



Influence of Carrageenan and Moringa Leaf Powder on Physico-chemical Properties of Porang-based Shirataki Noodles

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10.18805/ajdfr.DRF-504

ABSTRACT

Background: Shirataki noodles, made from porang (*Amorphophallus muelleri* Blume) flour, are a low-calorie and high-fiber food gaining popularity among health-conscious consumers. This study investigates the impact of varying concentrations of carrageenan and Moringa oleifera extract on shirataki noodles' physico-chemical and nutritional properties.

Methods: Nine formulations were developed by systematically varying the levels of carrageenan (0.5 g, 1.0 g and 1.5 g) and Moringa leaf powder (MLP) (0.25 g, 0.5 g and 0.75 g) and were analyzed for texture, moisture content, water absorption, color and nutritional attributes.

Result: Results showed that carrageenan significantly improved gel strength and elasticity, while MLP enhanced protein content (0.09-0.19 g/100 g compared to 0.05 g/100 g in control) and contributed natural pigments that modified noodle color. Optimal formulations, such as 0.5 g carrageenan with 0.5 g MLP, provided a balance between functional properties and nutritional quality, with a caloric content of only 11-13 kcal/100 g, much lower than traditional staples like white rice (130 kcal/100 g) or bread (293 kcal/100 g). These findings demonstrate the potential of combining carrageenan and MLP to create innovative shirataki noodles that meet modern dietary needs for functional, nutrient-enriched and low-calorie foods.

Key words: Carrageenan, Moringa leaf powder, Noodles, Porang, Shirataki.

INTRODUCTION

Noodles have long been a staple food globally, valued for their versatility, convenience and appeal across various cuisines. Conventional noodles, primarily made from wheat flour, are carbohydrate-rich and have a high glycemic index, raising health concerns such as obesity, diabetes and cardiovascular diseases. These issues have prompted a growing demand for healthier alternatives prioritizing low-calorie, high-fiber content (Slavin, 2013). Among these alternatives, shirataki noodles, made from porang (*Amorphophallus muelleri* Blume) flour, stand out due to their minimal caloric content and functional dietary properties. Glucomannan, the primary component of porang, has been widely studied for its health benefits, including improving glycemic control, reducing cholesterol levels and supporting gut health (Jian *et al.*, 2024; Zhang *et al.*, 2023).

Despite these advantages, shirataki noodles face significant challenges in achieving broader consumer acceptance. Their mushy texture and lack of nutritional diversity limit their appeal to health-conscious consumers. Addressing these limitations requires enhancing both the sensory and nutritional attributes of the noodles. Previous studies have identified carrageenan, a hydrocolloid derived from seaweed, as an effective agent to improve noodle elasticity and cohesiveness through its strong gel-forming properties (Campo *et al.*, 2009). Recent work shows that κ -carrageenan (κ -CG) forms synergistic interaction gels with konjac glucomannan (KGM), yielding stronger, more elastic networks than either hydrocolloid alone, *via* cooperative coil-to-helix transitions and hydrogen-bonding/

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How to cite this article: Yulianingsih, R., Hermanto, M.B. and Gania, N.Y. (2025). Influence of Carrageenan and Moringa Leaf Powder on Physico-chemical Properties of Porang-based Shirataki Noodles. *Asian Journal of Dairy and Food Research*. 1-10. doi: 10.18805/ajdfr.DRF-504.

Submitted: 23-01-2025 **Accepted:** 25-10-2025 **Online:** 13-11-2025

electrostatic associations. These κ -CG/KGM mixed gels display higher gel strength, improved elasticity and reduced syneresis and their performance can be tuned by κ -CG level and KGM acetylation/deacetylation state (Jati *et al.*, 2023; Li *et al.*, 2024; Wu *et al.*, 2021). In parallel, moringa oleifera leaves (powder/extract) have been increasingly incorporated into cereal and noodle systems in the last few years to raise protein/mineral content, antioxidants and functional quality, with several studies reporting improved texture or chewiness alongside greener/yellower hues from intrinsic pigments (Anwar *et al.*, 2007; Fatima *et al.*, 2024; Fidyasari *et al.*, 2024; Liu *et al.*, 2025). Notably, a 2023 study combining moringa leaf powder with KGM (and acetylated starch) demonstrated quality improvements and good consumer acceptance in noodles, supporting the

compatibility of these ingredients in gel-based, gluten-free matrices (Thuy *et al.*, 2023). We hypothesize that carrageenan's gel-forming properties will compensate for moringa's fiber-induced textural drawbacks by creating a reinforced network (He *et al.*, 2012), while moringa's protein 8-25% content; (Gopalakrishnan *et al.*, 2016) will cross-link with carrageenan to enhance structural stability while boosting nutritional value and moringa's polyphenols (e.g., chlorogenic acid) may inhibit starch retrogradation, extending shelf life (Rocchetti *et al.*, 2020).

