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Edible Film Made of Corn Starch-Carrageenan-Rice Bran: The Characteristic of Formula's Viscosity, Water Content, and Water Vapor Transmission Rate

Edible Film *Pati Maizena-Karagenan-Bekatul Padi: Karakteristik Viskositas Formula, Kadar Air, dan* Water Vapour Transmission Rate

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Abstract

This research aimed to obtain the best formulation of corn starch, carrageenan, and rice bran as the main components of edible film to improve formula's viscosity, water content, and Water Vapour Transmission Rate (WVTR). This research was an experimental research using Randomized Complete Block Design (RCBD). The first factor was corn starch concentration (1.5%; 2.5%; 3.5%), the second factor was carrageenan concentration (0.67%; 1%; 1.33%), and the third factor was rice bran concentration (0.12%; 0.25%; 0.38%). The analysis of variance showed that the interaction of corn starch, carrageenan, and rice bran has a significant impact on the viscosity, water content, and WVTR value of the edible film. Based on the viscosity, water content, and WVTR value of the edible film, the best formulation was found in the edible film with the corn starch concentration of 2.5%, 1% carrageenan, and 0.25% rice bran. The formula's viscosity value of this edible film was 165.1 ± 5.3 cP, with 14.65 ± 0.05% of water content, and 60.13 ± 0.05 $g/m^2/h$ of WVTR value.
Keywords: carrageenan, corn starch, edible film, rice bran

Abstrak

Tujuan dari penelitian ini adalah untuk mendapatkan formulasi terbaik dari pati maizena, karagenan, dan bekatul padi sebagai komponen dasar edible film *untuk meningkatkan viskositas formula. kadar air, dan* Water Vapour Transmission Rate (WVTR). *Penelitian ini dilakukan secara eksperimental dengan menggunakan Rancangan Acak Kelompok (RAK). Faktor pertama adalah konsentrasi pati maizena (1,5% ; 2,5% ; 3,5%), faktor kedua adalah konsentrasi karagenan (0,67%; 1%; 1,33%), dan faktor ketiga adalah konsentrasi bekatul padi (0,12% ; 0,25% ; 0,38%). Hasil analisis ragam menunjukkan interaksi penambahan pati maizena, karagenan, dan bekatul padi berpengaruh nyata terhadap viskositas formula* edible film, *kadar air, dan nilai WVTR* edible film. *Formulasi terbaik sesuai karakteristik viskositas formula* edible film, *kadar air, dan nilai WVTR* edible film *adalah* edible film *dengan konsentrasi pati maizena 2,5%, karagenan 1%, dan bekatul 0,25% yang memiliki nilai viskositas formula* edible film *sebesar 165,1 ± 5,3 cP, kadar air* edible film *sebesar 14,65 ± 0,05%, dan nilai WVTR* edible film *sebesar 60,13 ± 0,05 g/m^2/jam.*
Kata kunci: *bekatul padi,* edible film, *karagenan, pati maizena*

INTRODUCTION

These days, plastic packaging becomes a dominant contributor of waste globally, and its amount has increased up to 8% (Muizniece-Brasava, Dukalska, & Kantike, 2011). From the whole amount of plastic packaging, under 5% of wastes are recycled and the remaining is left accumulated in the environment (Espitia et al., 2014). According to the Ministry of Environment and Forestry data, the total amount of waste generation in Indonesia in 2019 is estimated to reach over 68 million tons. Meanwhile, the total plastic wastes are around 9.52 million tons (Suryani, 2016). The pile of wastes will cause environmental pollution since plastic has a non-biodegradable characteristics or cannot be decomposed easily by the microorganism, so that it is needed to produce biodegradable and more eco-friendly packaging.

Edible film packaging is an alternative to reduce the impacts of a non-biodegradable plastic wastes. Generally, the edible film is made of biopolymer, such as polysaccharides, protein, lipid, or composite, and other added substances. Any additional substances are used, i.e., plasticizer, vitamin, anti-microbial, and essential oil with food-grade characteristics (Lamdande, Garud, & Kadam, 2013; Rusli et al., 2017; Erkmen & Bozoglu, 2016).

