the Least Significant

Difference (LSD) test to pinpoint specific group differences. All statistical analyses were conducted using SPSS version 21. A significance level of $p < 0.05$ was applied in all tests.

RESULTS AND DISCUSSION

The results of this study showed that the nutrification of Moringa leaf flour (*Moringa oleifera*) significantly affected the macronutrient content of wet noodles. The addition of Moringa leaf flour resulted in a consistent decrease in carbohydrate content and an increase in protein and fat contents across the different treatment levels (Figure 1).

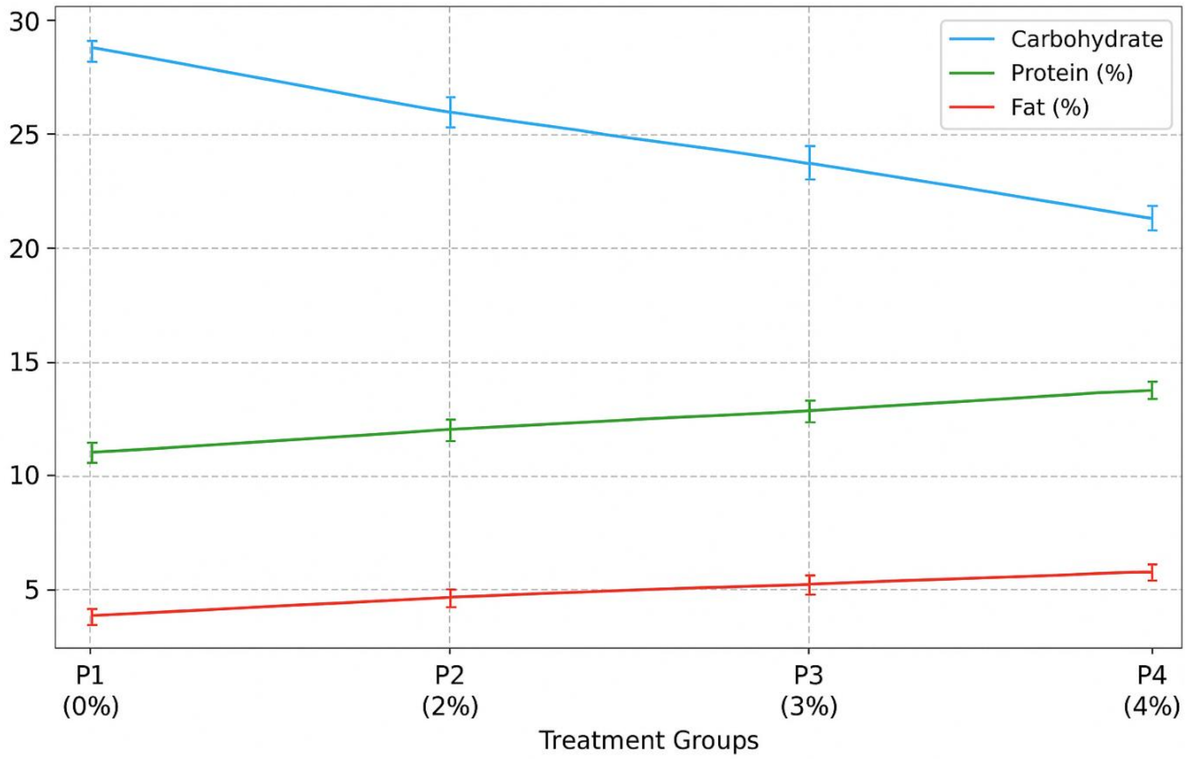

Figure 1. Comparison of macronutrient content (carbohydrates, proteins, and fats) in wet noodles fortified with Moringa leaf flour

Carbohydrate Content

The carbohydrate content of the wet noodles decreased progressively with higher concentrations of Moringa leaf flour. The control group (P1) had the highest carbohydrate content, whereas the P4 treatment (4% Moringa flour) showed the lowest value at 25.677%. This trend can be scientifically explained by the compositional characteristics of Moringa leaf flour, which contains a lower proportion of carbohydrates compared to wheat flour. Substituting wheat flour with Moringa flour consequently reduced the overall carbohydrate concentration. This finding is consistent with the results of Shi et al. (2014), who emphasized that *Moringa oleifera* leaves contain relatively high amounts of proteins (27.1 g/100 g dry weight), essential vitamins such as vitamin A, C, and E, and minerals including calcium, potassium, and iron, while being low in carbohydrates compared to cereal flours. As such, the substitution of wheat flour which typically contains approximately 70–75% starch (carbohydrates) with Moringa leaf flour in wet noodle formulations naturally leads to a dilution of the total carbohydrate content, while simultaneously enhancing the nutritional density in terms of proteins, fibers, and micronutrients.

