__Original Research Article__

Physical Quality of Fast SealingDissolving Edible Films as Food Packaging Based Glucomannan and Gelatin

.

ABSTRACT

The edible film is an alternative that can be used as eco-friendly packagingmaterial(biodegradable) as a plastic substitute. The material that can be used in making edible filmsis glucomannan, which can dissolve easily but is less elastic. It is necessary to add strong, elastic and easily soluble material using gelatin to improve the properties of edible films. Edible films composed of hydrocolloids had hydrophilic properties which bind easily with water. The research to obtain edible film formulated glucomannan and gelatin with the best physical quality, fast sealing and fast dissolving. The research material used glucomannan and gelatin with different concentrations designed by 5 treatments and 3 replications consisting of T1: 0,5% gelatin, T2: 0.625% gelatin, T3: 0.75% gelatin, T4: 0,875 gelatin and T5: 1% gelatin. The variables tested were solubility, total soluble matter, swelling, water content, thickness, L*, a*, b* color, browning index and whiteness index. The research method was experimental, calculatedwith Analysis of Variance (ANOVA) using Completely Randomized Design (CRD) andDuncan's Multiple Range Test (DMRT) if there were differences.The results showed highly significant differences ($P<0.01$) on swelling and thickness. The results showed significant differences ($P<0.05$) on total soluble matter, water content and L* color. However, there were no significant differences ($P>0.05$) on solubility, a* color, b* color, browning index and whiteness index. The results of the data based on physical quality consist of solubility ranging from 11.2-24.5%, total soluble matter 27.6-60.6%, swelling 3.49-7.75%, water content 11.5-12.15%, thickness 0.09-0.14 mm, L* color 91.3-92.5, a* color 0.78-1, b* color 1.52-2.81, browning index 2.23-3.7 and whiteness index 94.51-99.34. In conclusion, the use of edible films formulated with glucomannan and gelatin with a concentration of 0.5% produces the best physical quality, the resulting edible film has high solubility and is easy to seal.

Keywords: Edible film; fast sealing dissolving,gelatin, glucomannan

1. INTRODUCTION

The majority of the food industry in Indonesia uses plastic as the main material for its product packaging. The food industry is one of the sectors that uses plastic as the main material for packaging and the intensity of the use of plastic materials for food products to increase every year, this is because plastic is an easy material, adding aesthetic and flexible value because plastic has sheet shapes and can changed shape according to the desired design and size. The use of packaging must be considered both in terms of health and the environment, plastic composed of synthetic polymers that are difficult to degrade for a very long time, causing pollution and if the plastic is burned it will produce a carbon emission that can damage the environment [1]. There is a packaging development technology from natural food ingredients that can be a solution to reduce the use of plastic packaging using edible films as a solution to the right choice of biodegradable packaging for food products and is safe for consumption directly by humans.

Edible film is a thin layer suitable for consumption and is composed of the main components which are hydrocolloid, fat or a composite combination of both. Edible films can provide product protection against oxygen and fat oxidation processes, reduce water evaporation rates and improve product appearance [2]. Edible film as food product packaging can also make it easier for consumers to consume food products, this is due to the nature of edible film packaging which has a transparent color and can be consumed directly together with the product it is packaged [3]. The innovation of fast sealing dissolving edible film packaging can be interpreted as food packaging that can be sealed so as to avoid product leakage and dissolve easily in water, including edible films and product materials that are also packaged. along with the packaged.

The main ingredient components for making edible film are important for making proper edible film packaging. The use of hydrocolloid components in the form of polysaccharides type of the glucomannan is the right choice for making edible films. Glucomannan is a low-calorie polysaccharide and soluble dietary fiber [4]. Glucomannan which is used as a single component tear easily and has fewer stable properties to protect products packaged using edible films against oxygen, carbon dioxide and lipids [5]. It is necessary to add other components to create edible films with better physical properties by adding other ingredients.

Gelatin is a protein-containing compound with a content of 85-92% with a low-fat content and is obtained from the results of partial hydrolysis of animal bone and skin collagen. Gelatin has hydrophilic properties, has a transparent color, has no taste and aroma, can form a thin and strong layer [6]. Making edible films based on glucomannan and gelatin is expected to produce edible film packaging in the form of pouches that can protect the packaged product, be transparent, not easily torn, strong, sealable and easy to dissolve.

Based on the explanation above, it is necessary to conduct research on the physical quality of food packaging in the form of fast sealing dissolving edible films using a combination of glucomannan and gelatin in terms of solubility, total soluble matter, swelling, water content, thickness, L* color, a* color, b* color, browning index and whiteness index.

2. MATERIALS AND METHODS

2.1 Materials

The research material was edible film fast sealing dissolving formulated glucomannan and gelatin. The ingredients used in the research consist of glucomannan (Konjac), gelatin (Hakiki), lactic acid (PT. Bratoco) and aquades. The equipment used in the research consisted of teflon, silicon mat, digital scale, aluminum foil, plastic clip, label paper, erlenmeyer 500 ml (Pyrex), erlenmeyer 250 ml (IWAKI), spatula spoon, thermometer 30 cm, measuring cup 100 ml (Herma), measuring cup10 ml (Pyrex), hot plate (SH-2), magnetic stirrer,beaker glass 100 ml (Duran), centrifugation tube, centrifugator (Gemmy PLC-03), plastic cup and filter cloth. The equipment used in the test consisted of petri dish, filter paper, analytical scale (Mettler AJ 150), oven (Memmert), clamp, desiccator, glass funnels (Pyrex), colorimeter (CS-10) and digital thickness gauge (Syntek).

2.2Methods

The research method used the experimental method. Statistical calculations used the analysis of variance (ANOVA) with a complete random design (CRD) consisted 5 treatments and 3 replications followed by Duncan Multiple Range Test (DMRT) if there are differences. The treatments consisted of T1: 0.5% of gelatin, T2: 0.625% of gelatin, T3: 0.75% of gelatin, T4: 0.875% of gelatin and T5: 1% of gelatin.

2.2.1 Glucomannan Solution

The process for preparing glucomannan solution is based on [7] with some modifications on the amount of lactic acid used and microwave power. Glucomannan was weighed as much as 3 g and dissolved using 100 ml of distilled water using a 500 ml Erlenmeyer then added 4 ml of lactic acid. The glucomannan solution was homogenized using a hot plate and magnetic stirrer for 20 minutes until the texture of the glucomannan solution turned denser. The glucomannan solution was heated using a microwave at 75% power for 5 minutes followed by 50% power for 5 minutes then the glucomannan was cooled to room temperature and the glucomannan solution was put into a centrifugation tube. The glucomannan solution was centrifuged at 5000 rpm for 10 minutes, the sediment and supernatant were separated from the centrifugation process to produce a clear glucomannan solution.