One of the polysaccharide types that is widely used in the production of the edible film is starch. Starch is used to make an edible film since it is a renewable natural resource that abundantly available. It can also decompose naturally and the film generated is transparent, odorless, and non-toxic (Nouraddini, Esmaiili, & Mohtarami, 2018). Corn starch also has a hygroscopic characteristic, similar to any polysaccharides found around us. Among other starch types, the hygroscopic nature of corn starch is much lower than cassava starch, rice starch, or even potato starch. However, corn starch utilization still has some weaknesses, such as deficient mechanics and water holding ability.

As one of the natural organic polymer types, carrageenan can improve the characteristic of edible film. Carrageenan is a polymer in the form of sulfate polysaccharides extracted from red seaweed (*Rhodophyceae*). Based on its chemical structure and features, there are three types of carrageenan; those are lambda, iota, and kappa. Kappa carrageenan is one of the carrageenan types that is frequently used in edible film research. It has a specific characteristic that can form a robust gel so that it can increase the ability to produce a well-formed film (Paula et al., 2015; Farhan & Hani, 2017).

The use of filler is also an alternative to improving edible film from polysaccharides-based composite from its mechanical characteristic. Adding filler will increase the mechanical feature of the young modulus and tensile strength (Harper, 2004). Several fillers used are including cassava dregs (Teixeira et al., 2012; Versino, López, & García, 2015), lignin (Privas, Leroux, & Navard, 2013), wheat bran, and rice bran (Cano et al., 2014).

Some research on polysaccharides-based edible film has been performed; some of them are including an edible film made from canna starch (Santoso et al., 2011), an edible film from lindur fruit (Jacoeb, Nugraha, & Utari, 2014), edible film made from taro starch (Pangesti, Rahim, & Hutomo, 2014), edible film made from breadfruit-chitosan starch (Setiani, Sudiarti, & Rahmidar, 2013), an edible film from corn starch (Kusumawati & Putri, 2013), edible film made from sago starch, and carrageenan (Anggraeni & Pranoto, 2011), edible film made from rice bran and carrageenan (Thakur et al., 2016), edible film from carrageenan and locust bean gum (Martins et al., 2012). However, research on corn starch and carrageenan-based edible film with the addition of rice bran as the filler has not been performed before.

Rice bran is chosen as filler since it is high in fiber, which can improve the mechanical characteristic (young modulus and tensile strength). Besides, this ingredient can also inhibit water vapor in edible film. Rice bran as a byproduct of the rice fermentation process contains about 15-20% of fat, 12-16% of protein, 23-28% of fiber, and 7-10% of ash. Rice bran is also rich in vitamin B and E (Carroll, 1990). The high fiber content of rice bran is potentially used as a filler to improve the characteristic of edible film. According to Rossman (2009), soluble and insoluble fiber can be used to formulate edible film.

In this research, the edible films made of corn starch and carrageenan and the addition of rice bran as filler. This research aims to generate corn starch-carrageenan-rice bran formulation as the main ingredients of edible film. Edible film yielded from the composite of corn starch-carrageenan-rice bran will be measured, more specifically for the formula's viscosity, water content, and WVTR of the edible film.

METHOD

Tools used in this research are including beaker glass, thermometer, hotplate stirrer (Thermo Scientific Cimarec), magnetic stirrer, aluminum foil, analytical scale (Kern ABS 220-4N), spatula, measuring cup, measuring pipette, oven, desiccator, 35 cm x 21 cm stainless steel mod media, dehumidifier (KRIS PD20E-20, RRC), oven (Memmert), viscometer (Brookfield), furnace (Fuji), climatic chamber (Biobase).

Any ingredients used in this research is including commercial corn starch under the brand of "Maizenaku", grade I BPPT carrageenan, commercial rice bran flour under the brand of "Bekatul Sehat Barokah Jaya", glycerin "Brataco" and distilled water.

