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Physical and Organoleptic Characteristics of Non-Gluten Macaroni from Composite Flour (Tapioca, Rice, and Corn) with Xanthan Gum Addition

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A B S T R A C T

Macaroni is a widely popular pasta product traditionally made from durum semolina wheat flour, which contains high levels of gluten. In this study, gluten-free macaroni was developed using alternative flour sources. The objective of this study was to evaluate the effects of different proportions of tapioca flour, rice flour, and corn flour, along with the addition of anchovy flour and xanthan gum, on the physical (rehydration capacity and cooking loss) and organoleptic (color, aroma, taste, and texture) characteristics of gluten-free macaroni. A factorial Completely Randomized Design (CRD) with two factors and two replications was used. Factor I was the proportion of tapioca flour, rice flour, and corn flour (55:35:10 g, 60:20:20 g, and 65:5:30 g). Factor II was the xanthan gum concentration (1%, 2%, 3%). If a significant difference was detected, further analysis was conducted using Duncan's Multiple Range Test (DMRT) at a 5% significance level, followed by a hedonic organoleptic evaluation using the Friedman test. The results demonstrated a significant interaction between flour composition and xanthan gum concentration on rehydration capacity, which ranged from 100.52% to 105.47%, and cooking loss, which averaged between 1.28% and 3.19%. Organoleptic evaluation revealed significant differences in color and texture, while taste and aroma were not significantly affected. These findings suggest that optimizing flour composition and xanthan gum concentration can enhance the quality of gluten-free macaroni, providing an alternative for individuals with gluten intolerance.

Contribution to Sustainable Development Goals (SDGs):

SDG 2: Zero Hunger by promoting the diversification of food sources,
SDG 3: Good Health and Well-Being) by providing a gluten-free alternative beneficial for individuals with gluten intolerance,
SDG 12: Responsible Consumption and Production by utilizing locally available, nutrient-rich ingredients such as anchovy flour. Developing gluten-free macaroni not only supports dietary diversity but also contributes to sustainable food production and improved public health.

1. INTRODUCTION

1.1. Research Background

Macaroni is one type of processed pasta that is very popular with the public. According to Ref. [1], pasta is the simplest cereal product, such as spaghetti, macaroni, vermicelli, and noodles. Macaroni is generally made from wheat flour. On the other hand, wheat flour is an imported commodity. The popularity of macaroni in Indonesia is currently causing an increase in the volume of wheat imports, so the development of local raw material macaroni is sought that can replace the use of wheat flour as a source of carbohydrates. Composite flour can be used as an alternative in making non-gluten macaroni whose properties are close to macaroni from wheat flour. The use of composite flour aims to obtain certain characteristics in processed products, both

to increase nutritional value and to meet functional food needs. The use of composite flour such as tapioca flour, rice flour, and corn flour can be used as an alternative, and the use of these flours can make innovative products, namely gluten-free macaroni. According to [2], composite flour can consist of a mixture of wheat flour with other flours, such as tuber flours, legumes, or cereals. Tapioca starch is a starch that is quite low in protein content and can provide chewiness. However, if the tapioca is quite a lot, it will give the food a chewy and even stickiness. While rice flour, in addition to being a binder, also functions as a thickener, the dough maker becomes elastic because rice starch contains 2 components, namely amylose and amylopectin. Corn flour contains protein and dietary fiber, which can also be a natural dye in macaroni products.

In general, local food ingredients have many advantages over wheat flour, including high fiber content, low glycemic index, and gluten-free. One of the advantages of gluten-free pasta is that it is good for people with celiac disease. According to [3] Individuals with gluten intolerance, such as people with allergies to gluten, people with celiac disease, and people with Autism Spectrum Disorder (ASD), must avoid gluten to avoid adverse effects on the body.

In making non-gluten macaroni, food additives are also needed, which function as a binder so that the ingredients used are not brittle and easily broken when passing through the molding process. The use of food additives such as hydrocolloids can improve the dough quality of gluten-free products. The hydrocolloid used in making gluten-free macaroni is xanthan gum. The use of xanthan gum as a hydrocolloid in pasta making provides several advantages, especially from the aspect of water absorption. Compared to other hydrocolloids such as guar gum, xanthan gum binds water more strongly. [4].

