



Physicochemical Characteristics of Gluten-Free Gyoza Wrappers Made from Rice Flour and Mocaf with the Addition of Kappa Carrageenan

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ABSTRACT

This study examines the production of gluten-free gyoza wrappers from rice flour and mocaf with the addition of kappa carrageenan. Mocaf has a high amylopectin starch, causing the resulting product to have a sticky texture. Rice flour has a higher amylose than Mocaf, a property that correlates strongly with the ability of gluten-free dough to form a more stable and viscoelastic structure. Kappa carrageenan has the ability to form strong gels through the formation of double helix structures that associate with each other, thereby increasing the viscoelastic properties of food systems. In combination with starch, carrageenan interacts through hydrogen bonds and physical associations, producing a more stable composite gel network that is able to retain water and increase the flexibility and integrity of the dough structure. The purpose of this study was to determine the effect of rice flour and mocaf proportions with the addition of kappa carrageenan on the physicochemical and organoleptic characteristics of gluten-free gyoza wrappers, as well as the best treatment that produces gluten-free gyoza wrappers with organoleptic qualities that are close to or equal to commercial gyoza wrappers. This study used a completely randomized design (CRD) with a factorial pattern and three replicates. The first factor was the proportion of rice flour: mocaf (40:60; 50:50; and 60:40), while the second factor was the addition of kappa carrageenan (8, 10, and 12%). The data were analyzed using ANOVA and DMRT post-hoc test at a 5% confidence level. The best treatment was found in the rice flour: mocaf ratio (40:60) with 8% carrageenan addition, which produced a moisture of 53.72%; ash of 1.67%; starch of 41.97%; amylose of 9.46%; amylopectin of 32.51%; color of 2.56 (same as bone white with R); aroma of 3.04 (same as neutral with R) and texture of 4.04 (slightly more elastic than R).

Contribution to Sustainable Development Goals (SDGs):

SDG 6: Zero Hunger

SDG 3: Good Health and Well-being

SDG 9: Industry, Innovation and Infrastructure

SDG 11: Sustainable Cities and Communities **SDG 15:** Life on Land

1. INTRODUCTION

1.1. Research Background

Global awareness of gluten-related health issues has increased significantly in recent years. Conditions such as celiac disease, wheat allergy, dermatitis herpetiformis, and gluten

intolerance are driving a shift in consumer behavior toward gluten-free foods. This trend has directly impacted the growth of the gluten-free food market, which is projected to increase from US\$6.7 billion in 2022 to US\$14 billion in 2032 [1]. Gluten, the main protein complex in wheat flour consisting of gliadin and glutenin, plays a role in the viscoelastic properties of wheat-based dough [2]. However, in individuals with certain



sensitivities, gluten consumption can trigger immune and non-immune responses that negatively impact health [3].

Gyoza wrappers are traditionally made from wheat flour, water, and salt as thin sheets of dough that serve as a wrapper for meat and vegetable fillings. Wheat flour-based gyoza wrappers exhibit characteristic rheological properties and texture determined by the gluten protein network during processing and storage [4],[5]. However, in the context of gluten-free product development, alternative formulations using gluten-free flours such as tuber flours have successfully produced dumpling wrappers with good structural integrity and sensory acceptance [6].

Local food ingredients such as mocaf and rice flour are promising alternatives to wheat flour. Mocaf has a high starch (>80%), higher than wheat flour (60–68%), which contributes to product structure, water absorption, and texture [7]. Meanwhile, rice flour plays a role in structure formation through the process of starch gelatinization, in which starch granules absorb water, swell, and produce a three-dimensional network formed by starch molecules (mainly amylose) that connect the swollen granules through hydrogen bonds, thereby increasing the viscoelasticity of the gel [8]. However, gluten-free starch-based systems tend to have a fragile and less elastic structure, requiring the addition of hydrocolloids.

Kappa carrageenan is a hydrocolloid widely used in gluten-free food formulations, known for its stabilizing, thickening, and gel-forming properties. Kappa carrageenan can interact with starch and water to form a stronger gel network, increasing viscosity and improving dough texture and stability [9]. This interaction between starch and hydrocolloids is key to improving the characteristics of gluten-free starch-based products.

Based on this description, research on the physicochemical characteristics of gluten-free gyoza wrappers made from rice flour and mocaf with the addition of kappa carrageenan is very important to produce products with properties, texture, and stability that can resemble commercial gyoza wrappers. This study is expected to provide a scientific basis for the development of gluten-free gyoza wrappers while supporting the use of local food ingredients.