This research used Randomized Complete Block Design (RCBD), which consists of three factors: the proportion of corn starch, carrageenan, and rice bran. There are 27 variations made from the combination of corn starch, carrageenan, and bran dissolved in 300 ml of distilled water with the following proportions:

Corn Starch	: 1.5%; 2.5%; 3.5% (b/v).
Carrageenan	: 0.67%; 1%; 1.33% (b/v).
Rice Bran	: 0.12%; 0.25%; 0.38% (b/v).

Raw Material Characterization and Film Production Process

The quality of corn starch, carrageenan, and rice bran as raw material is examined using water content (AOAC, 2005) and ash content.(AOAC, 2005)(AOAC, 2005).

The process in edible film production performed by using gel casting method, begun with dissolving and heating corn starch (1.5% ; 2.5% ; 3.5% (b/v)) in 150 ml of distilled water up to the temperature of 70 ºC (Maran et al., 2013) as well as carrageenan (0.67%; 1%; 1.33% (b/v)) and rice bran (0.67% ; 1%; 1.33% (b/v)) in 150 ml of distilled water up to the temperature of 60 ºC (Alves, Costa, & Coelhoso, 2010; Purwoto & Christri, 2017). After each solution reaches this temperature, the temperature is maintained for 30 minutes. Then, mixing those two solutions and glycerin (2% v/v) for 20 minutes. The mixed solution was stirred using a magnetic stirrer to make it homogeneous. Then, the solution was poured into a film mold and dried under RH conditions of 40% ± 5% (temperature conditions 30 ºC ± 5 ºC) for 24 hours. After the drying process, the edible film to be used was separated from the mold and wrapped in aluminum foil, stored in a closed container filled with silica gel prior to analysis.

The Analysis of Edible Film Formula Viscosity and Water Content

The measurement was performed at room temperature. The spindle is immersed in the solution for 1 minute to achieve temperature balance between the solution and the spindle. Three viscometer readings of each solution were recorded and then the average value of those readings.

The analysis of water content was performed following the related method (AOAC, 2005). The cups were dried at 105 °C for 30 minutes then desiccated. Then, it was weighed. ± 3 grams of the sample was put in a cup and placed in an oven at 105 °C for 3 hours. It was then chilled in a desiccator and then weighed. The water content is determined using the equation of:

$$\text{water content} = \frac{\text{film initial weight-dried film weight}}{\text{film initial weight}}\ x\ 100\% \quad (1)$$

The Analysis of Water Vapour Transmission Rate (WVTR)

Water vapor Transmission Rate (WVTR) of the edible film was measured by using the gravimetric method by modifying the technique proposed by Xu et al. (2005) and Breemer, Polnaya, & Pattipeilohy (2012). Edible film samples that will be examined is covered in the cup containing 10 grams of silica gel. Then, the cup is placed in the climatic chamber with the RH condition of 75% at the temperature of 25 ºC±2. Water vapor diffused through the film was then absorbed by the silica gel so that its weight was increasing. The weight of the cup was noted every hour for around 8 hours. From the data earned, the linear regression was drawn and the slope was determined. Water vapor transmission rate is defined by the following equation:

$$\text{WVTR} = \frac{\text{slope of cup's weight increase}}{\text{surface area}} \quad (2)$$

Best Treatment Selection

The data obtained were then analyzed using the General Linear Model- Analysis of Variance (GLM-ANOVA) with α = 0.05. If there is a significant difference between the treatments, the testing process is continued with the Tukey test. The data obtained were then processed by using the MiniTab17 software application.

The best treatment was performed based on the test result of Tukey 5%. However, if it is difficult to determine the best treatment, then the Weighting Test will be carried out (De Garmo, Sullivan, & Cerook, 1984).

