

The Potential of Cassava Starch to Improve the Quality of Artificial Nori Made from Green Grass Jelly Leaves and Papaya

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Abstract - Artificial nori is a dry sheet food product resembling nori made from materials other than seaweed. In this study, nori was made from green grass jelly and papaya. The quality of artificial nori can be influenced by its binding material. Cassava starch has potential as a binder in making analog nori. This study aims to determine the potential of cassava starch to improve the quality of artificial nori made from green grass jelly leaves in terms of moisture content, total dissolved solids, water absorption capacity, texture, and sensory quality. The addition of 5% cassava starch to artificial nori made from grass jelly and papaya leaves reduced the total dissolved solids, water absorption capacity and hard texture of artificial nori, but had no effect on other sensory properties. Cassava starch has the potential to improve the texture of artificial nori so that it is drier but not too brittle.

Keywords: artificial nori, Binder, green grass jelly, papaya, texture.

I. INTRODUCTION

Nori is a thin, dry, greenish-black sheet food product made from seaweed. *Porphyra* seaweed, as the raw material for nori, thrives in subtropical aquatic habitats such as those found in Japan, Korea, and China, making it difficult to cultivate in Indonesia. However, due to the popularity of nori in Indonesia, it is imported from its countries of origin to meet consumer demand. The popularity of nori presents an opportunity for the development of similar products using raw materials available in Indonesia.

In Indonesia, there are papaya and green grass jelly plants. Papaya (*Carica papaya* L.) is a tropical fruit widely consumed by the population. The nutritional composition of papaya fruit per 100 g includes 86.8 g of water; 12.1 g of carbohydrates; 0.5 g of protein; 0.3 g of fat; 0.27 g of fiber; 0.5 g of ash; 0.204 g of potassium; 0.011 g of phosphorus; and 0.001 g of iron, as well as 0.45 g of vitamin A and 0.075 g of vitamin C. Additionally, papaya fruit is a source of lycopene

and carotenoids, including β -carotene and β -cryptoxanthin. Green grass jelly (*Premna oblongifolia*) is a plant capable of forming gel obtained from the pectin compounds it contains (Palupi, 2015). In addition to fiber, 100 g of green grass jelly provides 122 calories, 29 g of carbohydrates, 1 g of fat, 6 g of protein, 100 mg of calcium, 100 mg of phosphorus, 3.3 mg of iron, 107.5 IU of vitamin A, 80 mg of vitamin B1, 17 mg of vitamin C, and 66 g of water (Umumah et al., 2018). Green grass jelly also contains bioactive compounds such as chlorophyll, flavonoids, saponins, alkaloids, tannins, steroids, and glycosides.

The production of artificial nori requires the use of binding agents that can enhance integrity, resulting in a dense and compact texture. Cassava starch allows it to be used as a binder in making artificial nori. The addition of binding agents serves to form a gel that can improve the texture of nori, a gel-forming activity also possessed by green grass jelly leaves. This study aims to determine the potential of cassava starch to improve the quality of artificial nori made from green grass jelly leaves in terms of moisture content, total dissolved solids, water absorption capacity, texture, and sensory quality.

II. MATERIAL AND METHOD

2.1 Materials

The materials used in this study consisted of Bangkok papaya fruit purchased from Pasar Bulu, Semarang, green grass jelly leaves purchased from HEINZ ABC Official Shop, cassava starch, salt, garlic powder, margarine purchased from Pasar Sampangan, Semarang, sesame oil purchased from, and distilled water purchased from Toko Kimia Indrasari, Semarang.

2.2 Equipment

The equipment used during the research included baking trays, analytical balances, ovens, a hand refractometer (Digital Hand-Held Refractometer Atago Pocket 3810 PAL1, Japan), and a texture analyzer (Brookfield CT, USA).