1.2. Literature Review

Gyoza wrappers are typically made from wheat flour, where the flour is mixed with water and gluten protein to form a network structure that provides elasticity, cohesion, and viscosity to the dough [10]. Since gyoza wrappers are conventionally made from wheat-based dough, the development of gluten-free gyoza wrapper formulations requires the substitution of non-wheat starch-based ingredients, such as rice flour and mocha flour, as well as the addition of hydrocolloids such as kappa carrageenan to replace the structural function of gluten.

1.2.1. Mocaf

Analysis of amylose and amylopectin is related to the functional properties of mocaf, such as solubility, swelling power, and water and oil binding capacity (WAC) [11]. Mocaf has higher water solubility than regular cassava flour due to partial hydrolysis during fermentation. In addition, higher starch tends to have higher swelling power because amylose and amylopectin bind water during heating. The integrity of

amylopectin plays an important role in swelling power and grain structure. Mocaf absorbs water more easily due to the degradation of polymer bonds in starch, which shortens the chains, thereby increasing its water absorption capacity [12]. Meanwhile, the oil absorption values of mocaf and cassava flour do not differ significantly compared to their water absorption.

1.2.2. Rice Flour

The functional properties of rice flour include water absorption index, solubility, and swelling power of various rice varieties [13]. The composition of flour, such as carbohydrates, fiber, protein, and amylose, are the main factors that affect the water absorption index. The water absorption capacity of rice flour ranges from 5.38 to 6.26 [13]. Solubility is directly related to temperature, while amylose has an inverse relationship with the solubility of rice flour [14]. The swelling of rice flour tends to be influenced by amylose and protein, which inhibit the swelling of grains due to disulfide bonds and intermolecular bonds in proteins, resulting in a broad and strong network [14].

1.2.3. Kappa Carrageenan

The properties of carrageenan include solubility, viscosity, gel formation, and pH stability. The solubility of carrageenan is highly dependent on its chemical structure, and temperature is the main factor affecting solubility, with heating being the most effective method. In addition, carrageenan solutions show stability at pH values above neutral, while hydrolysis occurs at low pH [15]. The hydroxyl and sulfate groups in carrageenan are hydrophilic, while the 3,6-anhydro-D-galactose groups are more hydrophobic. Kappa carrageenan is less hydrophilic because it contains more 3,6-anhydro-D-galactose groups [16]. The solubility of carrageenan is also influenced by the degree of sulfation and 3,6-anhydro-D-galactose in the molecule [17]. Kappa carrageenan is less hydrophilic because it contains more 3,6-anhydro-D-galactose groups [16].

Increasing the concentration of carrageenan in solution causes the viscosity to increase logarithmically, because the number of interacting polymer chains increases and forms a complex network [18]. Kappa-carrageenan is a fraction that can form a gel in water. Carrageenan has the ability to form a gel when a hot solution cools. The gel formation process is thermoreversible, meaning that the gel melts when heated and reforms when cooled [18].

1.2.4. Starch-Hydrocolloid Interaction

Kappa carrageenan in an aqueous medium binds through its sulfate groups to form double helical structures that associate with each other upon cooling. This structure creates a three-dimensional gel matrix that can hold water molecules and other components such as starch [15]. Hydrocolloids and starch can interact through hydrogen bonds between hydroxyl groups in the polysaccharide chain and starch. This interaction slows down water mobility and changes the way starch granules expand during gelatinization, thereby modifying the viscosity profile of the dough and increasing the stability of the gel structure [19]. When starch is mixed with hydrocolloids, the hydrocolloids tend to inhibit starch granule swelling and modify the thickening curve, namely gelatinization characteristics, peak viscosity, and structure retention, which ultimately affect the elasticity and cohesiveness of the final product texture [19].

1.3. Research Objective

This study aims to determine the treatment of rice flour and mocaf proportions with the addition of kappa carrageenan on physicochemical characteristics, as well as the best treatment to produce gyoza wrappers that have organoleptic qualities close to or equivalent to commercial gyoza wrappers.

2. MATERIALS AND METHODS

This research was conducted from August to November 2025 at Food Analysis Laboratory and Sensory Testing Laboratory of UPN "Veteran" East Java, Trunojoyo University Madura and PT Padi Flour Nusantara. The ingredients used for the gluten-free gyoza wrappers were Rose Brand rice flour, Ladang Lima brand mocaf, CV Surya Artathama brand kappa carrageenan, Rose Brand tapioca flour, salt, sesame oil, and water. The research used a completely randomized design (CRD) with two replications. The first factor was the proportion of rice flour:mocaf (40:60; 50:50; and 60:40), while the second factor was the addition of kappa carrageenan (8, 10, and 12%). Data were analyzed using ANOVA and DMRT at a 5% confidence level.