RESULTS AND DISCUSSION

Raw Material Characteristic

The result of the raw material analysis can be seen in Table 1. From the analysis of raw material quality, the result shows that corn starch's water content is 11.81% and ash content is 0.05%. Meanwhile, carrageen has 11.78% water content and 22.63% ash content. Additionally, rice bran's water content is 8.87% and its ash content is 8.02%.

Water content is one of the essential characteristics contained in the raw material. Water content referred to the water amount contained in the ingredients and stated in the form of a percentage. Water content analysis must be carried out to determine the amount of water contained in the raw material, which will affect the shelf-life of the raw material as a film base material. Setiani et al. (2013) stated that the water content of materials is related to metabolic activities during storage, such as microbial activity. The higher the water content is, the shorter the shelf-life of raw materials will be. This phenomenon happens as high water content will cause raw material to be easily contaminated by microbes. According to Bourbon et al. (2011), water content provides a hydrophobic indication that affects the mechanical properties of the ingredient, such as its tensile strength, modulus young and the WVTR edible film value produced.

The ash content in a material is a combination of inorganic or mineral components found in a food ingredient. This element is also known as organic substance or ash content. Ash content indicates the amount of mineral contained in certain ingredients. The higher the ash content of a material, the lower its purity. Ash content will affect the character of the edible film. Suptijah, Suseno, & Anwar (2013) stated that the mineral content in raw materials would affect the viscosity and strength of the gel produced. The higher mineral content of material causes increasing viscosity. However, if the mineral content is too high, the gel strength will get lower.

The Viscosity of Edible Film Formula

The viscosity of the edible film formula produced is ranging from 86.4 cP to 394.4 cP. As per the variance analysis result, the concentration of corn starch and rice bran bring significant impact. The interaction between the three factors also significantly impacts the viscosity value of the edible film formula. The formula of an edible film with the lowest viscosity was the formula with a concentration of 1.5% corn starch, a 0.67% carrageenan, and a 0.12% rice bran. Meanwhile, the formula of an edible film with the highest viscosity was the formula with 3.5% corn starch concentration, 1.33% carrageenan and 0.12% rice bran. Viscosity is the resistance of a solution to flow, which is caused by the friction force of material against shape changes if the material is subjected to absolute pressure. Viscosity indicates the thickness of a solution. The thicker a solution is, the greater the force required to make it flow at a certain speed. The viscosity of the edible film formula is expected to be neither too low nor too high. According to Budiman & Prangdimurti (2011) and Saberi et al. (2016), the viscosity value to form a good film is 113 cP - 255 cP. The viscosity value affects the ease of the molding process, drying speed, thickness, permeability and mechanical properties. The result of viscosity analysis on the edible film formula is illustrated in Table 2.

The test results show that the increasing concentrations of corn starch and carrageenan will also increase the edible film formula's viscosity. The interaction between corn starch and carrageenan in escalating the edible film formula's viscosity occurs due to the hydroxyl groups of the two components bonding to one another. This condition is in line with the result of Al-Hassan & Norziah (2012) research, which indicates that the viscosity of the edible film formula will increase when starch and hydrocolloids increase. When the starch and carrageenan concentrations increase, the starch and hydrocolloid associations become more dominant and most of the water molecules are mobilized. Moreover, an increase in the starch and hydrocolloid concentration has caused a rise in the polymer amount, which composing the film matrix. As a result, the film tissue will be higher and denser.

Table 1. The characteristic of corn starch, carrageenan and rice bran

Raw Material	Parameter		Literature	
	Water Content (%)	**Ash Content (%)**	**Water Content (%)**	**Ash Content (%)**
Corn starch	11.81 ± 0.07	0.05 ± 0.01	10,9[1]	0,03[1]
Carrageenan	11.78 ± 0.22	22.63 ± 0.14	Max. 12[2]	15 – 40[2]
Rice Bran	8.87 ± 0.37	8.02 ± 0.05	10,19[3]	11,08[3]

Description: [1](Neder-Suárez et al., 2016), [2](FAO/WHO Expert Committee, 2014), [3](Rosniyana, Hashifah, & Norin, 2007). The number that is following a ± symbol refers to the deviation standard.