2.2.2Edible Film Solution

The process of making an edible film solution starts with taking 3 g of glucomannan solution, dissolving it in 25 ml of distilled water, heating using a hot plate-magnetic stirrer to a maximum temperature of 60^{o}C, adding gelatin slowly according to the treatment, including 2, 2.5, 3, 3.5 or 4 g, stirred until a homogeneous solution for 10 minutes, turned off the hotplate, removed the magnetic stirrer and filtered the edible film solution into a 100 ml beaker glass using a filter cloth.

2.2.3Edible Film Drying

The process of drying edible film starts with pouring 10 ml of edible film solution using a measuring cup, pouring it into Teflon which has been placed on a silicone mat, leveling it with a spatula spoon and drying it for 24 hours at room temperature.

2.2.4Solubility

The solubility analysis procedure was based on [8] with some modifications to the length of soaking time, the size of the edible film and the length of oven time after soaking. Solubility analysis begins by cutting the edible film sample with a size of 5 x 5 cm, preparing filter paper and petri dish, weighing the petri dish using an analytical scale, drying the petri dish in the oven with a temperature of 100^{o}C-105^{o}C for 30 minutes, taking the petri dish using a clamp, put filter paper on top of the petri dish, place the edible film sample on top of the petri dish and put the sample in the oven at 100^{o}C-105^{o}C for 30 minutes, samples were taken using clamp and the edible film was weighed after drying using an analytical balance as the initial weight or before immersion (W_0). After calculating Wo, proceed with preparing a plastic cup containing 20 ml of distilled water, soaking the edible film sample for 10 minutes, removing the insoluble sample, filtering it using filter paper, placing the filter paper containing the insoluble edible film sample on a petri dish, put the insoluble sample into the oven at

100^oC-105^oC for 30 minutes, put the petri dish in a desiccator for 10 minutes, re-weigh the edible film sample using an analytical scale as the final dry weight after immersion (W_1) and calculate the solubility analysis using the formula. The formula of calculating the solubility percentage:

$$S = \frac{W0 - W1}{W0} \times 100\%$$

Explanation:
S = Solubility value
W_0 = Dry weight before immersion
W_1 = Dry weight after immersion

2.2.5Total Soluble Matter

The total soluble matter analysis procedure was based on [9] with several modifications to the size of the edible film, the amount of distilled water, soaking time, centrifugation time, oven temperature and baking time. Analysis of total soluble matter starts with cutting the edible film sample with a size of 5 x 5 cm, weighing the edible film using an analytical scale, preparing a centrifugation tube containing 6 ml of distilled water, placing the edible film into the centrifugation tube, closing the centrifugation tube, soaking the edible film for 10 minutes, centrifuged the sample using a centrifugator at 3000 rpm for 5 minutes, filtered the remaining edible film sample in a centrifugation tube using filter paper, placed the remaining sample on a petri dish, dried the remaining film pieces in the oven at 100^oC-105^oC for 30 minutes, weigh the sample and calculate the total soluble matter analysis using the formula. The formula of calculating the total soluble matter (TSM):

$$TSM\ (\%) = \frac{(\text{Weight of edible ilm before test} - \text{Weight of edible ilm after test}) \times 100}{\text{Weight of edible ilm before test}}$$

2.2.6Swelling

The swelling analysis procedure is based on [10] with some modifications to the size of edible film. Swelling analysis begins by cutting the edible film sample with a size of 5x5 cm, weighing the initial weight (W_1) of the edible film using an analytical scale, recording the weighing results before soaking using distilled water, preparing distilled water using a 100 ml measuring cup, pouring the distilled water into a plastic cup, putting the edible film into a plastic cup containing 30 ml of distilled water, soak the edible film for 2 minutes, remove the edible film using spatula spoon and remove the water on the surface of the edible film using a tissue, weighing the final weigh of edible film (W_2) after soaking using an analytical scale, record the weighing results after soaking using distilled water and calculating the swelling using the formula. The formula of calculating the swelling:

$$\text{Swelling}\ (\%) = \frac{W2 - W1}{W1} \times 100\%$$

Explanation:
W_1 = Initial weight before immersion
W_2 = Final weight after immersion

2.2.7Water Content

The water content analysis procedure was based on [8] with some modifications to the size of the edible film and the length of oven time for the samples. Analysis of the water content begins by cutting the edible film with a size of 5 x 5 cm, preparing filter paper and petri dish, weighing the edible film using an analytical scale, drying the petri dish in the oven for 30 minutes at 100^{o}C-105^{o}C, put the petri dish in a desiccator for 10 minutes, weigh the petri dish, put the filter paper on the petri dish, put the sample on filter paper, dry in the oven with a temperature of 100^{o}C-105^{o}C for 30 minutes until it reaches a constant weight, put the petri dish in a desiccator for 10 minutes, weigh the edible film after drying and calculated the water content analysis using the formula. The formula of calculating the water content:

$$\text{Water Content (\%)} = \frac{(\text{Initial sample weight (g)} - \text{Final sample weight (g)}}{\text{Initial sample weight (g)}} \text{ x } 100\%$$

2.2.8Thickness

The thickness analysis procedure was based on [11] with some modifications in terms of tool type and accuracy. Thickness analysis begins by cutting the edible film with a size of 5 x 5 cm, choose 5 different points are determined on the sample, pressing the on button in the tool, pulling the handle of the digital thickness gauge, placing and clipping the edible film to the jaws of the digital thickness gauge, the position between the anvil and spindle, pressing the off button, observed and measured the average thickness of the edible film at 5 different points with an accuracy of 0.01 mm and calculated the thickness analysis using the formula. The formula of calculating the thickness:

$$\text{Thickness (mm)} = \frac{A + B + C + D + E}{5}$$

Explanation:
A = Thickness area 1 (mm)
B = Thickness area 2 (mm)
C = Thickness area 3 (mm)
D = Thickness area 4 (mm)
E = Thickness area 5 (mm)
5 = Number measurement area

2.2.9Color

The color analysis procedure was based on [12] with some modifications to the size of edible film. Color analysis begins by cutting the edible film with a size of 5 x 5 cm, pressing the on button to turn on the colorimeter, adjusting the position of the edible film sample in such a way that the sensor is in contact with the sample, placing the edible film in a transparent glass or plastic container, pressing the target button until the tool makes a sound indicating that the reading has been completed, the numbers L*, a* and b* are recorded on the monitor screen of the tool, pressed reset for the next measurement and pressed the off button to turn off the colorimeter tool.

Explanation:
L = brightness
a+ = red
a- = green
b+ = yellow
b- = blue

2.2.10Browning Index

The calculation of browning index analysis based on [13]. The formula of calculating the browning index:

$$BL = \frac{[100\,(x - 0{,}31)]}{0{,}172}$$

$$X = \frac{(a* + 1{,}75L*)}{(5{,}645L* - a* - 3{,}02b*)}$$

2.2.11Whiteness Index

The calculation of whiteness index analysis based on [14]. The formula for calculating the whiteness index (WI):

$$WI = 100 - \sqrt{(100 - L)^2 + a^2 + b^2}$$

3. RESULTS AND DISCUSSION

3.1 Solubility

The results of the analysis of variance showed that the treatment using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave no significantly different results (P>0.05) to the solubility. There was no significant effect on each treatment due to the addition of gelatin which had a low interval so that the solubility level was not much different. The effect of using different amounts of gelatin in making edible films on the solubility can be seen in Table 1.