Moringa oleifera is also widely recognized for its exceptional nutritional and medicinal attributes. It has been described as a "Miracle Tree" because nearly every part of the plant-leaves, pods, seeds and flowers-contains essential nutrients and bioactive compounds that contribute to health and wellness (Athira *et al.*, 2021). In addition, moringa demonstrates detoxifying and antioxidant activity that helps reduce heavy metal toxicity (Jiraungkoorskul and Jiraungkoorskul, 2016) and provides food and nutritional security through its macro- and micronutrient richness (Ravani *et al.*, 2017). Incorporation of moringa leaf powder into fiber-enriched noodles has been proven to improve dietary fiber content, stability and sensory acceptance during storage (Ganga *et al.*, 2019), while its phenolic compounds exhibit antimicrobial activity that supports extended shelf life (Das *et al.*, 2020). These properties highlight moringa's strong potential as a natural fortificant in functional noodle products.

Optimizing the physico-chemical properties of shirataki noodles involves a careful balance between texture and nutrition. While glucomannan provides structural stability, its low protein content and lack of gluten necessitate supplementation with other functional ingredients. Traditional solutions, such as adding wheat gluten, are incompatible with the health-focused ethos of shirataki noodles. Instead, carrageenan and *Moringa oleifera* extract offer complementary roles: carrageenan enhances gel elasticity (Zhang *et al.*, 2023), while moringa provides protein, antioxidant and natural pigmentation (Arendse and Jideani, 2022). However, such synergistic effects have not been systematically investigated in porang-based shirataki.

This study investigates the effects of carrageenan and *Moringa oleifera* Leaf Powder (MLP) on porang-based shirataki noodles, aiming to characterize their synergistic textural and nutritional effects and identify an optimal formulation for consumer acceptance. The findings will advance functional food innovation by leveraging plant-based ingredient synergies.

MATERIALS AND METHODS

The primary materials included porang flour, carrageenan and *Moringa oleifera* leaf. Porang flour was sourced from Hydrocolloid Food Indonesia and produced from dried porang tubers through washing, slicing and sun-drying to ~10% moisture, followed by milling, separation of impurities using a cyclone and sieving to pass through an

80-mesh sieve. The flour contained glucomannan at 60-85%, verified by the supplier certificate of analysis. *Moringa oleifera* leaf powder (MLP) was purchased from a commercial online store (Malang, Indonesia). According to the supplier, the product was produced from mature moringa leaves through selection, washing, shade-drying to low moisture content and grinding into fine powder (80 mesh). Food-grade κ -carrageenan (κ -CG; Danisco, Indonesia) synergized with glucomannan to improve gel strength and elasticity. Supplementary materials included calcium hydroxide (analytical grade), used as a coagulant to stabilize noodle structure and distilled water for all processing steps to avoid contamination.

Experimental design and rationale for concentrations

Nine formulations were developed by varying carrageenan (0.5 g, 1.0 g and 1.5 g per 250 mL slurry) and MLP (0.25 g, 0.5 g and 0.75 g per 250 mL slurry). The concentration ranges for carrageenan were determined primarily from preliminary experiments conducted in our laboratory, which showed that concentrations below 0.5 g produced weak gel structures with poor elasticity, while concentrations above 1.5 g resulted in overly rigid textures and reduced sensory acceptance.

Shirataki noodles preparation

The process flow for shirataki noodle preparation is shown in Fig 1. A total of 10 g dry mix consisting of porang flour and

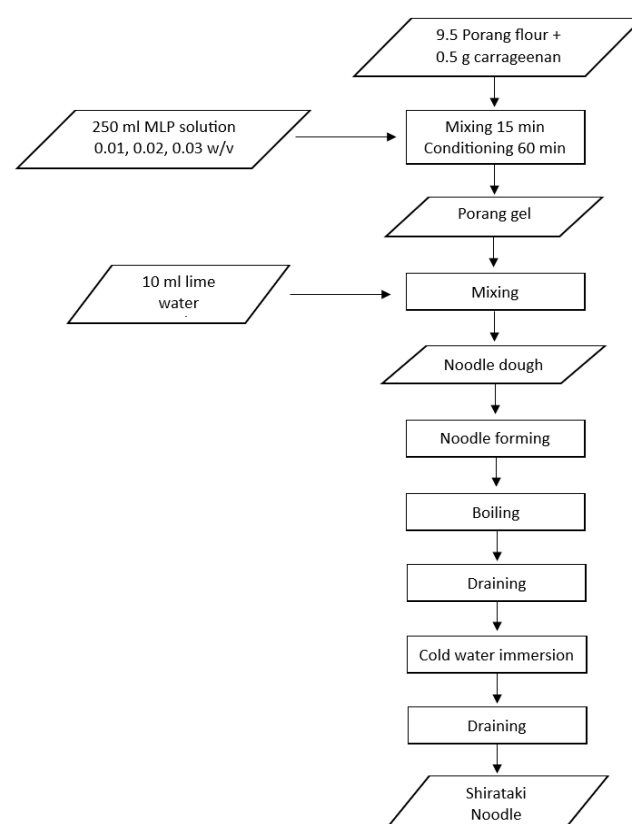


Fig 1: Flow diagram of shirataki noodle preparation.

carrageenan (according to the formulation levels described in the previous section) was combined with the specified amount of MLP and 250 mL distilled water in a plastic container. The mixture was stirred manually for 15 min until homogeneous, then rested for one hour for hydration and partial gelation. A lime water solution (1 g calcium hydroxide in 10 mL distilled water) was added and mixed thoroughly. The dough was extruded through a pasta maker into noodle strands, boiled at 100°C for 3 min, cooled in ice water, drained and stored in sealed standing pouches at 4°C until analysis.