In addition to macaroni raw materials that use local and gluten-free ingredients to complement the nutritional value of macaroni, macaroni products are developed with the addition of anchovy rice flour. The addition of anchovy flour serves as a flavoring and substitute for MSG so that it can increase the nutritional content of the food, especially the protein and calcium content. So, by making this food development, it is hoped that it can meet the nutritional needs of children, especially protein and calcium.

1.2. Literature Review

Macaroni is an extruder-processed product resulting from extrusion techniques that is classified as a snack food other than the chips and cracker group, which is consumed as a break between main meals [5]. The specialty of macaroni is rich in complex carbohydrates, especially starch, high in protein, low in fat, and does not cause fat. Besides that, it is easy to prepare, is available in various shapes and sizes, and can be used in various types of dishes. It is also simpler and easier to store than other grain products such as bread and cakes and is durable because macaroni is a dry food product [6].

Factors that can influence the preparation of non-gluten macaroni are gelatinization and starch. The amount of amylose-amylopectin fraction greatly affects the gelatinization profile of starch. Amylose has smaller size with an unbranched structure. Amylopectin is a large molecule with a multi-branched structure and forms a double helix. When starch is heated, some of the double helix of the amylopectin fraction stretches and detaches as hydrogen bonds are broken. If a higher temperature is applied, more hydrogen bonds will be broken, causing water to be absorbed into the starch granules. In this process, amylose molecules are released into the water phase that envelops the granule, so the structure of the starch granule becomes more open, and more water enters the granule, causing the granule to swell and increase in volume. The water molecules then form hydrogen bonds with the sugar hydroxyl groups of the amylose and amylopectin molecules. On the outside of the granule, the amount of free water decreases while the amount of released amylose increases. Amylose molecules tend to leave the granule because of their shorter structure and solubility. This mechanism explains that the heated starch solution will be thicker [7].

1.3. Research Objective

This study aims to analyze the effect of the proportion of tapioca flour, rice flour, and corn flour, with the addition of xanthan gum on the physical characteristics (rehydration power, cooking loss) and organoleptic (color, aroma, taste, and texture) of non-gluten macaroni.

2. MATERIALS AND METHODS

2.1. Material and Tools

The ingredients used in making non-gluten macaroni are anchovy rice, Rose Brand tapioca flour, Rose Brand white rice flour, Iels Organic Foods yellow corn flour, xanthan gum, water, and egg yolk.

The tools used for making non-gluten macaroni include an electric oven, digital scales, macaroni maker, stove, pan, 80 mesh sieve, measuring cup, container, spoon. Tools used for analysis in this research include oven, hot plate, a measuring cup, and a thermometer.

2.2. Design Experiment and Analysis

This study used a completely randomized design (CRD) factorial pattern with two repetitions consisting of two factors Factor I: the proportion of tapioca flour; rice flour; and corn flour, A1 (55 g tapioca flour: 35 g rice flour: 10 g corn flour), A2 (60 g tapioca flour: 20 g rice flour: 20 g corn flour), and A3 (65 g tapioca flour: 5 g rice flour: 30 g corn flour). While Factor II was the addition of xanthan gum (1%; 2%; 3%).

Table 1. Treatment combination between the proportion of Tapioca Flour, Rice Flour, and Corn Flour with Xanthan Gum

Tapioca flour: Rice flour: Corn Flour	Xanthan Gum		
	B1	B2	B3
A1	A1B1	A1B2	A1B3
A2	A2B2	A2B2	A2B3
A3	A3B3	A3B2	A3B3

Description:
A1B1: Proportion of tapioca flour, rice flour, corn flour (55 grams: 35 grams: 10 grams) and the addition of 1% xanthan gum.
A1B2: Proportion of tapioca flour, rice flour, corn flour (55 grams: 35 grams: 10 grams) and the addition of xanthan gum 2%.