Table 1. The Solubility Value of Edible Film in All Treatments Using Gelatin

Treatment*	Solubility (%)
T1	24.5±2.89
T2	22.7±11.13
T3	20.6±7.45
T4	11.2±7.86
T5	20.5±10.28

T1:0.5%, T2:0.625%, T3:0.75%, T4:0.875%, T5:1%

Explanation: The use of gelatin with different percentages in edible films with glucomannan showed no significant different in each treatment onthe solubility (P>0.05).

The highest average value of edible film solubility was found in T1 using gelatin concentration of 0.5% with 24.50%. Meanwhile, the lowest average value of edible film solubility was found in T3 to T5 with the addition of 0.75%, 0.875% and 1% respectively which resulted in a solubility value of 20.6%, 11.2% and 20.5%. The decrease in the solubility of edible films in water was due to the ratio of glucomannan and gelatin used when making edible films. The high concentration of gelatin added causes the solubility value of the edible film to decrease. This is due to the gelatinization process in the manufacture of edible films which results in hydrogen bonds in the film so that the molecular structures of glucomannan and gelatin bind to each other and form a compact network and only small molecules can dissolve. The low solubility value is due to the addition of gelatin in each treatment which causes an increase in hydrogen bonding which can reduce the cavity volume so that the hydroxyl groups make it difficult to interact with water. The increase in hydroxyl groups (-OH) in konjacglucomannan indicates a greater opportunity to form intermolecular hydrogen bonds[15]. This shows that the two materials used interact with each other to form hydrogen bonds. Konjacglucomannancan interact with gelatin, and form aggregates that are resistant to smelting and gel formation[16].

The low solubility value can also be caused by the denaturation of the proteins found in gelatin which causes a loss of its physiological activity. Denatured proteins will reduce their solubility. The existence of heating and stirring during the manufacture of edible films can cause the protein to coagulate, the high temperature used in the manufacturing process causes the protein to denature quickly. Denaturation generally results in a loss of biological activity and a significant change in solubility. Heat has the ability to denature proteins and form complexes between the electrostatic interactions of polysaccharides and proteins. This interaction has the ability to form hydrophobic or disulfide bonds that make the matrix difficult for water to pass through[17]. Heating changed the three-dimensional structure of proteins, showing functional peptide groups such as CO and NH as well as polar and hydrophobic side chain groups involved in intramolecular hydrogen bonds and electrostatic interactions in their native state. Therefore, these functional groups are available for intermolecular interactions[18]. Prolonged heating in particular increased the water resistance of the films leading to lower solubility values as the size of the saccharide molecules decreased (ribose < glucose < lactose) [19].

The highest solubility value in T1 with the use of 0.5% gelatin was due to the low ratio of edible film consistedglucomannan and gelatin. The low molecular weight can help the entry of gelatin between the polymer chains so that the volume of free space between the polymers increases. The solubility value of an edible film is influenced by the hydrophilic component as a constituent material so that edible films expand more easily and then disintegrate. The hydrophilic nature of these two components causes the film to absorb water quickly. Polysaccharides will expand during the heating process and affect the temperature stability of the protein, when the polysaccharide chain length exceeds a certain range, the steric effect of long-chain polysaccharides prevents protein aggregation behavior. Polysaccharides can fill the protein aggregation network and heating can increase the stability of the protein-polysaccharide components. Glucomannan was reported to be effective as an ingredient that can increase the strength and adhesiveness of myofibril gel protein[20]. Edible film has the ability to dissolve easily in water because it has hydrophilic natural proteins which make it easier for interactions to occur in water. Gelatin has lower hydrophobic amino acids than hydrophilic amino acids which causes the film to absorb water more easily [21]. The content of amino acids in gelatin which have hydrophilic properties such as serine and tyrosine [22]. This shows that the basic material for forming edible films can determine the level of solubility of an edible film.

Solubility is a property that measures the ability of a film to dissolve when consumed and determines whether an edible film is easily degraded when used as a product packaging. Based on JIS (Japanese Industrial Standard) the maximum solubility value that an edible film must have as a food product packaging is 14%. This shows that the glucomannan and gelatin as based of edible films obtained from the results of this research have found the standards for food product packaging in the T3 with the addition of 0.75% gelatin which resulted in a solubility value of 11.2%. This research wants to obtain edible films that have a high level of solubility, strong and flexible so that they can be used as packaging for food products that are ready for consumption, especially as a protector for food products that have a low water content such as products that can be eaten immediately such as powdered milk, instant noodle seasoning, candy, etc. Edible film with a high solubility percentage proves that the edible film has good characteristics because it is easily decomposed in nature (biodegradable) so that it can replace plastic, especially as primary packaging. A low solubility value can be applied to food products that have a high water content so that an edible film is needed that is water resistant so that the solubility level of the edible film can be determined according to the needs of the food product to be packaged.

3.2Total Soluble Matter

The results of the analysis of variance showed that the treatment using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave significantly different results (P<0.05) to the total soluble matter. The effect of using different amounts of gelatin in making edible films on the total soluble matter can be seen in Table 2.

Table2. The Total Soluble Matter Value of Edible Film in All Treatments Using Gelatin

Treatment	Total Soluble Matter (%)
T1	60.6^{b} ±14.65
T2	35.5^{ab} ±6.96
T3	27.6^{a} ±10.73
T4	43.0^{ab} ±14.65
T5	48.5^{ab} ±4.97

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: ^{a,b} Different superscripts showing the use of different percentages of gelatin on edible films with glucomannan showed significant different (P<0.05) on the total soluble matter.

The highest average value of total soluble matter edible film was found in T1 using gelatinconcentration of 0.5% with 60.6%. Meanwhile, the lowest total soluble matter value for edible film was found in T3using gelatin concentrationof 0.75% with 27.6%. The total soluble matter is the amount of material that dissolves when soaking and stirring results in a precipitate or edible film residue that does not dissolve during the test and is weighed to determine the weight of the dissolved material.

The decrease in the total soluble mattervalue of the film was affected by the addition of gelatin concentration in each treatment. The lower the total soluble mattervalue in the edible film indicates the more precipitate produced. The total value of the total soluble matterof the edible film is high, it means the less remaining edible film is not dissolved. The low total solubility of the film is evidenced by the large amount of remaining insoluble film, this indicates high stability of the protein network so that water molecules find it difficult to penetrate the edible film matrix. The total soluble mattervalue is low as a result of the use ofmore added gelatin, this is directly proportional to the solubility value and low water content as well.