Physical properties analyses

The noodles underwent detailed analyses to evaluate their physical and chemical properties. Moisture content was determined gravimetrically by drying the noodles at 100–105°C (24 h drying time) to a constant weight and water absorption was calculated as the percentage weight gain after boiling the noodles. Textural attributes, including hardness, cohesiveness, gumminess and chewiness, were measured using a Texture Analyzer (Brookfield CT3-1000; Probe TA44, diameter probe 4 mm, speed measurement 1 mm/s). The analyzer applied a compressive force and the resistance was recorded in terms of force (g) and deformation distance (mm). Color parameters (L^* , a^* , b^*) were analyzed using image processing. Digital images of noodles were captured under standardized lighting and evaluated with ImageJ (Fiji) software based on the CIE $L^*a^*b^*$ system.

Chemical properties analysis

Protein content was determined via the Kjeldahl method ($N \times 6.25$), fat content via Soxhlet extraction, carbohydrate content by difference and ash content gravimetrically after incineration. Caloric content was calculated using Atwater factors.

Replication and statistical analysis

All analyses were performed in triplicate ($n = 3$). Data were analyzed by Analysis of Variance (ANOVA) and significant differences among means ($p < 0.05$) were separated using Tukey's HSD.

RESULTS AND DISCUSSION

Moisture content

Moisture content is a critical factor in determining the texture, stability and sensory characteristics of noodles. It also significantly influences their shelf life and microbial stability. In this study, the moisture content of shirataki noodles ranged from 96.04% to 96.52% (Fig 2). The highest value was recorded in the treatment with 0.50 g MLP (96.45%), while the lowest value occurred with 0.25 g MLP and 0.50 g κ -carrageenan (96.30%).

Two-way ANOVA indicated that Moringa (MLP) levels had a significant effect ($p < 0.01$), while κ -carrageenan and the interaction were not significant ($p > 0.05$). Tukey's HSD further revealed that the 0.50 g MLP treatment yielded significantly higher moisture content than 0.25 g, while 0.75 g did not differ significantly from either level. This highlights that MLP was the decisive factor in determining moisture content, whereas carrageenan had no statistically significant influence in this study.

The increase in moisture content observed at higher MLP levels in some treatments may be attributed to the hygroscopic nature of moringa leaf powder, which contains dietary fibers and proteins with high water-binding capacity. These components can form hydrogen bonds with water molecules, enhancing the stability of water within the noodle matrix. Similar moisture-enhancing effects of plant powders rich in polysaccharides have been reported in noodle systems (Wang *et al.*, 2024). Similarly, κ -carrageenan

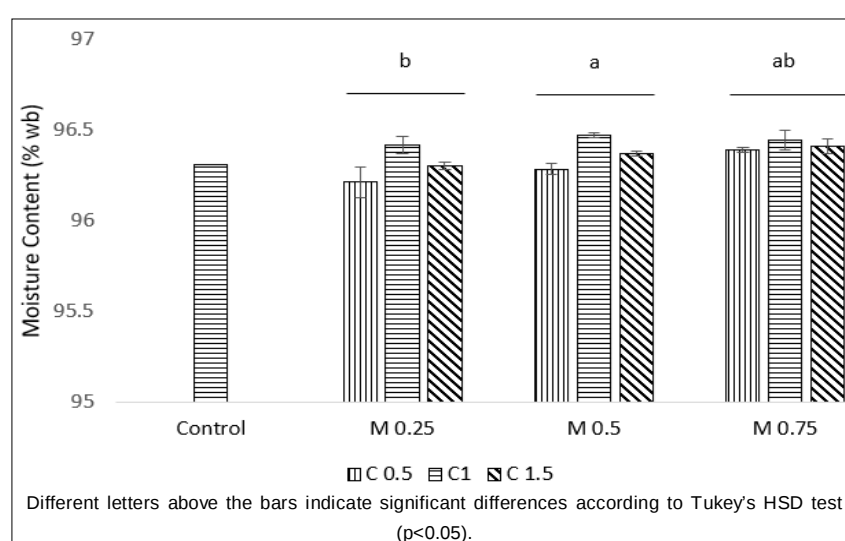


Fig 2: Moisture content of shirataki noodles as affected by different concentrations of moringa leaf powder (MLP) and κ -carrageenan.

contributes to water retention through its hydrophilic nature and ability to form stable gel networks with konjac glucomannan. The cooperative coil-to-helix transition and electrostatic interactions between these two hydrocolloids result in a denser, more hydrated gel matrix, reducing water migration and syneresis (Chen *et al.*, 2019; 2021). However, in this study, carrageenan concentration did not significantly affect noodle moisture content. Although the interaction effect was insignificant, descriptive observations showed that the combination of high MLP (0.75 g) and high carrageenan (1.5 g) did not always produce the highest moisture values. This suggests an excessive solid load may reduce free water availability or slightly disturb gel network formation, limiting further moisture retention.