2.3 Research Procedure

The research was conducted in two stages: preliminary research and main research. The preliminary research involved formulation trials to produce artificial nori from papaya fruit and green grass jelly. The main research stage involved the production of artificial nori from papaya fruit and green grass jelly with addition 5% of cassava starch and no binding material. The nori was then analyzed for its physical and chemical properties, including moisture content, total dissolved solids, water absorption capacity, and texture. Sensory quality analysis of nori included assessment of color, aroma, taste, and texture.

2.3.1 Process of making artificial nori from papaya fruit and green grass jelly

The process of making artificial nori from papaya fruit and green grass jelly involves three stages: mixing, molding, and baking (Agusta et al., 2017). Papaya fruit and green grass jelly leaves are separately blended. The mashed papaya is then placed in a bowl and mixed with green grass jelly paste, seasonings such as salt and garlic powder, and binding agents (P0: no binding agent added, P1: addition of 5% cassava starch (w/w)). The mixture is then molded into thin sheets in trays greased with margarine and baked in an oven at 100°C for 2 hours until the nori becomes flexible. The nori sheets are then brushed with sesame oil and baked again in the oven at 100°C for 3 hours until they are dry.

2.3.2 Moisture Content Testing

Moisture content testing is conducted using the oven drying method. Dry nori is ground into powder using a mortar. A porcelain cup is weighed, and its weight is recorded as weight A. The nori sample is then placed in the porcelain cup, and its weight is measured as 2 g, recorded as weight B. Duplicate weighing of the nori sample is performed. The porcelain cup containing the sample is heated in an oven at 105°C for 4 hours. The porcelain cup containing the sample is removed from the oven, cooled in a desiccator for 15 minutes, and then weighed. The cup is then heated again in the oven for 1 hour to achieve a constant weight (AOAC, 2009). The constant weight obtained is recorded as weight C. The moisture content can be calculated using the formula:

% Moisture Content =

$$\frac{(\text{Weight B} - (\text{Weight C} - \text{Weight A}))}{\text{Weight B}} \times 100\%$$

2.3.3 Total Dissolved Solids Testing

Total dissolved solids testing are performed using a hand refractometer. Dry nori samples are ground into powder and dissolved in distilled water. The refractometer prism is rinsed

with distilled water and wiped with a cloth. The sample solution is then dropped onto the refractometer prism in 1 - 2 ml increments, and the Brix degree is measured (AOAC, 2000).

2.3.4 Water Absorption Capacity Testing

Dry nori samples are cut into 2 × 3 cm pieces, weighed, and recorded as W₀, then soaked in distilled water for 10 seconds. The samples are removed and the surface dried with tissue paper. The dried samples are then weighed again, recorded as W. The soaking process is repeated until a constant weight is achieved (Maulana and Sunardi, 2021). The water absorption capacity can be calculated using the formula:

$$\% \text{ Water Absorption Capacity} = \frac{(W - W_0)}{W_0} \times 100\%$$

2.3.5 Texture Testing

Texture testing is performed using a texture analyzer. Artificial nori samples in sheet form are cut into 5 × 5 cm pieces. The probe or puncture needle is installed and positioned, and the device is set to zero on the monitor. The test start menu is selected, causing the probe to puncture the sample. Texture testing is completed when the probe returns to its original position (Nugroho et al., 2018). The results of the test can include graphs and numerical values.

2.3.6 Sensory Testing

Sensory testing involves descriptive evaluation by a semi-trained panel of 25 individuals from the Faculty of Animal agricultural Science at Diponegoro University, Semarang. Descriptive evaluation is conducted by presenting nori samples on plastic plates and sample papers. Panelists are asked to taste the product and evaluate its texture, color, taste, and aroma. A scale of 1 - 10 is used, where a value of 10 represents the strongest intensity. Panelists are asked to fill out a form provided by the researcher, which includes instructions, panelist responses, testing guidelines, and researcher identity (Widyastuti et al., 2020).

2.3.7 Data analysis

Data obtained from the testing results are analyzed using t-test by SPSS 26.0 for Windows software at a confidence level of 95%.