3. RESULT AND DISCUSSION

The results of objective observations on gluten-free gyoza wrappers included testing of water, ash, starch, amylose, amylopectin and multiple comparison tests to determine the sensory assessment between gluten-free and commercial gyoza wrappers.

3.1. Moisture

Statistical analysis showed a significant interaction ($p \leq 0.05$) between the ratio of rice flour to mocaf and the addition of kappa carrageenan, and each treatment had a significant effect ($p \leq 0.05$) on the moisture of gluten-free gyoza wrappers. Figure 1 shows that the highest moisture in gluten-free gyoza wrappers was found in the rice flour:mocaf ratio (40:60) with the addition of 8% kappa carrageenan, namely 53.72%. Meanwhile, the lowest moisture for gluten-free gyoza wrappers was found in the rice flour:mocaf ratio (50:50) with the addition of 12% kappa carrageenan, which was 48.43%. This is thought to be because mocaf tends to have a higher moisture than rice flour. This is also based on the characteristics of mocaf, which is easily hydrated due to fermentation and enzymatic modification. Fermentation partially breaks down cell walls and starch granules, making the -OH groups in starch molecules more exposed. Hydroxyl groups are hydrophilic, making them more likely to form hydrogen bonds with water molecules.

The addition of kappa carrageenan tends to increase the moisture due to its hydrophilic nature, which forms a three-dimensional gel network that traps water molecules, thereby increasing water retention in the dough matrix and preventing water loss during processing and cooking. However, in this study, the addition of kappa carrageenan actually decreased the moisture in gluten-free gyoza wrappers. This is thought to be due to the formation of a very dense gel network at higher carrageenan concentrations, trapping some of the initially free or easily measurable water within the gel structure and making it undetectable by wet-based moisture measurement methods.

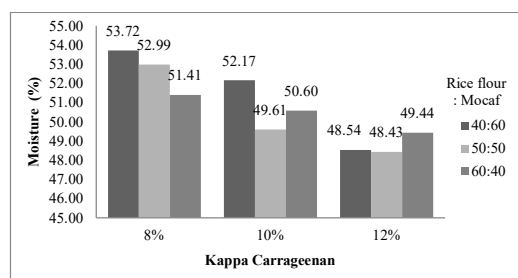


Fig. 1. Moisture gluten-free gyoza wrappers

3.2. Ash

Statistical analysis showed a significant interaction ($p \leq 0.05$) between the proportion of rice flour : mocaf and the addition of kappa carrageenan, and each treatment had a significant effect ($p \leq 0.05$) on the ash of gluten-free gyoza wrappers. Figure 2 shows that the rice flour:mocaf ratio (60:40) with 12% kappa carrageenan produced the highest ash of 2.10%. Meanwhile, the lowest ash was found in the rice flour and mocaf ratio (50:50) with 8% kappa carrageenan, which was 1.61%.

This is thought to be due to differences in flour characteristics. The highest proportion of rice flour added produced the highest ash content. Rice starch has the ability to undergo gelatinization, which produces a strong gel matrix that can bind mineral components more stably under heat conditions, thereby producing higher ash [20]. In addition to the proportion of flour used, the addition of kappa carrageenan also affects the ash of gluten-free gyoza wrappers. This is due to the hydrophilic properties and mineral ion binding ability of carrageenan, so that the minerals contained in the dough can be more tightly bound in the gel network that is formed.

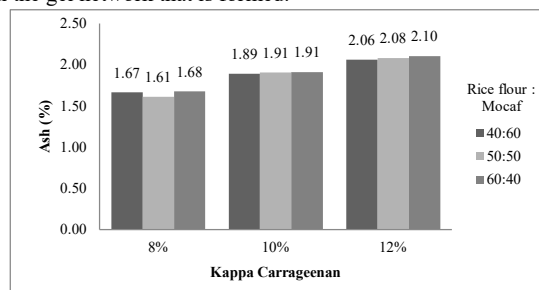


Fig. 2. Ash gluten-free gyoza wrappers

3.3. Starch

Statistical analysis results show a significant interaction ($p \leq 0.05$) between the proportion of rice flour : mocaf and the addition of kappa carrageenan, and each treatment has a significant effect ($p \leq 0.05$) on gluten-free gyoza skin starch. Figure 3 shows that the rice flour:mocaf ratio (60:40) with the addition of 8% kappa carrageenan produced the highest starch content, namely 42.90%. Meanwhile, the lowest starch was found in the rice flour:mocaf ratio (40:60) with the addition of 12% kappa carrageenan, namely 37.16%.