Water absorption

The water absorption values observed in this study ranged below 100%, as shown in Fig 3. This result contradicts to the typical expectation for dried noodles, where water absorption usually exceeds 100% due to their low initial moisture content. In contrast, shirataki noodles are categorized as fresh (wet) noodles, with an exceptionally high initial moisture content of 96.53%. Such a high moisture level indicates that the noodles were already nearly saturated with water before cooking, resulting in minimal capacity for further water uptake and, instead, promoting water loss during the boiling process.

From Fig 3, the lowest water release was observed in the control group (~92%), which lacked the addition of MLP and carrageenan. This result can be attributed to the absence of structural modifications in the noodle matrix, which allowed the noodles to retain water more effectively during cooking. However, with the incorporation of MLP and carrageenan, water release increased progressively, particularly in the combination of Moringa 0.75 g and Carrageenan 1.5 g. Based on the Tukey HSD results, Moringa concentration significantly affected water

absorption ($p < 0.05$), with the lowest value observed at the highest level (0.75%). In contrast, carrageenan concentration did not cause a significant difference ($p > 0.05$) and the interaction effect was also non-significant.

The increased water release can be explained by the structural changes induced by the added ingredients. Moringa leaf powder (MLP), containing protein and fiber, can bind water within the noodle matrix. However, these components restrict free water mobility at higher concentrations and promote water expulsion during thermal processing. Carrageenan, known for its gel-forming properties, stabilizes the water within the noodle structure. However, at higher concentrations, it can create a denser and more rigid gel matrix that facilitates water release during thermal processing. These observations are consistent with the findings of Elleuch *et al.* (2011), who reported increased water loss in noodles enriched with high-fiber additives and Imeson (2009), who highlighted the impact of gel-forming agents on water dynamics in food products.

These results underscore the role of functional ingredients, such as MLP and carrageenan, in modulating water dynamics in noodle products, as discussed by Chua *et al.* (2010) and Williams and Phillips (2009). Similar patterns have been reported by Thuy *et al.* (2023), who found that noodles fortified with moringa leaf powder and konjac glucomannan exhibited improved rehydration capacity and reduced cooking loss when optimal ratios were used, but excessive concentrations of fortifying agents increased structural density and led to greater water expulsion during cooking. This supports our observation that over-concentration of Moringa compromises water-holding ability under thermal stress.

Texture analysis

The textural properties of noodles, including hardness, deformation, cohesiveness, gumminess and chewiness,

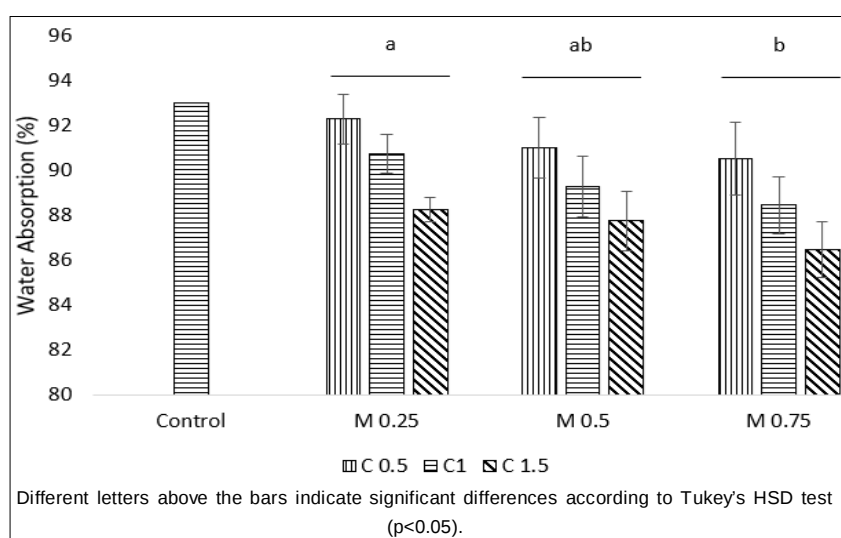


Fig 3: Water absorption of shirataki noodles as affected by different concentrations of moringa leaf powder (MLP) and k-carrageenan.

are critical in determining the structural integrity, mechanical stability and overall eating quality of noodles. The results, illustrated in Fig 4 (a: Hardness, b: Deformation, c: Cohesiveness, d: Gumminess, e: Chewiness), reveal significant variations across treatments, emphasizing the role of ingredient interactions in shaping noodle texture. Based on the variance test analysis, the concentration of moringa and carrageenan affected hardness, deformation and chewiness, but did not affect gumminess.