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A1B3: Proportion of tapioca flour, rice flour, corn flour (55 grams: 35 grams: 10 grams) and the addition of 3% xanthan gum.
A2B1: Proportion of tapioca flour, rice flour, corn flour (60 grams: 20 grams: 20 grams) and the addition of 1% xanthan gum.
A2B2: Proportion of tapioca flour, rice flour, corn flour (60 grams: 20 grams: 20 grams) and the addition of xanthan gum 2%.
A2B3: Proportion of tapioca flour, rice flour, corn flour (60 grams: 20 grams: 20 grams) and the addition of 3% xanthan gum.
A3B1: Proportion of tapioca flour, rice flour, corn flour (65 grams: 5 grams: 30 grams) and addition of 1% xanthan gum.
A3B2: Proportion of tapioca flour, rice flour, corn flour (65 grams: 5 grams: 30 grams) and the addition of xanthan gum 2%.
A3B3: Proportion of tapioca flour, rice flour, corn flour (65 grams: 5 grams: 30 grams) and the addition of xanthan gum 3%.
The data obtained were analyzed using Analysis of Variance (ANOVA) at the 5% level. If there were significant differences, further tests were conducted using the DMRT (Duncan Multiple Range Test) method at the 5% level..

2.3. Making of Non-Gluten Macaroni

Preparation and weighing of ingredients to be used, namely tapioca flour, rice flour, corn flour and anchovy flour with formulations of (55 g: 35 g: 10 g), (60 g: 20 g: 20 g), (65 g, 05 g, 30 g) Addition of xanthan gum (1%; 2%; 3% (b/b)), egg yolk 10% (b/b), and water 60% (b/v). Mixing all ingredients and then kneading the dough. Macaroni molding with a macaroni maker. Steam macaroni at 1000C for 15 minutes. Drying using an electric oven at 64oC for 2 hours. Dried macaroni was analyzed for physical characteristics (rehydration power, cooking loss). Dry macaroni is boiled for 15 minutes to become ready-to-eat macaroni, and then organoleptic analysis (texture, color, aroma, and taste) is carried out.

3. RESULT AND DISCUSSION

3.1. Analysis of Physical Characteristics of Non-gluten Macaroni

3.1.1. Rehydration Power

The results of ANOVA analysis showed that the treatment of the proportion of tapioca flour: rice flour: corn flour with the addition of xanthan gum showed a real interaction ($p \leq 0.05$) on the rehydration power of macaroni. The mean value of macaroni rehydration power can be seen in **Table 2.**

Based on Table 2, the rehydration power of macaroni ranges from 100.52% to 105.47%. The highest rehydration power value is in the proportion of tapioca flour: rice flour: corn flour 65:05:30 with the addition of xanthan gum 3% and the lowest rehydration power is 100.52% in the proportion of tapioca flour: rice flour: corn flour 55:35:10 with the addition of xanthan gum 1%. The graph of the relationship between the treatment of the proportion of tapioca flour: rice flour: corn flour and the addition of xanthan gum to the rehydration power of macaroni can be seen in Figure 1,

Table 2. Results of rehydration power analysis of non-gluten macaroni

Formulation	Rehydration Power (%)
A1B1	100.52±0.44[a]
A1B2	100.73±0.11[a]
A1B3	101.34±0.34[b]
A2B1	102.24±0.11[c]
A2B2	102.71±0.25[c]
A2B3	102.97±0.20[d]
A3B1	103.48±0.35[e]
A3B2	104.05±0.11[f]
A3B3	105.47±0.32[g]

Note: mean values accompanied by different letters mean significantly different ($p \leq 0.05$).

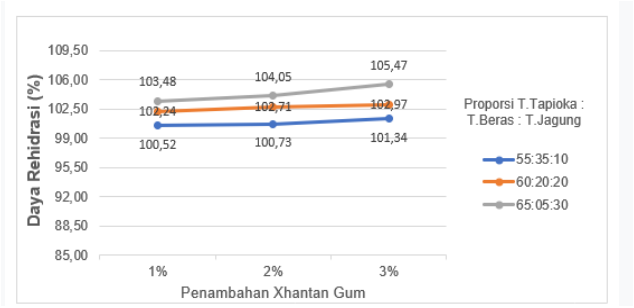

Figure 1. The relationship between the treatment of the proportion of tapioca flour, rice flour corn flour and the addition of xanthan gum on the rehydration power of macaroni.

Rehydration power is the process of water absorption back into dry ingredients that have previously undergone gelatinization [8]. The lower the hydration power, the shorter the time the macaroni can be served. **Figure 1**. shows that the higher the proportion of tapioca flour and corn flour, and the lower the proportion of rice flour and the higher the addition of xanthan gum, the higher the rehydration power. The starch content in the raw materials, especially the amylose content, can play an important role in the rehydration power of a product, where the higher the amylose content in the material, the higher the water absorption capacity.