In this study, the effect of increasing concentrations of Moringa leaf flour on the proximate composition of wet noodles was quantitatively evident. Specifically, a consistent decline in carbohydrate content was observed across treatments: from 28.286% in treatment P2 (lower substitution level) to 25.677% in treatment P4 (higher substitution level). This trend clearly reflects the compositional contrast between the two flours. As reported by Kaur et al. (2023), wheat flour is dominated by starch granules, whereas Moringa leaf flour is rich in dietary fiber and has a lower total carbohydrate content, typically around 20–25% depending on leaf maturity and processing methods. Therefore, replacing part of the wheat flour with Moringa leaf flour reduces the overall starch load, which directly contributes to the decrease in measurable carbohydrate levels in the final product.

Moreover, Moringa leaves are known to be an excellent source of both soluble and insoluble dietary fibers, which not only contribute to total fiber content but also influence starch behavior during cooking. Anoop et al. (2023) noted that fiber can form a matrix that interferes with starch gelatinization, reducing enzymatic hydrolysis during digestion. This suggests that the actual glycemic impact of such noodles may also be reduced, making them potentially beneficial for individuals with type 2 diabetes or metabolic syndrome, who require low glycemic index foods. Additionally, Helmi et al. (2020) found that food formulations enriched with Moringa leaf flour showed a notable reduction in carbohydrate content along with improved fiber levels and enhanced functional properties, such as satiety and gut health support. Taken together, the reduction in carbohydrate content observed in this study not only supports previous findings but also illustrates the mechanistic basis behind it primarily the substitution of starch-dense flour with a high-fiber, low-carb ingredient. This highlights the potential of Moringa leaf flour as a nutritional modifier in carbohydrate-rich foods such as noodles, aligning with current trends in developing functional foods tailored for health-conscious consumers.

Protein Content

A progressive increase in protein content was clearly observed with the incremental addition of *Moringa oleifera* leaf flour in the wet noodle formulations. The protein content increased from 5.289% in treatment P2 (lower substitution level) to 6.345% in treatment P4 (higher substitution level). This enhancement in protein levels can be directly linked to the intrinsic nutritional properties of Moringa leaves, which, according to Manu (2022), contain approximately 20–30% crude protein by dry weight, depending on the age of the leaves, harvesting time, and drying methods used. The scientific foundation for this increase lies in the rich amino acid profile and protein composition of Moringa leaves. Unlike many plant-based protein sources that may lack one or more essential amino acids, Moringa leaf protein is considered complete, containing all nine essential amino acids, including lysine, methionine, tryptophan, and threonine. Of particular significance are the sulfur-containing amino acids such as methionine and cysteine, which are typically limiting in cereal-based products like noodles made from wheat flour. The incorporation of Moringa thus complements the amino acid deficiencies in wheat flour, enhancing not only the total protein content but also the biological value of the resulting product (Sudha et al., 2014; Visalakshmi et al., 2022).

Moreover, proteins from Moringa are known for their high digestibility and bioavailability, making them a valuable source of dietary protein, especially in populations where access to animal proteins is limited. The digestibility of Moringa protein has been reported to range between 80–90%, making it suitable for nutritional interventions in vulnerable groups such as children, pregnant women, and the elderly who may be at risk of protein-energy malnutrition (PEM). The inclusion of such a protein-rich component into a widely consumed staple like noodles offers a practical and culturally acceptable strategy for improving dietary protein intake without requiring major dietary changes. These findings are in agreement with those of Shahzad et al. (2022), who documented a significant increase in protein levels in wheat-based food products such as chapatti and biscuits when fortified with Moringa leaf powder. Similarly, Shweta et al. (2023) observed that the protein content of composite flour bread increased by more than 15% upon 10–15% substitution with Moringa flour, underscoring the effectiveness of Moringa as a plant-based fortificant.