Hardness ranged from 42.83 g to 92.30 g, with the highest value observed in noodles containing 0.5 g carrageenan and 0.75 g MLP, while the lowest was found in noodles with 1.0 g carrageenan and 0.25 g MLP. Carrageenan increased hardness by forming a denser gel network, consistent with its gel-forming properties (Imeson, 2009). MLP also contributed to hardness, particularly when combined with higher carrageenan levels, where its solid content and proteins reinforced the noodle matrix. The interaction between carrageenan and MLP proteins enhanced the gel structure by forming additional cross-links, creating a more cohesive and stable matrix. These observations align with findings by Zhang *et al.* (2023), which highlighted the role of polysaccharides in enhancing structural integrity through gel network formation. Furthermore, research on the interaction between carrageenan and konjac glucomannan supports this, demonstrating enhanced gel strength and stability due to synergistic effects (He *et al.*, 2012).

Deformation values ranged from 0.6% to 1.4%, with the highest deformation observed in noodles containing 0.25 g MLP and 1.5 g carrageenan, suggesting that this combination creates a gel network with better elasticity. Conversely, combinations with 0.75 g MLP showed reduced deformation, indicating a denser, less flexible structure likely caused by the high solid content of Moringa. This reduction in deformation reflects a loss of elasticity, which can negatively impact sensory properties such as chewiness and mouthfeel. These results align with studies by Jian *et al.* (2024), which discussed the impact of protein-polysaccharide interactions on the mechanical properties of gel matrices. Additionally, studies on carrageenan-konjac mixtures indicate that the optimal ratio enhances gel elasticity and mechanical stability, further supporting these observations (He *et al.*, 2012).

Cohesiveness, which reflects the internal bonding strength of noodles, ranged from 0.45 to 0.60. The highest cohesiveness was observed in noodles containing 1 g carrageenan and 0.25 g MLP, indicating a balanced proportion between carrageenan and Moringa components that promoted a uniform gel network. In contrast, excessive levels of either ingredient reduced cohesiveness, likely due to phase separation and structural heterogeneity within the gel matrix network. This result aligns with findings by Elleuch *et al.* (2011), who noted that fiber and protein components enhance cohesiveness at optimal concentrations. These findings align with studies on jelly

candies, where balanced interactions between carrageenan and konjac produced cohesive and stable gel matrices (Kaya *et al.*, 2015). Additionally, Jian *et al.* (2024) emphasized that excessive concentrations of hydrocolloids can lead to structural instability, reducing cohesive strength.

Gumminess values ranged from 21.6 to 48.9, with the highest mean observed in noodles containing 0.5 g carrageenan and 0.75 g Moringa Leaf Powder (MLP), while the lowest was found in the combination of 1 g carrageenan and 0.25 g MLP. Two-way ANOVA showed that carrageenan, MLP and their interaction significantly affected gumminess ($p < 0.001$). Treatments with excessive MLP (0.75 g) generally reduced gumminess when combined with higher carrageenan levels, likely due to gel heterogeneity and disruption of matrix uniformity. Conversely, moderate levels of carrageenan and MLP promoted a dense gel network through hydrocolloid-protein synergy, enhancing the mechanical strength of the noodle matrix. These results agree with Zhang *et al.* (2023), who reported that optimal hydrocolloid-protein interactions are crucial for achieving stable gel matrices with desirable mechanical strength.

Chewiness values ranged from 0.23 to 0.76, with the highest value observed in noodles containing 0.75 g MLP and 1 g carrageenan. Higher chewiness in this combination may be due to increased gel density and matrix compactness, which require greater energy to break down during mastication. Conversely, the lowest chewiness was found in noodles containing 0.25 g MLP and 1.5 g carrageenan, suggesting that excessive carrageenan without sufficient solid content from MLP leads to a softer, less resistant structure. These results confirm previous findings that hydrocolloid-protein and hydrocolloid-starch interactions can modulate chewiness by altering gel firmness and elasticity (He *et al.*, 2012; Zhang *et al.*, 2023).

The findings emphasize the importance of balancing carrageenan and MLP concentrations to optimize textural attributes. Among the tested formulations, Moringa 0.5 g and Carrageenan 1 g provided the most consistent performance across hardness, cohesiveness, chewiness and elasticity, indicating stable gel formation without excessive rigidity. Similar synergistic effects between hydrocolloids and plant-based proteins have been reported (Burey *et al.*, 2008; Elleuch *et al.*, 2011; Williams and Phillips, 2009), highlighting the role of controlled ingredient ratios in achieving balanced mechanical properties (Jian *et al.*, 2024; Zhang *et al.*, 2023). In agreement, Thuy *et al.* (2023) demonstrated that combining MLP with konjac glucomannan and acetylated starch improved noodle firmness and reduced breakage, emphasizing the importance of moderate hydrocolloid-protein interactions. Reviews on gluten-free noodles also noted that κ -carrageenan can mimic gluten-like viscoelasticity (Lubowa *et al.*, 2025), which aligns with our observation that carrageenan-moringa synergy enhances gel density and elasticity. Although the interaction effect was not statistically