Table 2. The characteristic of corn starch-carrageenan-rice edible bran edible film

Formula	Formula's Viscosity (cP)	Water Content (g)	WVTR (g/m^2/h)
M1K1B1	95,9±2,6^{op}	20,54±0,06^{a}	66,83±0,12^{a}
M1K1B2	86,4±4,1^{p}	19,05±0,07^{bc}	62,81±0,16^{fg}
M1K1B3	108,2±2,9^{no}	19,14±0,11^{b}	65,13±0,17^{c}
M1K2B1	234,0±5,8^{i}	18,40±0,21^{d}	66,42±0,34^{bc}
M1K2B2	144,3±10^{m}	17,80±0,04^{g}	63,60±0,06^{def}
M1K2B3	276,2±7,9^{h}	18,07±0,04^{de}	65,38±0,05^{bc}
M1K3B1	280,0±4^{h}	17,82±0,14^{fg}	63,29±0,25^{efg}
M1K3B2	239,4±4,2^{i}	16,76±0,06^{hi}	62,47±0,02^{fgh}
M1K3B3	234,5±5,1^{i}	16,87±0,03^{hi}	63,51±0,40^{defg}
M2K1B1	142,7±3,9^{m}	18,85±0,05^{c}	66,55±0,26^{ab}
M2K1B2	120,6±2,8^{n}	18,28±0,04^{de}	64,42±0,39^{cde}
M2K1B3	190,0±1,7^{k}	17,91±0,02^{fg}	64,35±0,07^{cde}
M2K2B1	208,3±2,4^{j}	16,77±0,14^{hi}	62,50±0,07^{fgh}
M2K2B2	165,1±5,3^{l}	14,65±0,05^{o}	60,13±0,05^{j}
M2K2B3	381,2±5,2^{ab}	15,75±0,05^{kl}	62,29±0,17^{gh}
M2K3B1	311,3±2,6^{ef}	16,10±0,01^{jk}	61,33±0,29^{hij}
M2K3B2	297,3±7,1^{fg}	16,25±0,01^{j}	61,35±0,12^{hij}
M2K3B3	371,2±6,6^{bc}	16,14±0,02^{jk}	62,31±0,16^{efg}
M3K1B1	103,7±3^{o}	15,21±0,09^{m}	64,16±0,06^{cde}
M3K1B2	191,5±6,3^{k}	15,21±0,02^{m}	64,64±0,05^{cd}
M3K1B3	152,9±4,4^{lm}	16,61±0,02^{i}	61,52±0,19^{hi}
M3K2B1	289,6±7,4^{gh}	14,94±0,07^{n}	61,52±0,24^{hi}
M3K2B2	345,2±5,2^{d}	15,89±0,09^{kl}	60,45±0,33^{ij}
M3K2B3	362,8±5,1^{c}	15,04±0,02^{m}	61,38±0,33^{hij}
M3K3B1	394,4±3,2^{a}	14,78±0,02^{no}	65,03±0,12^{c}
M3K3B2	313,7±4,1^{e}	14,83±0,03^{no}	60,55±0,30^{ij}
M3K3B3	335,3±4,8^{d}	16,88±0,16^{h}	60,76±0,20^{ij}

Description: Numbers followed by different notations indicate the significant difference (α <0.05) with Tukey's test.
M = *Pati Maizena* (Corn Starch); K = *Karagenan* (Carrageenan); B = *Bekatul Padi* (Rice Bran)

This condition will lead to an increase in the viscosity of the edible film formula. Lagarrigue & Alvarez (2001) also suggested that carrageenan, an electrolyte polymer, can bind with other hydrophilic compounds, such as the hydroxyl groups of corn starch. Carrageenan, which also has several hydroxyl bonds, also provides a place for binding with the hydroxyl group of corn starch. Consequently, the bonds that occur between carrageenan the corn starch will grow.