The solubility of glucomannan-gelatin edible films has a relatively high solubility, especially edible films with a low gelatin concentration, making them suitable for packaging that dissolves easily in hot water. thetotal soluble matter value increases when agar is included in the formulation [23]. The total soluble matter value increases when the polysaccharide content in the protein mixture is low due to reduced protein interactions in the presence of polysaccharides and due to the formation of less dense polymer networks [19]. This shows that the high value of total dissolved substances gives less remaining undissolved film so that the resulting edible film can be used for ready-to-consume products. In minimizing changes the taste in the mouth, it is better to use a film that can really crumble when eaten with packaged products.

3.3Swelling

The results of the analysis of variance showed that the treatment using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave highly significant different results (P<0.01) to the swelling. The effect of using different amounts of gelatin in making edible films on the swelling can be seen in Table 3.

Table3. The Swelling Value of Edible Film in All Treatments Using Gelatin

Treatment	Total Soluble Matter (%)
T1	7.75^{c}±0.69
T2	6.26^{bc}±1.65
T3	5.56^{ab}±0.11
T4	4.79^{ab}±1.27
T5	3.48^{a}±0.44

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: ^{a,b,c} Different superscripts showing the use of different percentages of gelatin on edible films with glucomannan showedhighly significant different (P<0.01) on the swelling.

The highest average of swelling value was found in T1 using gelatin concentration of 7.75%. Meanwhile, the lowest swelling value was found at T4 when using gelatin concentration of 1% with 3.45%. There was a decrease in swelling value due to the swelling of the edible film along the addition of gelatin which is thought to have occurred because the high concentration of gelatin used made the amount of solids increase, more complex and the composition of the gelatin formed from protein causes easy protein denaturation due to heating so that it could lose its physiological function. The decrease in swelling caused by the high concentration of gelatin is able to bind water molecules through hydrogen bonds which causes a decrease in the amount of free water in the edible film.

The composition and concentration of materials used in making edible films affect water absorption which results in swelling and affects water absorption. The edible film with the highest swelling value was found at T1 using gelatin concentration of 0.5% with 7.75%. This is presumable because the use of a higher ratio of glucomannan and less gelatin will form an edible film layer that is thinner, elastic and tends to be sticky which makes it easier for the bond between water and the hydrocolloid film results in faster swelling and higher water absorption. If the concentration of gelatin is too low making the resulting gel will become soft and if the concentration of gelatin is too high making the resulting gel will become stiffer [24].

The addition of gelatin which is composed of high concentrations of animal collagen network protein will produce thicker, strongerand less easily broken edible film characteristics which affect the increase in total solids which causes it to be more difficult for water to enter so that the swelling of the edible film by water becomes low. The swelling capacity of the edible film becomes important when the product coated with this material is in contact with water for a few minutes enough to cause a considerable swelling of the edible film. This can be related to the water retention capacity of the hydrocolloid film as a hydrophilic substance. However, protein-based edible films show lower swelling index values [25].

Gelatin is composed of a combination of amino acids in the form of glycine-proline, glycine-proline-hydroxyproline which are linked together by peptide bonds. The longer the amino acid groups are arranged, the greater of gel strength produced by the gelatin. At high temperatures, which are more than 40°C, the amino acid chains will break simultaneously, followed by the addition of increasing concentrations. The structure of the gelatin composition is susceptible to being degraded by heat, the longer and higher of heating temperature will make the shorter of gelatin chains [26]. The glucomannan chain whichis hydrated in water will expand into a form with a more open chain[27].

The amount of gelatin concentration in the solution is also a reason, the higher the dissolved material, it will produce thicker material and resulting thickness will increase. The denser and more complex the matrices on the edible film make it more difficult and lower the transmission rate of water vapor because water vapor is difficult to permeate the edible film [28]. Therefore, the swelling test measured on edible film depends on the concentration and character of the material used in the producing process [29]. Edible film packaging with low absorption capacity with high water resistance is good for protecting the product and maintaining the shelf life of food products, this is because packaging with low water absorption can reduce microbial activity.

3.4Water Content

The results of the analysis of variance showed that the treatment using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gavesignificant different results (*P*<0.05) to the water content. The effect of using different amounts of gelatin in making edible films on the water content can be seen in Table 4.

Table4. The Water Content Value of Edible Film in All Treatments Using Gelatin

Treatment	**Water Content (%)**
T1	$12.15^{c}\pm0.16$
T2	$11.87^{ab}\pm0.29$
T3	$11.49^{a}\pm0.01$
T4	$11.93^{b}\pm0.22$
T5	$11.91^{b}\pm0.26$

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: $^{a,b,\ c}$ Different superscripts showing the use of different percentages of gelatin on edible films with glucomannan showed significant different (*P*<0.05) on the water content.

The highest average value of edible film water content was found in T1using gelatin concentration of 0.5% with 12.15%. Meanwhile, the lowest average value of edible film moisture content was found in T3 using gelatin concentration of 0.75% with 11.49%. The large use of gelatin in the making process of edible films is due to the reduced water content in the edible film. There is a decrease in water content along with an increase in the concentration of gelatin in making edible films because gelatin carries dissolved solids in solution so as to form hydrogen bonds between molecules making up the edible film. The high concentration of gelatin used caused a decrease in the water content in the film because gelatin was able to reduce the amount of free water in the film because gelatin binds water molecules through strong hydrogen bonds. The large amount of gelatin in the edible film solution allows the availability of less free water to play a role in the polymerization reaction [28]. The addition of gelatin concentration in the manufacture of edible films can affect the amount of polymer that increases and the viscosity that forms the film network so that the more polymers that make up the film network, the amount of solids increases which makes the amount of water in the edible film decrease [30]. The hydrophilic nature of gelatin causes swelling when dissolved in water due to absorption. The increase in the viscosity of the solution occurs because the water which was initially free to move becomes not free or cannot move due to the presence of gelatin[31]. This causes when the edible film is dried only a small amount of free water can evaporate. Gelatin has dense protein chain interactions so that as the addition of this ingredient causes a lower water content which will affect the flexibility of the film which becomes brittle. The low water content can occur due to the interaction between polysaccharides and proteins due to heating which can increase the stability of the protein-polysaccharide components so that the water content in the film becomes low.

Moisture content is an edible film property that has an influence on the stability of packaged products. The moisture content value determines the amount of water retained in the edible film sample. According to the Japanese Industrial Standard (JIS) the maximum water content quality standard for edible film is 13%. This shows that the use of glucomannan and different concentrations of gelatin in making edible films in this research found the standards in the value of 11.49%-12.15%, with the lowest results in the T3 treatment using of 0.75% gelatin which produced levels of water content by 11.49% and the highest yield was in T1 with the use of gelatin as much as 0.5% which resulted in a water content of 12.15%. The low percentage of gelatin used indicates that the water content is always higher in hydrophilic biopolymers. This is directly proportional to the solubility value so that it can be seen that the higher the water content contained in the film sample, the higher the solubility level. Films with a high water content act as a protector for food products that have a low moisture content against damage caused by the presence of oil or fat. The most films made from polysaccharides and proteins have low moisture retention properties, especially under high relative humidity but have good gas barriers so that composite films consisting of proteins and polysaccharides have good characteristics [32]. The high water content in the film will easily become a medium for microbial growth which results in the film being easily decomposed in nature (biodegradable). Films with a low water content will be more difficult or resistant to microbiological damage, and will not provide a water supply to the product which causes damage and decreases the shelf life of the product. High or low water content in the film will greatly affect the resistance of the resulting edible film.