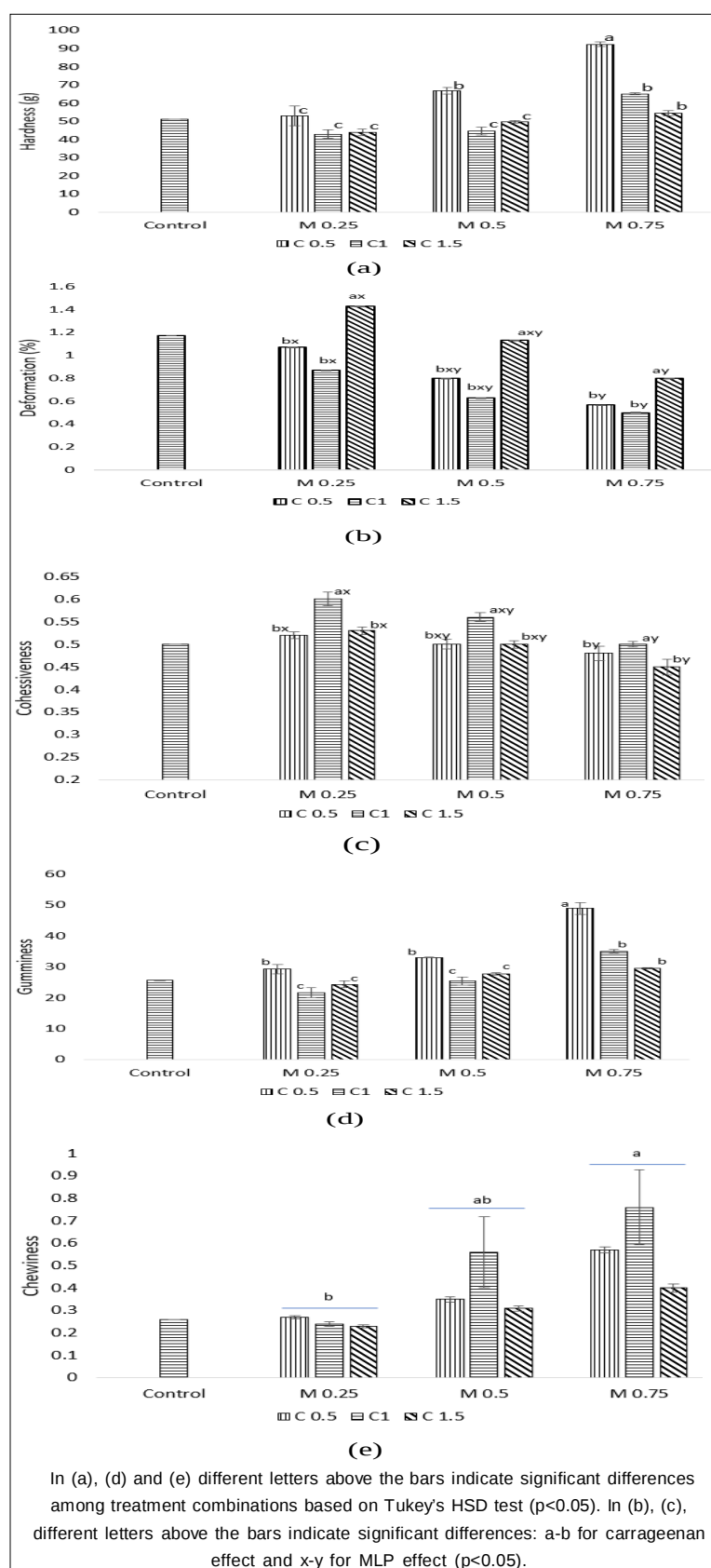


Fig 4: Textural properties of noodles with varying concentrations of carrageenan (C) and MLP (M) (a: Hardness, b: Deformation, c: Cohesiveness, d: Gumminess, e: Chewiness).

significant for all parameters, descriptive trends consistently showed that moderate levels of both ingredients produced a more balanced gel structure. At the same time excessive concentrations tended to reduce deformation and cohesiveness.

Color

The color attributes (L^* , a^* and b^*) of shirataki noodles were significantly influenced by the incorporation of Moringa Leaf Powder (MLP) and carrageenan ($p < 0.05$) as shown in Fig 5.

Brightness (L) declined progressively with increasing MLP concentration (Fig 5a). The control sample ($L^* = 75.43$, a)

was significantly brighter than all treatments. At 0.25 g MLP, brightness dropped to 56.68-50.54 (b-c), further decreasing to 49.02-45.28 (c-cd) at 0.5 g and reaching the lowest values at 0.75 g MLP (38.44-44.70, cd-d). These results confirm that MLP was the primary factor reducing brightness through chlorophyll and polyphenol pigments, while carrageenan introduced only minor within-level variations.