Increasing concentration of rice bran has lead to decreased viscosity of the edible film formula. However, at the highest concentration of rice bran, it will pass through a polynomial increase. The increase in viscosity occurs due to the increasing amount of insoluble solids in the edible film formula. According to Branco & Gasparetto (2003), viscosity is also affected by the existence of insoluble solids, such as insoluble fiber. Those insoluble solids have caused the formula's viscosity to increase. Cho & Dreher (2001) stated that rice bran is dominated by water-insoluble fiber, yet it contains water-soluble fiber, which is approximately only 2%. The bran's insoluble fiber content consists of cellulose (8.7% - 11.4%), hemicellulose (9.6% - 12.8%) and some lignin.

Viscosity's rise is also caused by the interaction between the bran with the corn starch while the carrageenan matrix reduces the mobility of water molecules. The formation of intermolecular hydrogen bonds between starch and carrageenan resulted in an edible film that has a more compact structure. Also, the three-dimensional tissue structure formed by carrageenan provides a robust intermolecular interaction between starch and carrageenan. This will further minimize the free volume and inter-molecular distance in the film structure. The more compact structure of the edible film as a result of the increasing hydrogen bonds in the intermolecular bonds causes higher tensile strength of the film. The interaction between corn starch and rice bran in increasing the tensile strength of edible film occurs due to the chemical and structural compatibility between corn starch and rice bran. This condition allows strong adhesion between the starch polymer matrix and fibers of rice bran. Additionally, the chemical structure similarity between corn starch and rice bran can induce strong intermolecular interactions through hydrogen bonds. This result is in line with the outcome of research performed by Chen et al. (2017) dan Nordin et al. (2018), which stated that adhesion of the fibers to the film matrix increases the tensile strength. According to Mastromatteo et al. (2008), adding bran concentration to the edible film will increase the number of immobilized water molecules so that the edible film formula's viscosity will also elevate.

Water Content of Edible Film

The water content of the resulted edible film is ranging from 14.65% to 20.54%. Based on the variance analysis result, corn starch concentration and rice bran bring significant impact. The interaction of those factors also has a significant impact on the water content of the edible film. The formula of the edible film with the lowest water content is the formula with a concentration of 1.5% corn starch, 0.67% carrageenan, and 0.12% rice bran. Meanwhile, the highest water content was found in a formula with a concentration of 1.5% corn starch, 0.67% carrageenan and 0.12% rice bran. It is crucial to determine the parameter value of water content since it closely relates to the resistance of the edible film to microbes' activity. Junianto, Haetami, & Maulina (2013) stated that fungi and molds are generally growing in organic products if the product's water content is between 20% to 60%. Whereas, if the water content exceeds 60%, the bacteria will quickly grow. Thus, the water content aspect is one of the critical parameters that must be met for the edible film. The analysis result of the water content of the edible film is presented in Table 2.

The testing results showed that the edible film's water content was getting lower with the increasing concentration of corn starch and carrageenan. The interaction between corn starch and carrageenan in lowering the water content of the edible film formula occurs due to the hydroxyl groups of the two components bonding to one another. This is in line with the statement of (Bourtoom, 2008) that the larger the polymer that makes up the film matrix, the lower the amount of water left in the film tissue. Increasing corn starch and carrageenan element will elevate the number of polymers make up the film matrix. The larger the polymer that makes up the film matrix will increase the number of solids so that the amount of water in the edible film will be lower. Rangel-Marrón et al. (2013) suggested that low polysaccharide concentration in the edible film-forming solution allows more free water availability to involve in the polymerization reaction.

Decreasing water content due to the concentration increase of the edible film primary substance is also caused by carrageenan as the main ingredient in this process. Carrageenan will carry dissolved solids in the edible film solution, which then causes the formation of hydrogen bonds between the constituent molecules of edible film. This resulted in a reduction in the free water content in the resulting edible film. There will be reduced water interaction space as a result of starch bonding in the carrageenan's double helix structure. According to, the availability of free OH groups from starch is reduced due to interactions with the anionic sulfate groups of carrageenan.