3.4Thickness

The results of the analysis of variance showed that the treatment using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave highly significantly different results (*P*<0.01) to the thickness. The effect of using different amounts of gelatin in making edible films on the thickness can be seen in Table 5.

Table5. The Thickness Value of Edible Film in All Treatments Using Gelatin

Treatment	Thickness (mm)
T1	$0.092^{a}\pm0.007$
T2	$0.093^{a}\pm0.005$
T3	$0.108^{ab}\pm0.011$
T4	$0.119^{ab}\pm0.012$
T5	$0.135^{b}\pm0.016$

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: ^{a,b} Different superscripts showing the use of different percentages of gelatin on edible films with glucomannan showed highly significant different (*P*<0.01) onthe thickness.

The highest average of thickness value was found in T5 using gelatin concentration of 1% with0.135 mm. Meanwhile, the lowest thickness value was found in T1 using gelatin concentrationof 0.05% with 0.092 mm. There was an increase in the thickness of the edible film in each treatment along with the addition of more gelatin. The increase in total solids occurs due to the addition of concentration of ingredients so that when the solution is poured and dried it will produce an edible film that is stiff and quite thick [28]. The interaction between glucomannan (polysaccharide) and gelatin (protein) also causes different levels of thickness. Glucomannan combined with protein can provide a synergistic effect so as to form a different texture.

Edible film with the highest thickness is found in T5 using gelatin concentration of 1% with 0.135 mm due to the highest use of gelatin. This happens because glucomannan is a polysaccharide that has a hollow structure so that when it is combined with gelatin which is composed of hydrocolloid materials as the main ingredient for making edible films it will produce a chain structure that is tighter, stronger and the addition of a larger amount of gelatin causes a stronger interaction and produce more total edible film solution so that the edible film produced will be thicker. Nonspecific protein-polysaccharide interactions are responsible for the attractive and repulsive forces that induce the formation of complexes where upon heating the polysaccharides can expand and affect the thermal stability of the protein. The polysaccharide chain length increases and exceeds a certain range, the steric effect of long-chain polysaccharides can prevent protein aggregation behavior [33]. The total dissolved solids affect the thickness of the edible film. Edible film with the lowest average thickness value is found in T1 with the use of 0.5% gelatin concentration with 0.092 mm. This can happen because the less concentration of added gelatin, the less amount of solution that is poured into the silicon mat and tends to be more dilute which causes the resulting thickness to be thinner.The thickness of the edible film will continue to increase along with the concentration of the added raw materials. The T2 thickness value using a gelatin concentration of 0.625%, which is 0.093 mm, also has an average thickness that is not much different because it is suspected that there isa rough surface on the silicon matso that the total polymer solids making up the edible film matrix do not have the same thickness at several points. The area of the mold and the suspension volume are also other factors that affect thickness [34].

The addition of several ingredients can increase the total solution which makes the resulting matrix denser and more complex which will affect the yield of edible films [35]. Thick edible films can affect the exit and entry of gas transmissions which affect the durability of the packaged product. The thickness level of edible film can also be an indicator of the high and low rates of water vapor transmission, where a low water up transmission rate is very good for packaged products. That way, the thickness of an edible film plays an important role as protectant during storage. Edible film thickness is affected by the nature, concentration and composition [36].

The edible film thickness value in this research was successful in obtaining a value of 0.092-0.135 mm which was considered quite good, because it is based on JIS (Japanese Industrial Standard) which is the film used as food product packaging must have a maximum thickness of 0.25 mm. The thicker the edible film will have better function as food packaging, this is because edible film with a high thickness value will be more resistant to microbial damage and its holding capacity will be greater so that it has a longer product shelf life. The thickness of the edible film packaging must pay attention to the product to be packaged. The thickness affects the mechanical properties but in its applicationthe thickness of the edible film needs to be adjusted to the type of food product to be layering without affecting the properties of the product itself [37].

3.5Color

The average of color value in the treatment using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible filmsshowed that the effect results gave significant different (P<0.05) on the intensity of lightness (L*) and the effect results gave not significant different (P>0.05) on the intensity ofredness (a*) and intensity of yellowness (b*) on the edible film. Differences in the color of each treatment occurs due to several factors.

The main ingredients and chemical components (sugars, flavonoids and organic acids), concentration, temperature and time are factors for color differences[38]. The color of edible films can be seen in Figure 1.

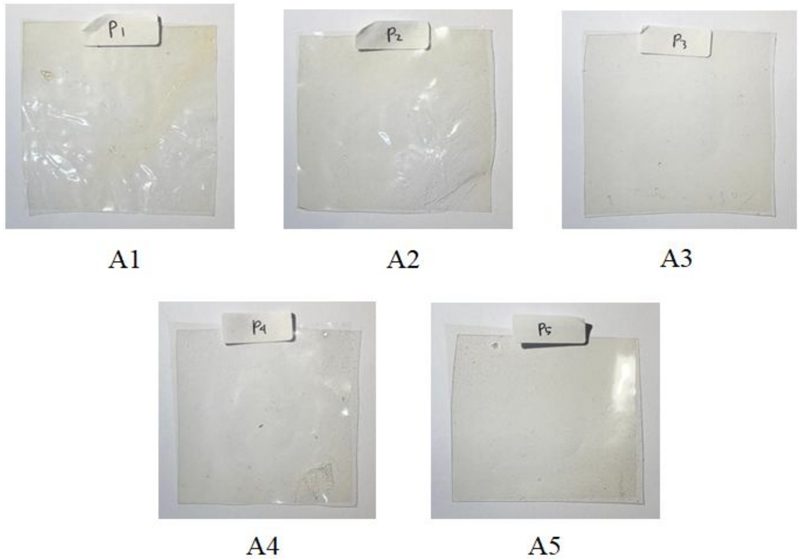

Fig. 1. Edible film colors: (A1) Edible film in T1, (A2) Edible film inT2, (A3) Edible film inT3, (A4) Edible film inT4, (A5) Edible film in T5

3.5.1Lightness Color Intensity (L*)

The results of the analysis of variance showed that the treatment of using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave significant different results (P<0.05) to the lightness color intensity (L*). The effect of using different amounts of gelatin in making edible film on thelightness color intensity (L*) can be seen in Table 6.

Table6. The Lightness Color Intensity Value of Edible Film in All Treatments Using Gelatin

Treatment	Lightness
T1	$91.3^{a} \pm 0.69$
T2	$92.21^{ab} \pm 0.48$
T3	$92.01^{b} \pm 0.39$
T4	$92.44^{b} \pm 0.06$
T5	$92.5^{b} \pm 0.28$

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: ^{a,b} Different superscripts showing the use of different percentages of gelatin on edible films with glucomannan showedsignificant different (P<0.05) on thelightness color intensity (L*).