The a^* values of shirataki noodles ranged from -4.05 to 6.13 (Fig 5b). The control exhibited the highest redness ($a^* = 6.13$), while MLP addition shifted values toward the green region, with the lowest ($a^* = -4.05$) recorded at 0.25 g

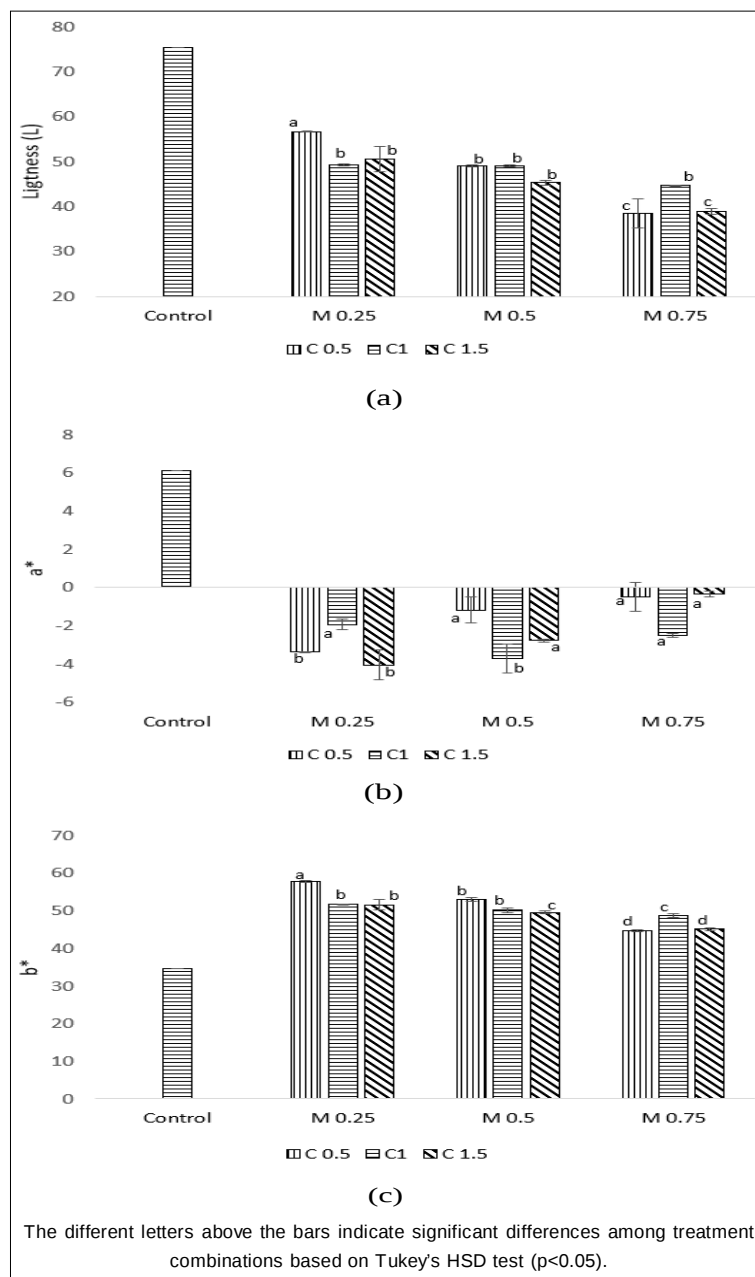


Fig 5: Visual attributes of shirataki noodles at various concentrations of MLP (M) and Carrageenan (C) (a: Lightness (L^*), b: Redness (a^*), c: Yellowness (b^*)).

MLP combined with 1.5 g carrageenan. At higher MLP levels (0.75 g), a^* values approached neutrality (-0.49 to -0.34), suggesting pigment modification or carrageenan-pigment interactions that reduced greenness intensity. Overall, MLP was the dominant factor, with carrageenan acting as a secondary modulator.

Yellowness (b^*) varied significantly, from 34.52 in the control to 57.83 in fortified noodles (Fig 5c). The control exhibited the lowest b^* , reflecting the pale color of konjac-based noodles. Incorporation of 0.25 g MLP markedly enhanced yellowness (highest at 57.83), while 0.5 g MLP yielded intermediate values (49.58-53.09). At 0.75 g MLP, b^* declined (44.79-48.67), consistent with chlorophyll masking carotenoids. Carrageenan contributed to minor differences within the same MLP level, reflecting its secondary role through matrix modification and light scattering.

At higher concentrations, however, the dominance of chlorophyll masked yellow tones and led to a darker appearance. Carrageenan, although less influential on its own, played a supportive role by modifying the noodle matrix and indirectly affecting how pigments were expressed. These findings are consistent with previous studies (Arendse and Jideani, 2022; Lubowa *et al.*, 2025; Thuy *et al.*, 2023), which highlighted that natural pigments in moringa interact with hydrocolloid systems to influence visual appearance in noodle products strongly.