This is thought to be because the starch in rice flour is more dominant than in mocaf, so when used in gluten-free gyoza skin formulations, rice flour provides more starch granules to the dough. The largest component of rice flour is starch, which is 76-82%. Meanwhile, mocaf tends to have low starch due to modifications in the fermentation process [21].

In addition, the addition of kappa carrageenan also affects the starch in gluten-free gyoza wrappers, with higher

concentrations of kappa carrageenan resulting in lower starch content. This is thought to be due to the formation of a denser gel network due to the addition of kappa carrageenan at high concentrations, so that some starch granules are trapped in the gel matrix and are not easily measured as free starch during analysis.

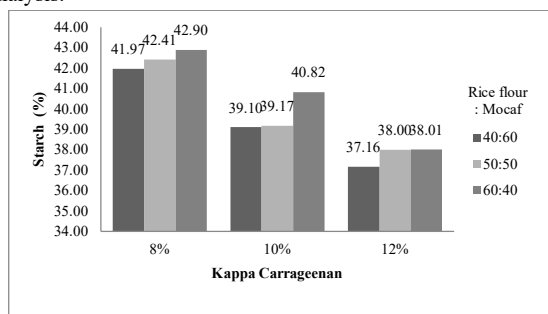


Fig. 3. Starch gluten-free gyoza wrappers

3.4. Amylose

Statistical analysis showed a significant interaction ($p \leq 0.05$) between the proportion of rice flour: mocaf and the addition of kappa carrageenan, and each treatment had a significant effect ($p \leq 0.05$) on the amylose of gluten-free gyoza wrappers. Figure 4 shows that the proportion of rice flour: mocaf (60:40) with the addition of 8% kappa carrageenan produced the highest amylose content, namely 11.06%. Meanwhile, the lowest amylose was found in the rice flour: mocaf ratio (40:60) with the addition of 12% kappa carrageenan, namely 6.01%.

This is thought to be due to the higher amylose of rice flour compared to mocaf, so that a higher proportion of rice flour will increase the amylose of gluten-free gyoza wrappers. Rice starch is generally a cereal starch that has a higher amylose than tuber starch [22].

The addition of hydrocolloids, kappa carrageenan, also affects the amylose in gluten-free gyoza wrappers, where the higher the kappa carrageenan, the lower the amylose. This is due to the ability of kappa carrageenan to form a three-dimensional gel network with starch, so that some of the amylose is trapped in the gel matrix and is not easily extracted or measured as free amylose during chemical analysis.

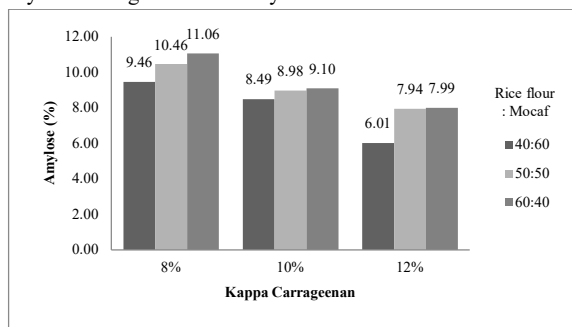


Fig. 4. Amylose gluten-free gyoza wrappers

3.5. Amylopectin

Statistical analysis results show that there is a significant interaction ($p \leq 0.05$) between the treatment of rice flour : mocaf ratio with the addition of kappa carrageenan and each treatment has a significant effect ($p \leq 0.05$) on the amylopectin of gluten-free gyoza wrappers. Figure 5 shows that the treatment of rice flour: mocaf (40:60) with the addition of 8% kappa carrageenan

produced the highest amylopectin value of 32.51%. Meanwhile, the lowest amylopectin value was found in the rice flour : mocaf ratio (60:40) with the addition of 12% kappa carrageenan, which was 30.02%. This is thought to be due to the differences in the functional properties of each starch. Amylopectin in mocaf is more easily gelatinized and absorbs water compared to amylopectin in rice flour, so more amylopectin remains in a soluble form that can be measured. The addition of kappa carrageenan has the same effect on starch, amylose, and amylopectin content, where the lower the addition of kappa carrageenan, the higher the starch, amylose, and amylopectin content.