The more tapioca flour and corn flour and the higher the addition of xanthan gum, the more water is bound to the starch gelatinization process during steaming, and the more gelatinized starch will form a cavity structure that makes it easier for water to enter during rehydration. This is supported by the statement of [9] that the higher the amylose content, the higher the water absorption capacity. Increasing amylose content will increase the capacity of starch granules to absorb water and volume development because amylose has a greater capacity to bind hydrogen than amylopectin. In addition, amylose is also easily absorbed water so that the rehydration power increases during the rehydration process as the amylose content increases.

The higher the addition of xanthan gum, the higher the rehydration power of macaroni. This is thought to be because xanthan gum is a hydrocolloid so it can easily bind water. Following Ref. [10] about the mechanism of xanthan gum, namely hydrophilic polymer compounds will expand when dispersed into water then the hydration process of water molecules occurs through the formation of hydrogen bonds and then the molecules will be trapped in a complex molecular structure.

3.1.2. Cooking Loss

The results of ANOVA analysis showed that the treatment of the proportion of tapioca flour: rice flour: corn flour with the addition of xanthan gum showed a real interaction ($p \leq 0.05$) on the rehydration power of macaroni. The average value of cooking loss of macaroni can be seen in Table 3 below:

Table 3. Results of cooking loss analysis of non-gluten macaroni

Formulation	Cooking Loss (%)
A1B1	3.19 ± 0.09^{g}
A1B2	2.88 ± 0.02^{f}
A1B3	2.70 ± 0.08^{e}
A2B1	2.69 ± 0.16^{e}
A2B2	2.50 ± 0.11^{d}
A2B3	2.14 ± 0.02^{c}
A3B1	2.33 ± 0.16^{c}
A3B2	1.85 ± 0.19^{b}
A3B3	1.28 ± 0.01^{a}

Note: mean values accompanied by different letters mean significantly different ($p \leq 0.05$).

The results of the study **Table 3.** Shows that the average cooking loss of macaroni ranges from 1.28% - 3.19%. The highest cooking loss value was found in the treatment of the proportion of tapioca flour: rice flour: corn flour 55: 35 : 10 with the addition of 1% xanthan gum (3.19%) and the lowest cooking loss value in the proportion of tapioca flour: rice flour: corn flour 65: 05: 30 with the addition of 3% xanthan gum (1.28%). The graph of the relationship between the treatment of the proportion of tapioca flour: rice flour: corn flour and the addition of xanthan gum to the cooking loss of macaroni can be seen in **Figure 2.**

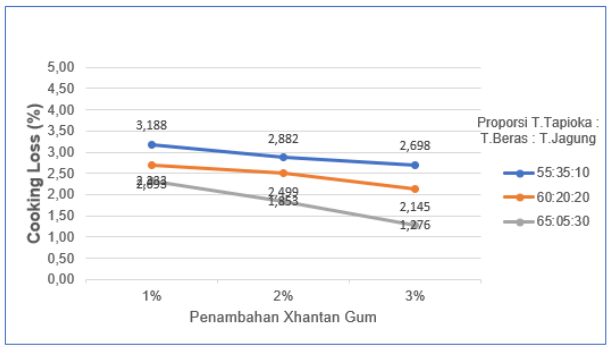

Figure 2. The relationship between the treatment of the proportion of tapioca flour: rice flour corn flour and the addition of xanthan gum on the rehydration power of macaroni.

Cooking loss is the loss of solids or ingredients from dry noodles that occurs during boiling. The greater the cooking loss value, the less desirable the dry noodle product [11]. Based on **Figure 2.**, the higher the proportion of tapioca flour and corn flour, the lower the rice flour, and the greater the addition of xanthan gum causes the cooking loss of macaroni to decrease. The difference in cooking loss value in macaroni can be influenced by the starch content of the basic ingredients. By [12] The small amount of total solids lost during the cooking process is caused by the high starch content in the material, causing the gel structure to form stronger.

In addition to the high starch content in the ingredients, the decrease in cooking loss value is also due to the addition of xanthan gum, where the greater the addition of xanthan gum, the smaller the cooking loss value. The decrease is thought to be due to the ability of xanthan gum to retain starch during the cooking process so that only a few solids are lost. This is supported by Ref. [13] The lack of solids linked during the cooking process is due to the formation of complex bonds between amylose and hydrocolloids, which will reduce the process of releasing amylose from starch granules.