The highest average value of lightness color intensity (L*) was found in T5 using gelatin concentration of 1% with 92.5. Meanwhile, the lowest brightness value was found in T1 using 0.05% gelatin concentration with 91.3. Edible film can produce different colors, namely bright, transparent and opaque or dull [39]. The increase in the brightness of edible films is influenced by the composition of the materials used. The type of addition of the main ingredient for making edible film will affect the intensity of the resulting color [40]. The higher use of gelatin gives a clearer color with higher lightness and the color is better. This is evidenced by the highest lightness color intensity (L*) edible film found at T5 with the use of 1% gelatin concentration with 92.5. It is because gelatin acts as a clarifier and gelatin in sheet form has a transparent color. Denatured gelatin will act as a clarifier [41]. This shows that the advantages of applying gelatin as an edible film are able to improve color characters [42].

The lightness level of a material can be interpreted as the ability of a material to reflect light that hits it. A lightness value (L*) that is close to 100 produces a brighter color, whereas a lightness value (L*) that is close to 0 produces a duller and darker color [43]. The results of this research show that the color brightness (L*) of edible films ranges from 91.3-92.5 which is considered suitable for use as product packaging with a transparent appearance so as to support it from an aesthetic point of view. The addition of the percentage of gelatin has an effect on the color level of an edible film because the color will be more attractive [44].

3.5.2RednessColor Intensity (a*)

The results of the analysis of variance showed that the treatment of using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave no significant different results (*P*<0.05) to the redness color intensity (L*). The effect of using different amounts of gelatin in making edible film on the redness color intensity (L*) can be seen in Table 7.

Table7. The Redness Color Intensity Value of Edible Film in All Treatments Using Gelatin

Treatment	Redness
T1	0.78±0.09
T2	0.96±0.07
T3	0.89±0.13
T4	0.96±0.05
T5	1±0.04

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: The use of gelatin with different percentages in edible films with glucomannan showed no significant different in each treatment onthe redness color intensity (*P*>0.05).

The highest average value of rednesscolor intensity (a*) was found in T5 using gelatin concentration of 1% with 1. Meanwhile, the lowest redness value was found in T1 usinggelatin concentrationof 0.05% with 0.78. The presence of redness pigment occurs because the composition of the ingredients for making edible films contains flavonoids. Flavonoids are natural compounds found in plant tissues that produce dyes[45]. The composition of the material in this research used a glucomannan solution derived from iles-iles tubers which contain flavonoids with the addition of lactic acid so that the glucomannan solution has a low pH and produces a thick pink liquid. Glucomannan flour was identified to contain flavonoids, alkaloids, saponins, tannins and carbohydrates [46].

The highest increase in rednesscolor was at T5 with the use of 1% gelatin concentration with 1, which was thought to occur due to the use of higher gelatin, although the results were not significant and the increase was relatively small, but the glucomannan solution which had a pink color and gelatin which had a tendency to yellow made the insensitivity value of redness color (a*) may increase. The factor of using heating temperature is related to the occurrence of the Maillard reaction on the edible film which causes the color of the edible film to become thicker. During the heating process there is an interaction that causes the food product to experience non-enzymatic browning (Maillard reaction) and tends to have a darker color so that if an edible film is tested using a colorimeter, the reddish value (a*) will be read which is greater and the a* value will be towardspositive [47]. The a* value indicates that the product has a redness and greennesscolor. The result of the number +a* (positive) indicates the product towards a red color with a scale of 0 to 100 while the result of the number -a* (negative) indicates the product towards a green color with a scale of 0 to -80 [48]. The results of this research show that the rednesscolor value (a*) of the edible film ranges from 0.78-1, the results of which are not significantly different and are included in the low red color value, so that when viewed from the visual appearance of the fast sealing dissolving edible film, it does not have an effect red.

3.5.3YellownessColor Intensity (b*)

The results of the analysis of variance showed that the treatment of using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave no significant different results (*P*<0.05) to the yellowness color intensity (L*). The effect of using different amounts of gelatin in making edible film on the yellowness color intensity (L*) can be seen in Table 8.

Table8. The Yellowness Color Intensity Value of Edible Film in All Treatments Using Gelatin

Treatment	Yellowness
T1	1.52±0.66
T2	2.38±0.75
T3	2.81±0.88
T4	1.78±0.44
T5	2.21±0.54

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: The use of gelatin with different percentages in edible films with glucomannan showed no significant different in each treatment onthe yellowness color intensity (*P*>0.05).

The highest average value of yellownesscolor intensity (b*) was found in T3 using gelatin concentrationof 0.75% with 2.81. Meanwhile, the lowest yellowness value was found in T1 using gelatin concentration 0.05% with 1.52. The tendency for a yellownesscolor (b*) is due to the composition of the gelatincolor. Gelatin powder or granules have a white to light yellow color and gelatin that has been made into sheets also has a transparent to light yellow color[49].

The intensity of the yellownesscolor (b*) of the edible film which has a higher tendency is indicated because the high use of gelatin gives the final result thickercolor on the edible film. Edible films made from gelatin tend to have a bright yellow color with a high level of clarity or transparency. The results of edible films that have a transparent to yellow color can occur because one of the properties of deturatedgelatin will act as a clarifier [44]. The b* value indicates that the product has a yellowness to bluenesscolor. The result of the number +b* (positive) indicates that the product has a yellow color with a scale of 0 to 100, while -b* (negative) indicates that the product has a blue color with a scale of 0 to -80 [50]. The results of this research showed that the value of yellowness (b*) of edible film ranged from 1.52 to 2.81 which is included in the color value of yellow which is low.

3.6Browning Index

The results of the analysis of variance showed that the treatment of using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave no significant different results (*P*<0.05) to the browning index. The effect of using different amounts of gelatin in making edible film on the browning index can be seen in Table 9.

Table9. The Browning Index Value of Edible Film in All Treatments Using Gelatin

Treatment	Browning Index
T1	2.23±0.66
T2	3.27±0.78
T3	3.7±0.92
T4	2.62±0.51
T5	3.11±0.57

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: The use of gelatin with different percentages in edible films with glucomannan showed no significant different in each treatment onthe browning index (*P*>0.05).

The highest average browning index value was found at T3 using gelatin concentration of 0.75% with3.7. The lowest browning index value was found in T1 using gelatin concentration 0.05% with 2.23. The average browning index results are directly proportional to the intensity of the yellowness color (b*). The browning reaction is indicated to occur due to the interaction between glucomannan (a complex carbohydrate) and gelatin (protein). The browning reaction can also be observed from changes in the b* value which is an indication of a yellowish color change in the browning reaction [51].