In this study, the quantitative relationship between Moringa flour concentration and protein content was linear and positively correlated, reaffirming the ingredient's potential for nutritional enhancement. From a formulation science perspective, this increase does not simply represent a numerical improvement, but rather reflects a strategic fortification process where Moringa flour acts as both a functional and nutritional additive. Furthermore, beyond basic nutritional value, Moringa leaf proteins have been associated with bioactive properties, including antioxidant, antimicrobial, and anti-inflammatory effects (Singh et al., 2021), which could confer additional health benefits to the final noodle product. These functional attributes expand the utility of Moringa beyond its macronutrient profile, positioning it as an ideal ingredient in functional food development.

Fat Content

The fat content of wet noodles exhibited a gradual and consistent increase as higher concentrations of *Moringa oleifera* leaf flour were incorporated into the formulation. Specifically, the fat content rose from 0.439% in treatment P2 to 0.645% in treatment P4. Although these values remain relatively low in absolute terms, the upward trend is scientifically significant and reveals important aspects of the proximate impact of Moringa flour in noodle production. The underlying biochemical explanation for this increase lies in the natural lipid content of Moringa leaves. While not as lipid-rich as Moringa seeds, the leaves contain measurable quantities of beneficial fats, especially polyunsaturated fatty acids (PUFAs) such as alpha-linolenic acid (omega-3) and linoleic acid (omega-6) (Abujazar et al., 2022; Paul et al., 2024). These fatty acids are incorporated into the leaf tissue as essential components of cell membranes (phospholipids) and act as energy reserves. When Moringa leaf powder is introduced into a food matrix like noodles, these naturally occurring fats are carried along and contribute to the overall fat content of the final product.

Although the fat levels contributed by Moringa are small compared to high-fat ingredients like oils or seeds, their presence is nutritionally meaningful. Omega-3 and omega-6 fatty acids are classified as essential fats, meaning they cannot be synthesized by the human body and must be obtained from the diet. These compounds have been extensively studied for their roles in cardiovascular protection, neurological development, and anti-inflammatory pathways (Benettayeb et al., 2022). Therefore, even a modest increase in unsaturated fats through functional fortification with Moringa offers added health value beyond caloric contribution. From a food science perspective, this modest fat increase represents a positive shift in nutritional quality. The fat content of traditional wheat-based noodles is typically low, and any improvement in lipid profile especially through the addition of healthy fats can enhance the functional food status of the product. Unlike saturated fats, which are associated with increased cardiovascular risks, the fats in Moringa leaves are predominantly unsaturated and health-promoting. Moreover, the fatty acid profile of Moringa is considered favorable, as it supports the recommended dietary ratio between omega-6 and omega-3 fatty acids.

Manu et al. (2022) and Shahzad et al. (2022) have also demonstrated that food products fortified with Moringa leaf powder consistently show slight but measurable increases in fat content, reinforcing that the observed trend is reproducible and expected, rather than a statistical anomaly. These findings validate the compositional integrity of Moringa as a plant-based enhancer with predictable effects on multiple macronutrient parameters. Furthermore, the total fat content in Moringa-fortified noodles, even at its highest level (0.645%), remains well within the range for low-fat food products, making the product suitable for health-conscious consumers, those on calorie-controlled diets, or individuals aiming to reduce saturated fat intake. This dual advantage introduction of healthy fats while maintaining low total fat content strengthens the case for Moringa as a strategic ingredient in functional and therapeutic food design.

Scientific Synthesis

The observed variations in the macronutrient composition namely, the reduction in carbohydrate content and the incremental increases in protein and fat levels clearly demonstrate the efficacy of *Moringa oleifera* leaf flour as a nutrifying agent in wet noodle formulations. These changes are not only quantitatively evident but also biologically plausible, considering the proximate and biochemical composition of Moringa leaves. Specifically, the substitution of starch-dense wheat flour with fiber and protein rich Moringa flour induced a multidirectional shift in macronutrient balance, leading to the creation of a more functionally enriched food product.