Water Vapor Transmission Rate (WVTR) of Edible Film

Water Vapor Transmission Rate (WVTR) edible film produced ranges from 60.13 g/m^2/h to 66.83 g/m^2/h. As per the variance analysis result, the concentration of corn starch and rice bran bring significant impact. The interaction of those factors also brings a significant effect on the WVTR value of the edible film. The edible film formula with the lowest WVTR value was the formula with 2.5% corn starch concentration, 1% carrageenan, and a 0.25% rice bran. While the formula with a concentration of 1.5% corn starch, 0.67% carrageenan and 0.12% rice bran had the highest WVTR value. WVTR is an indicator of the film's ability to maintain the water vapor transmission rate in a specific interval of time. Good packaging is expected to have a small permeability value to reduce the rate of water vapor transmission from the environment into the packaged product. Based on the Japanese Industrial Standard (1975) the maximum amount of WVTR is 10 g/m^2/h, while the transmission rate obtained in this study still does not meet the packaging film standard. However, the WVTR value of edible film in this study was even lower than the research conducted by Galdeano, et al. (2013), Wirawan, Pratiwi, & Ananingsih (2017) and Tóth & Halász (2019). The analysis result of the WVTR value of the edible film is presented in Table 2.

The test results show that the WVTR value decreases with corn starch, carrageenan and rice bran, but the WVTR will increase with a higher addition. Murdianto, Marseno, & Haryadi (2005) in their research stated that the increasing concentration of the gelling agents would lower the rate of water vapor transmission of edible film. This is because the increase in solution molecules causes the film matrix to increase so that a strong film structure with an increasingly compact and sturdy film network structure can increase the strength of the film to withstand the water vapor transmission rate. The straight-chain polymer components will form a dense network and space between cells in the edible film, which is formed is getting narrower so that it will be difficult for water to penetrate. At the same time, water vapor can penetrate easily into a tenuous film matrix.

According to Maran et al. (2013), the film solution component brings an impact on the water vapor permeability of the edible film. The materials used in this study (carrageenan, corn starch and glycerol) are hydrophilic, so these materials cause the water vapor permeability value to increase. Meanwhile, rice bran addition has a positive effect on reducing the rate of water vapor permeability. The decrease in the water vapor permeability rate of edible film composite starch corn starch-carrageenan-rice bran was related to the fiber content in rice bran with lower hydrophilicity than starch to high fiber crystallinity. According to Bilbao-Sáinz et al. (2010) , the transfer of water vapor will occur more quickly in non-crystalline regions. Rice bran, a component with cellulose, is a hydrophobic material that is difficult to dissolve in water, so the addition of rice bran to the film solution causes the edible film to have a low water vapor permeability value. Mastromatteo et al. (2008) and Fama et al. (2010) also reported that the addition of wheat bran in cassava starch significantly reduces WVTR edible film formation.

Best Treatment Selection

The determination of the best treatment on edible film corn starch-carrageenan-rice bran was tested for effectiveness, as stated by De Garmo et. al. (1984). The observation variables used were the viscosity formula of edible film, water content and WVTR. The higher for edible film formula's viscosity, and the lower for water content and WVTR value indicated the excellent quality of the