The browning index is indicated by a change in color from yellow to brown which occurs due to the Maillard reaction. Darkening of protein-based edible films is related to the formation of brown compounds during the advanced stages of the Maillard reaction [52]. The highest average browning index value is found in T3 with the use of gelatin concentration 0.625% with 3.7. This is indicated because of the more intensive Maillard reaction and T3 also has the highest yellow intensity value. High temperatures cause a rapid increase in the Maillard reaction which causes the brown color to become darker [53]. The increase and decrease in the browning index value is thought to occur due to several factors such as heating temperature and storage time.

3.7Whiteness Index

The results of the analysis of variance showed that the treatment of using gelatin with different percentages of 0.5%, 0.625%, 0.75%, 0.875% and 1% on edible films gave no significant different results (*P*<0.05) to the whiteness index. The effect of using different amounts of gelatin in making edible film on the whiteness index can be seen in Table 10.

Table10. The Whiteness Index Value of Edible Film in All Treatments Using Gelatin

Treatment	Browning Index
T1	94.51±2.5
T2	99.13±2.86
T3	99.34±1.81
T4	96.66±1.51
T5	98.57±2.06

T1:0.5%, T2:0.625%, T3 :0.75%, T4:0.875%, T5 :1%

Explanation: The use of gelatin with different percentages in edible films with glucomannan showed no significant different in each treatment onthe whiteness index (*P*>0.05).

The highest average whiteness index edible film value was found in T3 using gelatin concentration of 0.75% with 99.34. Meanwhile, the lowest average whiteness index value was found in T1 using gelatin concentration 0.5% with 94.51. Whiteness index is a physical characteristic of the brightness level of a product. Color is an important attribute for a biopolymer film as a packaging to protect the product, which will affect the appearance of the packaged product and is strongly influenced by storage conditions. The desired characteristics of edible film as a food filming include transparent color and light weight [54]. The color of the film can be measured with a colorimeter so that the values for L, a*, b* are produced and continued by calculating using the whiteness index formula.

Based on the above data, edible film has a low whiteness index due to the use of low gelatin. The low whiteness index value can be caused by several factors including the heating process, changes in pH and oxidation during the storage process. This is what causes the dyes contained in food to be damaged or even lost [55]. The decrease in the whiteness index value occurs gradually as the heating time increases [56]. This proves that the whiteness index value does not give a significant change because the temperature used is relatively stable, but the low gelatin used results in a film that is slightly opaque or less clear in appearance.

The whiteness index of the film increases with the addition of gelatin in the process of making edible films. This shows that the use of gelatin in the formulation of edible films contributes to the formation of a whiter matrix. The products added to gelatin can give a whitish color and produce a clearer color[57]. The whiteness index of gelatin will have an effect when applied to a product [58]. The whiteness index does not affect the properties of gelatin and does not interfere with the function of gelatin as a gel former in making edible films. The type of polysaccharide used is also indicated to affect the whiteness index of the edible film. The whiteness index value increased with the addition of peanut starch in making edible films, but the whiteness index decreased with the addition of glycerol [59]. Most of edible films made from polysaccharides and proteins have good transparency and luster properties so that they can improve the appearance of the product by adding color or gloss to make it more attractive to consumers [32].

4. CONCLUSION

Edible film formulated with glucomannan and gelatin using different concentrations of 0.5% to 1% produces a solubility value of 11.20-24.50%, total soluble matter 27.60-60.60%, swelling 3.49-7, 75%, moisture content 11.50-12.15%, thickness 0.09-0.14 mm, L* color 91.3-92.5, a* color 0.78-1, b* color 1.52-2.81, browning index 2.23-3.7 and whiteness index 94.51-99.34. Edible film formulated with glucomannan and gelatin concentration of 0.5% gives the best results on physical quality based on the application of edible films which arequickly dissolved in water, can be sealed and have a good physical appearance. The use of gelatin with a concentration of 0.5% resulted in a solubility value of 24.50%, total soluble matter 60.60%, swelling 7.75%, water content 12.15%, thickness 0.09 mm, color L* 91.3, color a* 0.78, color b* 1.52, browning index 2.23 and whiteness index 94.51.

REFERENCES

1. Kamsiati E, Herawati H, Purwani EY. The potential for developing biodegradable plastics based on sago starch and cassava in Indonesia. Journal of Agricultural Research and Development, 2017;36(2):67-76.

2. Amaliya RR, Putri WDR. Characteristics of edible film from corn starch with the addition of white turmeric filtrate as an antibacterial. Journal of Food and Agroindustry. 2014;2(3):43-53.

3. Huri D, Nisa FC. Effect of glycerol concentration and apple peel pulp extract on the physical and chemical characteristics of edible films. Journal of Food and Agroindustry. 2014;2(4):29-40.

4. Anggraeni DA, Widjanarko SB, Ningtyas DW. The proportion of porang flour (Amorphophallusmellerblume): cornstarch to the characteristics of chicken sausages. Journal of Food and Agroindustry. 2014;2(3):214-223.

5. Ferdian MA, Farida S. Characteristics of edible film from modified porang flour as instant noodle seasoning packaging. Proceedings of the National Seminar on Industrial Technology, Environment and Infrastructure (SENTIKUIN). 2021;4:A2.1-A2.8.

6. Novita DB, Rahmadhia SN. Physico-chemical properties of gelatin-based packaging with variations in the addition of glycerol and cherry leaf extract (Muntingiacalabura). Journal of Food Technology. 2021;15(2):1-13.

7. Manab A, Purnomo H, Widjanarko SB, Radiati LE, Thohari I. Physichochemical properties of kefir drink using modified porang flour (Amorphophallusoncophyllus) during storage period. Current Research in Nutrition and Food Science. 2017;5(3):288-299.

8. Harumarani S, Ma'ruf WF, Romadhon. Effect of different concentrations of glycerol on the characteristics of semirefined carrageenan composite edible films of Eucheumacottoni and beeswax. Journal of Processing and Biotechnology of Fishery Products. 2016;5(1):101-105.

9. Popovic S, Pericin D, Vastag Z, Popovic L, Lazic V. Evaluation of the edible film-forming ability of pumpkin oil cake; effect of ph and temperature. Food Hydrocolloids. 2011;25(1):470-476.

10. Nouraddinia M, Esmaiilia M, Mohtarami F. Development and characterization of edible films based on egg plant flour and corn starch. International Journal of Biological Macromolecules. 2018;120:1639-1645.

11. Ganesan AR, Shanmugam M, Seedevi P and Rajauria G. Development of edible film from acanthophoraspicifera: structural, rheological and functional properties. Food Bioscience. 2019;7(2):1-26.

12. Huri D, Nisa FC. Effect of glycerol concentration and apple peel pulp extract on the physical and chemical characteristics of edible films. Journal of Food and Agroindustry. 2014;2(4):29-40.

13. Bravo R.M, Zenteno EGR, Carranza PH, Sosa RA, Sánchez RA, López IIR, Velasco CEO. A potential application of mango (Mangiferaindica L. cv Manila) peel powder to increase the total phenolic compounds and antioxidant capacity of edible films and coatings. Food and Bioprocess Technology. 2019;12(9):1584-1592.