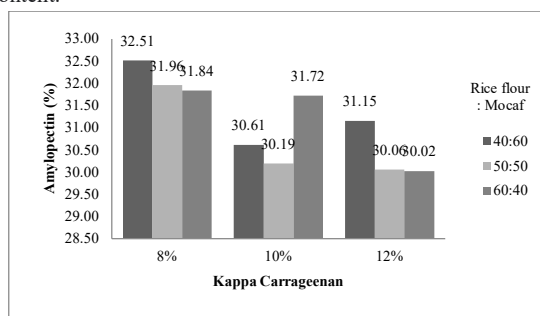


Fig. 5. Amylopectin gluten-free gyoza wrappers

3.6. Sensory Evaluation

This study conducted a multiple comparison test with 25 semi-trained panelists. The test assessed the color, aroma, and texture of gluten-free gyoza wrappers compared to commercial gyoza wrappers (R) on a scores scale of 1-5 (more or less than R).

Color

Table 1. Gluten-free gyoza wrappers color analysis

Treatment		Color
Rice flour : Mocaf (%)	Kappa Carrageenan (%)	
40 : 60	8	2.56 ^b
	10	2.20 ^a
	12	1.96 ^a
50 : 50	8	2.56 ^b
	10	2.64 ^b
	12	2.08 ^a
60 : 40	8	3 ^c
	10	2.68 ^c
	12	2.08 ^a

The results of statistical analysis showed that there was a significant interaction ($p \leq 0.05$) between the treatment of the proportion of rice flour: mocaf with the addition of kappa carrageenan and each treatment had a significant effect ($p \leq 0.05$) on the color of gluten-free gyoza skin. The treatment of the proportion of rice flour: mocaf (60:40) with the addition of 8% kappa carrageenan produced the highest color, namely 3 with the same bone white criteria as the control. Meanwhile, the lowest color value in the proportion of rice flour: mocaf (40:60) with the addition of 12% kappa carrageenan was 1.96 with the criteria of slightly less bone white than the control. The difference in color between gluten-free gyoza skin and the control was caused by the difference in flour used. The higher the addition of mocaf and kappa carrageenan, the lower the color match between gluten-free gyoza skin and the control.

Aroma

The statistical analysis showed no significant interaction ($p \geq 0.05$) between the rice flour : mocaf ratio and kappa carrageenan addition, and each treatment had no significant effect ($p \geq 0.05$) on the aroma of gluten-free gyoza skin. The average aroma scores for gluten-free gyoza skin compared to the control ranged from 2.40 to 3.04. The rice flour:mocaf ratio (50:50) with 10% kappa carrageenan added produced the lowest aroma score, 2.40, with the same neutral criteria as the control. Meanwhile, the highest aroma score was obtained from the rice flour : mocaf ratio (40:60) with 8% kappa carrageenan added, at 3.04, with the same neutral criteria as the control. Small differences in aroma tended not to be consistently detected, resulting in values that were not statistically significant.

Texture

The statistical analysis showed no significant interaction ($p \geq 0.05$) between the rice flour: mocaf ratio and the addition of kappa carrageenan. Neither treatment had a significant effect ($p \geq 0.05$) on the texture of gluten-free gyoza skin. The mean texture scores, compared with the control sample, ranged from 3.56 - 4.04. The lowest texture score (3.56) was observed in the formulation with a rice flour : mocaf ratio of 60:40 and 8% kappa carrageenan, with a slightly more elastic criterion than the control, at 3.56. Meanwhile, there were three samples that had the highest texture value, namely the proportion of rice flour: mocaf (40:60) with the addition of 8% kappa carrageenan, the proportion of rice flour: mocaf (40:60) with the addition of 10% kappa carrageenan, and the proportion of rice flour: mocaf (50:50) with the addition of 10% kappa carrageenan had a texture scores of 4.04 with the criteria of being slightly more elastic than the control.

4. CONCLUSION

Based on the analysis of variance (ANOVA), it was found that there was a significant interaction between the proportion of rice flour: mocaf with the addition of kappa carrageenan ($p \leq 0.05$) on the parameters of water, ash, starch, amylose, amylopectin, and color parameters in the sensory evaluation. However, there was no significant interaction ($p \geq 0.05$) on the pasta profile and aroma and texture parameters in the sensory evaluation.

The optimal treatment was the rice flour : mocaf proportion of (40:60) with the addition of 8% kappa carrageenan. This formulation produced gluten-free gyoza wrappers with a moisture of 53.72%, ash of 1.67%, starch of 41.97%, amylose of 9.46%, and amylopectin of 32.51%. In terms of sensory attributes, the product exhibited a color score of 2.56 (comparable to the off-white color of the reference), an aroma score of 3.04 (similar to the neutral aroma of the reference), and a texture score of 4.04 (slightly more elastic than the reference sample).

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