3.1.3. Organoleptic

Organoleptic analysis of non-gluten macaroni includes color, aroma, taste, and texture. This level of liking is called a hedonic scale; for example: score 1 for strongly dislike, score 2 for dislike, score 3 for somewhat like, score 4 for like, and score 5 for strongly like. The results of the organoleptic analysis with the Friedman test can be seen in **Table 4.**

Table 4. Results of the average organoleptic score of non-gluten macaroni

Formulation	Color	Fragrance	Taste	Texture
A1B1	2.96	2.84	2.60	3.60
A1B2	3.08	2.96	2.96	2.96
A1B3	2.96	2.80	2.64	2.84
A2B1	3.60	2.80	2.36	2.88
A2B2	3.64	3.16	2.84	2.88
A2B3	3.60	2.68	2.92	2.96
A3B1	4.00	2.88	2.80	3.00
A3B2	4.00	3.08	2.96	3.12
A3B3	4.04	3.24	3.08	2.84

Based on the results of the analysis, it shows that the average value of macaroni color has a value range of 2.96 - 4.04. The lowest average panelist favorite score was found in the treatment of the proportion of tapioca flour: rice flour: corn flour 55: 35: 10 with the addition of 1% xanthan gum 2.96 (rather like) and the highest average favorability score was found in the proportion of tapioca flour: rice flour: corn flour 65: 05: 30 with the addition of 3% xanthan gum which is 4.04 (like). Color liking in macaroni increases as the proportion of corn flour used increases.

Based on the results of the analysis, the value of macaroni aroma ranged from 2.68 to 3.24. The treatment of the proportion of tapioca flour: rice flour: corn flour 60: 20: 20 and the addition of xanthan gum 3% gave the lowest aroma value of 2.68 (somewhat like) The highest aroma value was found in the proportion of tapioca flour: rice flour: corn flour 65: 05: 30 with the addition of xanthan gum 3% 3.24 (rather like). This is due to the treatment of the proportion of flour used, which does not have a significant effect. Based on this, according to the panelists, the macaroons have almost the same aroma because the treatment of the proportion of flour and the addition of xanthan gum do not affect the aroma of macaroons, so it is difficult to distinguish the aroma.

The average value of the panelists' favorability score for the taste of macaroni products has a value range of 2.36 - 3.08. Treatment of the proportion of tapioca flour: rice flour: corn flour 60: 20: 20 and the addition of 3% xanthan gum gave the lowest aroma value with an average score of 2.36 (dislike). The highest aroma value was found in the proportion of tapioca flour: rice flour: corn flour 65: 05: 30 with the addition of 3% xanthan gum with an average score of 3.08 (somewhat like). The treatment of tapioca flour, rice flour and corn flour did not have a significant effect on the taste of the macaroni produced. The taste of the

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macaroons produced according to the panelists was almost the same with the difference in treatment. The addition of xanthan gum did not affect the flavor of the non gluten macaroni.

The average value of panelists' favorability score for the texture of macaroni products has a value range of 2.84 - 3.60. Treatment of the proportion of tapioca flour: rice flour: corn flour Macaroni with the proportion of tapioca flour: rice flour: corn flour 55: 35: 10 with the addition of 1% xanthan gum was most favored by panelists because the texture was not too sticky. This is thought to be because the amylopectin content of tapioca flour and rice flour is quite high so the more the proportion of tapioca flour, flour, and corn flour is added, the stickier the texture of the macaroni will be. This is because amylopectin is difficult to retrogradate to maintain the noodle structure [14]. In addition, starch with high amylose content is less adhesive and dry, while starch containing high amylopectin is adhesive and wet.

The addition of xanthan gum can also affect panelists' liking of macaroni texture, the more xanthan gum is added, the lower the value of macaroni texture, it is thought that because xanthan gum is added too much, the texture of macaroni can become too sticky, or too elastic, thus reducing the sensory quality of the product. The addition of xanthan gum can increase the robustness and strength of noodles [15].

4. CONCLUSION

The results showed that there was an interaction between the proportion of tapioca flour, rice flour, corn flour, and the addition of xanthan gum on rehydration power ranging from 100.52% - 105.47%, cooking loss 1.28% - 3.19%,. The results of the organoleptic test produced significant differences in color and texture, while the taste and aroma were not significantly different.

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