III. RESULTS AND DISCUSSIONS

The chemical properties of artificial nori made from papaya fruit and green grass jelly with cassava starch as binding agent and no binding agent are presented in Table 1.

Table 1: The Comparison of Chemical Properties of Artificial Nori from Papaya Fruit and Green Grass Jelly with cassava starch and no binding agent

Treatments	Moisture (%)	Total Dissolved (°Brix)
No binding	16.23±0.59 ^a	13.90±0.79 ^a
Cassava starch 5%	15.72±0.62 ^a	8.80±0.82 ^b

The values presented are mean ± standard deviation (n=10). Values with same superscripts that do not have similarities in the same column indicate significant differences after being analyzed using t-test.

3.1 Moisture content

The moisture content of the products ranged from 15.72 % to 16.23%. The T-test revealed that the highest moisture content, 16.23%, was obtained in nori without any binding agent (0%). Nori with cassava starch as the binding agent had moisture content similar to nori without any binding agent. Green grass jelly leaves contain crude fiber in the form of pectin compounds that have the ability to form gel. During the gel formation process, pectin coagulation occurs, forming fine fibers capable of trapping and retaining liquid. The three-dimensional network is connected by cross-linking polymer chains that are hydrocolloids. Hydration occurs through hydrogen bonding, causing water molecules to be trapped in the food material, which affects the high moisture content (Andriani et al., 2021). Additionally, the high moisture content of artificial nori without any binding agent is also due to the high pectin content, where pectin gel has principles similar to a sponge system filled with water. Cassava starch contains a relatively high amount of starch, which has the ability to bind water. During oven drying, the starch in cassava undergoes gelatinization. Gelatinization is the process of swelling of starch granules that cannot return to their original form. The swelling of starch granules is caused by water molecule penetration into the granules, trapping within the amylose and amylopectin molecular structures.

3.2 Dissolved solids

The values of total dissolved solids range between 8.80 and 13.9°Brix. T-test revealed that the highest total dissolved solids, 13.9°Brix, were obtained in nori without any binding agent (0%). Nori with cassava starch as the binding agent exhibited total dissolved solids more less compared without binding agent. The high total dissolved solids in the treatment without any binding agent could be attributed to the pectin content in green grass jelly, a constituent of the total dissolved solids. Apart from green grass jelly, papaya fruit, as a raw material, is one of the fruits with relatively high pectin content, reaching 7 grams. Papaya fruit also contains significant sugar content: 48.3% sucrose, 29.8% glucose, and

21.9% fructose. This is consistent with Hedyana et al. (2021), who stated that reducing sugars, non-reducing sugars, protein, pectin, and organic acids are constituents of total dissolved solids. The high pectin content results in more bound sugars, water, and dissolved solids.

According to Kamaluddin and Handayani (2018), a lower total dissolved solids value indicates lower water content and higher solids content in food materials, resulting in lower dissolved solids in the material. Artificial nori with 5% tapioca flour exhibited lower total dissolved solids compared to artificial nori without any binding agent. This is due to the lower water resistance of cassava starch as a binding agent. According to Putra et al. (2017), cassava starch has low water resistance due to its amorphous amylopectin content, resulting in the formation of many empty spaces and reduced mass density between starch chains.

The Physical properties of artificial nori made from papaya fruit and green grass jelly with variations in binding agents are shown in Table 2.

Table 2: The Physical Properties of Artificial Nori Papaya and Green jelly leaves with cassava starch as binding agent (5%) and no binding agent

Treatments	Water absorption capacity (%)	Texture (g)
No binding agent	35.78±0,30 ^b	276,3±16,12 ^b
Cassava starch 5%	21,68±0,19 ^a	234,1±29,57 ^a

Note: The values attached are the average ± standard deviation (n=10) with different superscripts indicating real differences after analysis by T-test.