Nutritional comparison of optimized shirataki noodles with common staple foods

The formulation of porang-based shirataki noodles is presented in Table 1. Calorie testing revealed the significant nutritional advantages of optimized shirataki noodles. Three optimal formulations were identified using the Effectiveness Index method: 0.5 g carrageenan with 0.25 g MLP, 0.5 g carrageenan with 0.5 g MLP and 1.5 g carrageenan with 0.75 g MLP. These formulations combine the functional benefits of MLP, such as protein enrichment and antioxidant properties, with the structural stability provided by carrageenan. With caloric values ranging from 11 to 13 kcal per 100 g, shirataki noodles are a low-calorie alternative to staple foods like white rice and bread, making them ideal for health-conscious consumers. The protein content increased with higher levels of MLP due to the protein-rich composition of Moringa leaves (Anwar *et al.*,

2007). This increase enhanced the nutritional profile and played a structural role by interacting with carrageenan to strengthen the gel matrix. Conversely, fat content remained minimal, consistent with the low-fat nature of porang flour and Moringa extract (Rahmi *et al.*, 2019). Variations in carbohydrate content reflected differences in ingredient ratios, with formulations containing higher amounts of Moringa extract showing reduced carbohydrate levels. Ash content, indicative of mineral levels, varied across treatments, with higher mineral profiles observed in formulations with more Moringa extract due to its significant calcium and potassium content (Anwar *et al.*, 2007). These findings align with previous reports on the nutritional role of *Moringa oleifera* as a functional food ingredient. Ravani *et al.* (2017) emphasized its importance in improving food and nutritional security, while Athira *et al.* (2021) described moringa as a “Miracle Tree” due to its rich composition of proteins, minerals and antioxidants that support human health. The results demonstrate that shirataki noodles offer substantial advantages as a low-calorie and functional food alternative. Shirataki noodles have significantly lower caloric content, ranging from 11-13 kcal per 100 g, compared to white rice (130 kcal/100 g), breakfast bread (293 kcal/100 g) and egg noodles (393 kcal/100 g). Additionally, the high water content of shirataki noodles (above 96%) enhances satiety without adding caloric density, making them particularly appealing to consumers on calorie-restricted diets. The minimal fat content and reduced carbohydrate levels further support their suitability for health-conscious individuals. Moreover, including moringa extract enriches the nutritional profile by increasing protein, calcium, potassium and antioxidant content, providing functional benefits such as improved digestion and potential anti-inflammatory properties (Anwar *et al.*, 2007). Our findings align Thuy *et al.* (2023), who reported that moringa-KGM-acetylated starch fortified noodles improved cooking quality and increased protein and mineral content without substantially raising caloric values. This suggests that moringa can be an effective fortifying agent in low-calorie noodle systems when used at optimized concentrations.

Beyond protein and minerals, moringa leaves are rich in bioactive compounds such as polyphenols and flavonoids, which contribute antioxidant activity (Moyo *et al.*, 2011). Incorporating moringa into shirataki noodles adds

Table 1: Nutritional comparison of shirataki noodles and common staple foods (100 g).

Treatment	Carrageenan (g)	MLP (g)	Fat (g)	Protein (g)	Carbohydrate (g)	Water content (%)	Ash content (g)	Calories (kcal)
Shirataki 1	0.5	0.25	0.07	0.09	2.93	96.25	0.66	13
Shirataki 2	0.5	0.5	0.03	0.14	2.59	96.7	0.54	11
Shirataki 3	0.5	0.75	0.02	0.19	2.82	96.3	0.67	12
Control	-	-	0.02	0.05	3.06	96.3	0.57	13
White rice ^a	-	-	0.28	2.69	28.17	68.0	0.2	130
Breakfast bread ^b	-	-	2.44	7.32	60.98	na	0.97	293
Egg noodles ^c	-	-	4.46	14.3	71.4	na	Na.	393

^a(USDA (a) 2019); ^b(USDA (b) 2019); ^c(USDA (c) 2023).

potential functional benefits beyond macronutrient improvement, aligning with consumer demand for health-promoting foods. From a market perspective, the combination of very low calorie density, high satiety value and functional nutrient enrichment positions these optimized shirataki noodles for niche markets such as weight management programs, diabetic-friendly diets and gluten-free functional foods. This aligns with trends noted by Lubowa *et al.* (2025), where hydrocolloid-based gluten-free noodles with added functional ingredients are gaining traction among health-conscious consumers.

CONCLUSION

This study highlights the potential of optimized shirataki noodles as a low-calorie, functional food. The combination of carrageenan and MLP enhances the noodles' textural and nutritional properties, making them an appealing alternative to traditional staples. Formulations with balanced concentrations of carrageenan and MLP offer superior physical characteristics and improved nutritional profiles. These findings underscore the versatility of shirataki noodles in addressing contemporary dietary preferences and pave the way for further innovation in functional food development.

ACKNOWLEDGEMENT

The present study was supported by Research and Community Service Agency, Faculty of Agricultural Technology, Brawijaya University.

Disclaimers

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Informed consent

Research did not involve animals.

Conflict of interest

No conflict of interest.

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