This pattern of nutritional modification aligns well with the original research hypothesis, which postulated that the addition of Moringa leaf flour would significantly alter and improve the macronutrient profile of wet noodles. The data support this hypothesis across all tested concentrations, with the 4% substitution level (P4) yielding the most pronounced increase in protein (from 5.289% to 6.345%) and fat (from 0.439% to 0.645%) contents, while also reflecting the greatest decrease in carbohydrates (from 28.286% to 25.677%). This trade-off illustrates a strategic reformulation of the noodle matrix, where nutritional enhancement is achieved without the use of synthetic additives, but rather through the inclusion of a natural, plant-based ingredient with well-documented health benefits.

Comparatively, these findings are in line with previous research efforts that have explored the fortification of staple foods using functional plant-derived ingredients. Ariyanto et al. (2023), for example, reported that the integration of legume and leafy vegetable flours into cereal-based products resulted in improved protein and micronutrient content, with a concurrent and manageable reduction in carbohydrate levels. Such results confirm that functional fortification through whole-plant materials like Moringa is a viable and effective strategy for enhancing the nutritional density of commonly consumed foods, particularly in regions prone to macronutrient and micronutrient deficiencies.

In the broader context of food science and nutrition, the scientific novelty of the current study lies in its focused application of Moringa leaf flour to wet noodle formulations, an area that remains underexplored in comparison to dry products such as breads, biscuits, or snacks. Unlike baked goods, wet noodles pose unique formulation and processing challenges, including hydration capacity, structural integrity, and textural properties. The fact that nutritional enrichment was achieved without compromising the basic form and consistency of the wet noodles adds substantial practical value to this research.

Moreover, the multi-nutrient enhancement observed specifically, the simultaneous increase in high-quality plant protein, the presence of unsaturated essential fatty acids, and a lower glycemic carbohydrate profile positions Moringa-fortified noodles as a functional food prototype. Such products are particularly relevant in current public health contexts, where there is increasing demand for health-oriented, plant-based, and nutritionally balanced staple foods. The integration of Moringa leaf flour into noodles not only contributes to satiety and metabolic health but also provides a platform for combatting protein-energy malnutrition (PEM) and micronutrient deficiencies, especially in low-income and food-insecure regions.

Furthermore, the study's findings contribute granular data regarding how specific substitution levels of Moringa flour quantitatively impact the proximate composition of noodles. These data can be used to guide precision formulation in future product development, depending on target nutritional goals (e.g., high-protein, low-carb, or fiber-enhanced variants). This level of specificity is often lacking in general fortification studies, which tend to apply single-concentration formulations without exploring gradational effects.

In conclusion, the outcomes of this research confirm that the incorporation of Moringa leaf flour at varying levels exerts a significant and multidimensional impact on the nutritional properties of wet noodles. The study not only validates the research hypothesis but also offers novel scientific insights into the functional use of Moringa in wet food systems. Importantly, it bridges a methodological gap in the literature by addressing wet noodle formulations—an understudied but culturally significant food type and provides a practical foundation for future innovations in the development of nutritionally enriched, plant-based functional foods.

CONCLUSION

The results of this research successfully address the initial objective of identifying the optimal concentration of Moringa leaf flour that enhances the macronutrient profile of wet noodles. The findings indicate that nutrification with Moringa leaf flour significantly improves the nutritional value of wet noodles, with a 4% supplementation level providing the most balanced enhancement in terms of increased protein and fat content and reduced carbohydrate levels. These results hold important implications for food technology and product innovation, particularly in the development of health-oriented noodle products targeted at nutritionally conscious consumers. Moreover, the use of Moringa-fortified noodles could contribute to improved dietary quality in institutional settings, such as school feeding programs, by offering a convenient and familiar food with enhanced nutritional content. Future studies are encouraged to expand upon these findings by evaluating the effects of Moringa leaf flour on additional parameters such as dietary fiber content, micronutrient enrichment, sensory characteristics, and consumer acceptability. Such research will be essential for refining formulation ratios and supporting large-scale application through evidence-based product development and consumer testing.

RECOMMENDATION

Based on the presentation of the research findings, it is recommended that further studies be conducted on the nutritional and organoleptic characteristics of wet noodles fortified with Moringa leaf flour. Future research should employ a wider variety of formulations and treatment methods to better understand the effects of different fortification levels and processing techniques on both the nutritional value and sensory qualities of the product. Such investigations will contribute to optimizing the formulation to achieve a balance between enhanced nutritional content and consumer acceptability.

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