3.3 Water absorption capacity

The water absorption capacity ranges between 21.68% and 35.78%. ANOVA and DMRT showed that the highest water absorption capacity, 103.16%, was obtained in nori with 5% agar powder as the binding agent, while the lowest water absorption capacity, 21.68%, was obtained from nori with 5% tapioca flour as the binding agent. Nori with CMC as the binding agent and nori without any binding agent exhibited water absorption capacity between nori with tapioca flour as the binding agent and nori with agar powder as the binding agent.

Artificial nori with 0% binding agent had relatively low water absorption capacity. The low water absorption capacity could be due to the moisture content, as higher moisture content tends to decrease water absorption capacity. During cooking, the ability of pectin gel to bind a significant amount of water results in the high moisture content of artificial nori. This causes a decrease in water absorption capacity.

The low water absorption capacity can be influenced by tapioca flour and its relatively high moisture content. Food materials like flour with high moisture content tend to have reduced water absorption capacity. Additionally, the low water absorption capacity may be due to the presence of amylose content in tapioca flour. According to Putra et al. (2013), the high amylose content in starch affects the reduced ability to absorb water.

The high-water absorption capacity is also influenced by agar powder as a source of fiber. Water absorption capacity is highly influenced by fiber content, where higher fiber content leads to higher water absorption capacity. Commercial nori has a relatively high-water absorption capacity of 97.5%, which can be influenced by the fiber content in commercial nori. The high-water absorption capacity in artificial nori with 5% CMC and 5% agar powder, as well as in commercial nori, indicates that nori easily crumbles when consumed, while artificial nori with 0% binding agent and 5% tapioca flour has relatively low water absorption capacity, making it difficult to crumble when consumed.

3.4 Texture

The texture values range between 234.1 g and 859.2 g. ANOVA and DMRT showed that the highest texture value, 859.2 g, was obtained in nori with 5% CMC as the binding agent, while the lowest texture value, 234.1 g, was obtained from nori with 5% tapioca flour as the binding agent. Nori with agar powder as the binding agent and nori without any binding agent exhibited textures between nori with tapioca flour as the binding agent and nori with CMC as the binding agent. These texture values represent the peak load or peak load force. The texture value or hardness represents the breaking force in texture testing, which determines the strain or stress on food materials until reaching the fracture condition.

Artificial nori with 5% binding agent has a chewy texture due to the high pectin content, which can form a gel. This is consistent with the study by Permatasari et al. (2016), which stated that a high concentration of added pectin in fruit leather production would result in a chewy texture. The high pectin content in cincau and papaya pulp will form a dense structure of fine fibers, resulting in a chewy gel texture.

The addition of tapioca flour produces a chewy texture due to the amylopectin component present in tapioca flour. The heating process causes amylopectin to form a chewy gel texture. Tapioca flour or cassava starch contains 17% amylose and 83% amylopectin. The amylose in tapioca flour will gelatinize to produce flexible and strong artificial nori. The amylose structure stimulates the formation of hydrogen bonds between glucose molecules. Additionally, the heating process

will result in the formation of a strong gel with amylose forming a three-dimensional network that can trap water.

3.5 Sensory quality

The sensorial properties of artificial papaya and green grass jelly nori with varying binding agent treatments are shown in Table 3. Values presented mean \pm standard deviation (n=5) with different superscripts indicating significant differences after being analyzed with the Kruskal-Wallis and Mann-Whitney tests.

3.5.1 Color

Table 3 indicates that the intensity of black color ranges between 5.8 – 7.4, green color intensity ranges between 3.48 – 4.24, and brown color intensity ranges between 5.76 – 8.24. Color is an important characteristic influencing food product selection. Food products with less attractive colors may be less preferred even if they have appealing taste, aroma, and texture and are rich in nutrients. Attractive colors increase consumer interest and appetite for the food product. The Maillard reaction is the main factor contributing to the brownish-black color in artificial nori. The Maillard reaction is a non-enzymatic browning reaction that occurs between reducing sugars and amino groups of amino acids due to heating. Brown color in the final product originates from melanoidin compounds produced by the Maillard reaction.