Table 3. Effectivity test to determine the characteristic of best *edible film*

Formula	Water content		WVTR		Viscosity		ΣNh
	Ne	Nh	Ne	Nh	Ne	Nh	
M1K1B1	-0,24	-0,06	-0,17	-0,08	0,0008	0,0002	-0,1423
M1K1B2	-0,22	-0,06	-0,16	-0,08	0,0007	0,0002	-0,1330
M1K1B3	-0,22	-0,06	-0,16	-0,08	0,0009	0,0002	-0,1361
M1K2B1	-0,21	-0,05	-0,16	-0,08	0,0019	0,0005	-0,1353
M1K2B2	-0,21	-0,05	-0,16	-0,08	0,0012	0,0003	-0,1303
M1K2B3	-0,21	-0,05	-0,16	-0,08	0,0023	0,0006	-0,1330
M1K3B1	-0,21	-0,05	-0,16	-0,08	0,0023	0,0006	-0,1297
M1K3B2	-0,19	-0,05	-0,16	-0,08	0,0020	0,0005	-0,1257
M1K3B3	-0,20	-0,05	-0,16	-0,08	0,0019	0,0005	-0,1273
M2K1B1	-0,22	-0,05	-0,17	-0,08	0,0012	0,0003	-0,1370
M2K1B2	-0,21	-0,05	-0,16	-0,08	0,0010	0,0002	-0,1327
M2K1B3	-0,21	-0,05	-0,16	-0,08	0,0016	0,0004	-0,1314
M2K2B1	-0,19	-0,05	-0,16	-0,08	0,0017	0,0004	-0,1258
M2K2B2	**-0,17**	**-0,04**	**-0,15**	**-0,07**	**0,0014**	**0,0003**	**-0,1168**
M2K2B3	-0,18	-0,05	-0,15	-0,08	0,0031	0,0008	-0,1222
M2K3B1	-0,19	-0,05	-0,15	-0,08	0,0026	0,0006	-0,1222
M2K3B2	-0,19	-0,05	-0,15	-0,08	0,0024	0,0006	-0,1227
M2K3B3	-0,19	-0,05	-0,15	-0,08	0,0031	0,0008	-0,1234
M3K1B1	-0,18	-0,04	-0,16	-0,08	0,0009	0,0002	-0,1235
M3K1B2	-0,18	-0,04	-0,16	-0,08	0,0016	0,0004	-0,1240
M3K1B3	-0,19	-0,05	-0,15	-0,08	0,0013	0,0003	-0,1242
M3K2B1	-0,17	-0,04	-0,15	-0,08	0,0024	0,0006	-0,1191
M3K2B2	-0,18	-0,05	-0,15	-0,08	0,0028	0,0007	-0,1204
M3K2B3	-0,17	-0,04	-0,15	-0,08	0,0030	0,0007	-0,1190
M3K3B1	-0,17	-0,04	-0,16	-0,08	0,0032	0,0008	-0,1228
M3K3B2	-0,17	-0,04	-0,15	-0,08	0,0026	0,0006	-0,1175
M3K3B3	-0,20	-0,05	-0,15	-0,08	0,0028	0,0007	-0,1237

Description: M = *Pati Maizena* (Corn Starch); K = *Karagenan* (Carrageenan); B = *Bekatul Padi* (Rice Bran). Ne = Estimated value; Nh = Result value; ΣNh = Total result value.

edible film. WVTR variable is given a weight of 1 and water content and viscosity of the formula are each given a weight of 0.5. The treatment with the highest product value (NP) or yield value (NH) is considered the best treatment because the value is obtained by considering all the variables that play a role in determining the edible film's best characteristics.

The de Garmo test results showed that the best treatment was M2K2B2 with a composition of 2.5% corn starch, 1% carrageenan and 0.25% bran with a viscosity value of the formula edible film of 165.1 ± 5.3 cP, edible film water content is 14.65% ± 0.05% and the WVTR edible film value is 60.13 $g/m^2/h$ ± 0.05 $g/m^2/h$. The overall ranking of corn starch combinations, carrageenan, and rice bran as raw materials for the edible film is presented in Table 3.

CONCLUSIONS

The results of the study showed that the interaction between the formula edible film starch corn starch-carrageenan-rice bran has a significant effect on the characteristics of the edible film including an increase in the viscosity of the formula, decreasing water content and WVTR. The best formulation according to the features of the formula's viscosity, water content, and WVTR value is an edible film with the addition of 2.5% corn starch, 1% carrageenan and 0.25% rice bran, which has viscosity formula 165.1 cP, water content 14.65%, and WVTR value 60.13 $g/m^2/h$.

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