Table 3: Sensory Quality of Artificial Nori with cassava starch (5%) as binding agent and no binding Agent

Treatments	color		
	black	Green	brown
No binding	7.08 \pm 0.95 ^a	3.88 \pm 1.09 ^a	5.88 \pm 1.09 ^a
Cassava starch (5%)	7.40 \pm 0.81 ^a	4.24 \pm 1.05 ^a	5.76 \pm 1.09 ^a
Treatments	Unique nori aroma	Umami taste	Crunchiness
No binding	4.96 \pm 1.09 ^a	4.92 \pm 1.03 ^a	5.96 \pm 1.05 ^b
Cassava starch (5%)	4.52 \pm 1.00 ^a	5.40 \pm 1.04 ^a	5.32 \pm 1.02 ^a

The blackish color in artificial nori may be due to compounds present in the raw materials. One of these is flavonoids in cincau leaves, resulting in blackish-green cincau jelly. Flavonoids in cincau leaves bind with monosaccharides or disaccharides, resulting in a blackish color. Chlorophyll, a green pigment, may suffer damage due to heating. Heating leads to protein denaturation, causing unprotected chlorophyll to be easily damaged. Additionally, heating affects chlorophyllase and lipoxygenase enzyme activity. Chemical degradation of chlorophyll can occur through oxidation reactions, pheophytinization reactions, and chlorophyllide formation. The brownish-green color in artificial nori results

from pheophytinization, where pheophytin, having a brownish-green color, is formed. This reaction occurs due to the release of magnesium ions from the center of chlorophyll molecules and their replacement with H ions, with more magnesium ions being released with increased heating (Lalopua, 2018).

Beta-carotene in papaya can degrade due to the heating process. Prolonged heating can deactivate enzymes in beta-carotene pigments, inducing non-enzymatic oxidation reactions. This can cause color fading, affecting the final product. Storage at room temperature also reduces beta-carotene pigments in foodstuffs. Air or oxygen and room temperature as factors causing reduction of beta-carotene pigments lead to isomerization and enzymatic and non-enzymatic oxidation. This results in the breakdown of conjugated bonds and color fading. According to Oktora et al. (2016), the reduction in beta-carotene compounds due to room temperature is caused by the degradation of all-trans β -carotene at room temperature, making it easily decomposable and resulting in food color fading.

Nori quality can be assessed based on its color. High-quality nori has sheets with blackish-green color, while sheets with green to light green color are of lower quality. Low-quality nori may be characterized by sheets with brown or green color. Commercial nori sheets with blackish-green color come from chlorophyll and phycobilin components found in *Porphyra* seaweed (Lalopua, 2018).

3.5.2 Aroma

Table 3 shows that the intensity of artificial nori aroma ranges from 4.52 – 5.68. Aroma is a key characteristic perceived by the olfactory sense and is important for consumer acceptance of food products. Aroma is generated by vapor during the cooking process, where cooking influences the aroma produced.

The aroma of artificial nori is greatly influenced by the drying process using an oven, resulting in the Maillard reaction. The Maillard reaction between amino groups and reducing sugars produces volatile compounds with a characteristic baked aroma. During the Maillard reaction, Strecker degradation occurs, resulting in pleasant aroma compounds from furfural and maltol formation. The Maillard reaction occurs in several stages, beginning with the reaction of amino acids and reducing sugars (aldose) to produce Schiff bases. Subsequently, changes occur via the Amadori reaction to form amino ketoses. The Amadori reaction products undergo dehydration, resulting in the formation of furfuraldehyde from pentoses or 5-hydroxymethyl furfural from hexoses. Further dehydration produces several methyl diketone products such as acetate, diacetyl, and

methylglycosyl, as well as active aldehyde-aldehyde compounds. The addition of sesame oil to the surface of artificial nori is believed to improve the aroma of the final product. This is in line with the opinion of Seftiono and Puspitasari (2019), who state that the drying process and the addition of sesame oil to the surface of analog nori will result in analog nori that is generally preferred by panelists. The addition of binding agents to food products generally does not affect the final aroma due to the neutral aroma of the binding agent.

3.5.3 Taste

Table 3 shows that the intensity of artificial nori taste ranges from 4.92 – 5.48. Taste is an important characteristic of a food product. Taste is a critical factor in the final decision-making of consumers regarding the acceptance of food products. If a food product has good texture, aroma, and color ratings but the taste is unacceptable, the food product may be rejected. The taste of a food product comes from the food itself and can change due to processing and the influence of other added ingredients (Hartati and Djauhari, 2017). Taste attributes consist of sweet, sour, salty, bitter, and umami or savory tastes.

The taste of artificial nori is influenced by added seasonings such as salt and garlic powder. The lack of savory taste may be due to the low content of glutamic acid in these seasonings. This is consistent with Natanael et al. (2021), who state that the lack or blandness of nori taste may be due to low levels of glutamic acid. Commercial nori has umami taste derived from free amino acids such as glutamic acid, taurine, alanine, and aspartic acid. According to Trahutami (2019), umami is a savory taste as the fifth taste proposed by Japanese scientists in 1908. In addition to umami taste, commercial nori also has a natural salty taste from the seaweed used. The natural salty taste of seaweed is produced by high iodine and mineral content.

Moreover, the less savory taste of artificial nori may be due to the added binding agents. Increasing hydrocolloid concentration can mask the flavor of added seasonings, resulting in a bland product taste. The application of sesame oil to artificial nori is believed to help improve the savory taste of artificial nori. This is in line with the opinion of Inats et al. (2020), who state that the addition of sesame oil can improve the organoleptic value of food products because it has a very savory taste.

3.5.4 Texture

Table 3 shows that the intensity of artificial nori texture ranges from 5.12 – 6.12. Texture is an important characteristic defined as the pressure sensation observed and felt when

biting, chewing, swallowing, or feeling the surface of a food material. The texture of a food material can be characterized as hard, soft, chewy, coarse, or fine. Artificial nori generally has a non-crispy texture, which may be due to the high moisture content of the material. This is consistent with Lalopua (2018), who states that moisture content greatly affects the texture of dry food products, with high moisture content resulting in less crispy texture. Artificial nori with less crispy texture may be less preferred by consumers.

The chewy texture of nori with 0% binding agent may be due to the high pectin content in green grass jelly and papaya, which has the ability to form a dense fibrous structure, resulting in a chewy gel texture. Meanwhile, with 5% tapioca flour addition, the chewy texture is due to tapioca flour added as a binding agent, where the amylopectin component forms a chewy gel texture during the heating process.

The tendency for a hard texture caused by the addition of CMC binding agents can increase the hardness of the product. According to Fitriana et al. (2021), increasing hydrocolloid content can lead to increased gel matrix, resulting in reduced porosity and decreased elasticity while increasing hardness. Artificial nori with agar addition has a texture that tends to be brittle, which may be due to the low concentration of agar added as a binding agent and the slow mixing process of the dough.

Table 4: Screen Printing Parameters

Printed Layer	Temp, °C	Absolute humidity, g/cm ³	Observation delamination
Interconnect Lines	25	16	Negative
	40	40	Two lines (12% of the total length) delaminated.
	80	80	Three Lines (18% of the total length) delaminated.
Dielectric (Force Concentrators)	25	16	Negative
	40	40	Negative
	80	80	Negative
P(VDF-TrFE)	25	16	Negative
	40	40	Complete delamination
	80	80	Complete delamination
MWCNT/PDMS	25	16	Negative
	40	40	Negative
	80	80	Negative

IV. CONCLUSION

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