14. Ghamari MA, Amiri S, Bari MR, Bari LR. Physical, mechanical, and antimicrobial properties of active edible film based on milk proteins incorporated with nigella sativa essential oil. Polymer Bulletin. 2021;79(2):1097-1117.

15. Manab A, Purnomo H, Widjanarko SB, Radiati LE. 2016. Research article: modification of porang (Amorphophallusoncophyllus) flour by acid and thermal process using conventional heating in waterbath and microwave irradiation. Advance Journal of Food Science and Technology. 2016;12(6):290-301.

16. Liu Y, Li B, Zhang K, Li J, Hou H. Novel hard capsule prepared by tilapia (Oreochromisniloticus) scale gelatin and konjacglucomannan: characterization, and in vitro dissolution. Carbohydrate Polymers. 2019;206(1):254-261.

17. Jones OG, McClements DJ. Recent progress in biopolymer nanoparticle and microparticle formation by heat-treating electrostatic protein–polysaccharide complexes. Advances in Colloid and Interface Science. 2011;167(1):49-62.

18. Guerrero P, Kerry JP, Caba KDL. FTIR characterization of protein–polysaccharide interactions in extruded blends. Carbohydrate Polymres. 2014;111(1):598-605.

19. Etxabide A, Kilmartin PA, Maté JI, Prabakar S, Brimble M, Naffa R. Analysis of advanced glycation end products in ribose-, glucose- and lactose-crosslinked gelatin to correlate the physical changes induced by maillard reaction in films. Food Hydrocolloids. 2021;117(1):1-14.

20. Yuan Y, Wan ZL, Yin SW, Yang XQ, Qi JR, Liu GQ, Zhang Y. Characterization of complexes of soy protein and chitosan heated at low pH.Lebensmittel-Wissenschaft& Technology - Food Science and Technology. 2013;50(1):657–664.

21. Santoso B, Marsega A, Priyanto G, Pambayun R. Improvement of the physical, chemical and antibacterial properties of canna starch-based edible films. Agritech. 2016;36(4):378-386.

22. Martelli SM, Moore G, Paes SS, Gandolfo C, Laurindo JB. The influence of plasticizers on the water sorption isotherms and water vapor permeability of chicken feather keratin films. Lebensmittel-Wissenschaft& Technology - Food Science and Technology. 2006;39(1):292-301.

23. Guerrero P, Garrido T, Leceta I, Caba KDL. Films based on proteins and polysaccharides: preparation and physical-chemical characterization. European Polymer Journal. 2013;49(11):3713-3721.24. Rosida DF, Taqwa AA. Study on product development of Bangkalan Madura senasesalak (Salaccazalacca (Gaert.) Voss) as jelly candy. Journal of Agrotechnology. 2019;13(1):62-74.

25. Galus S, Kadzińska J. Whey protein edible film modified with almond and walnut oils. Food Hydrocolloids. 2016;52:77-86.

26. Febriana LG, Stannia NAS, Fitriani AN, Putriana NA. Potential of gelatin from fish bones as an alternative to capsule shells made from halal: characteristics and pre-formulation. Pharmaceutical Magazine. 2021;6(3):223-233.

27. Yanuriati A, Basir D. Increased solubility of porang (AmorphophallusmuelleriBllume) glucomannan by wet and dry milling. Agritech. 2020;40(34):22730-23717.

28. Kusumawati DH, Putri WDR. Physical and chemical characteristics of corn starch edible film incorporated with black turmeric juice. Journal of Food and Agroindustry. 2013;1(1):90-100.

29. Mayachiew P, Devahastin S. Effects of drying methods and conditions on release characteristics of edible chitosan films enriched with Indian gooseberry extract. Food Chemistry. 2010;118:564-601

30. Syarifuddin A. Edible film characterization of grapefruit pectin albedo and arrowroot starch. Journal of Food and Agroindustry. 2015;3(4):1538-1547.

31. Farikha IN, Anam C, Widowati E. Effect of type and concentration of natural stabilizers on the physicochemical characteristics of red dragon fruit (Hylocereuspolyrhizus) juice during storage. Journal of Food Technoscience. 2013;2(1):30-38.

32. HammamAra. Technological, applications, and characteristics of edible films and coatings: a review. SN Applied Sciences. 2019;1(632):1-11.

33. Cui T, Zhou X, Sui W, Liu R, Wu T, Wang S, Jin Y, Zhanga M. Effects of thermal-induced konjacglucomannan-protein interaction on structural and rheological properties of wheat dough. Food Structure. 2021;33:1-11.

34. Wijayani KD, Darmanto YS, Susanto E. Characteristics of edible films from different fish skin gelatin. Journal of Fisheries Science and Technology, 2021;3(1):59-64.

35. Nugroho AA, Basito, Katri RB. Study on the manufacture of tapioca edible films with the effect of adding pectin to several types of banana peels on physical and mechanical characteristics. Journal of Food Technoscience. 2013;2(1):73-79.

36. Singh TP, Chatli MK, Sahoo J. Development of chitosan based edible films: process optimization using response surface methodology. Journal of Food Science and Technology. 2015;52(5):2530-2543.

37. Kwon DK, Han JA. Development of hyaluronic acid-based edible films for alleviating dry mouth. Food Science and Human Wellness. 2022;12(2):371-377.

38. Velásquez F, Espitia J, Mendieta O, Escobar S, Rodríguez J. Non-centrifugal cane sugar processing: a review on recent advances and the influence of process variables on the quality attributes of final products. Journal of Food Engineering. 2019;255:32-40.

39. Pavlath AE, Orts W. Edible films and coatings for food application. chapter 1. edible films and coatings: why, what and how. New York: Springer Science+Business Media; 2009.

40. Maruddin F, Ako A, Hairawati, Taufika M. Characteristics of edible films made from whey and casein using different types of plasticizers. Journal of Animal Husbandry Science and Technology, 2015;5(2):97-101.

41. Widowati E, Parnanto NHR, Muthoharoh. Effect of polygalacturonase and gelatin enzymes on the classification of super red dragon fruit juice (Hylocereuscostaricensis). Journal of Agricultural Product Technology. 2020;13(1):56-69.

42. Miskiyah, Juniawati, Iriani ES. Potential of antimicrobial edible film as a meat preservative. Livestock Bulletin. 2015;39(2):1-10.

43. Soebroto JU, Susenoa TIP, Widoeri TE. Effect of LFC-12 concentration as an edible coating and storage time on the physicochemical properties of black rice flakes (Oryza sativa L. Indica). Journal of Food Technology and Nutrition. 2012;11(2):1-8.

44. Hasnelly, Nurminadari IS, Nasution MEU. Utilization of milk whey into edible films as packaging with the addition of cmc, gelatin and plasticizers. Pasundan Food Technology Journal. 2015;2(1): 62-69.

45. Prasetyo DA, Vifta RL. 2022. Effect of extraction method on total flavonoid content of red ginger extract (ZingiberofficinalevarRubrum). Journal of Holistics and Health Sciences. 2022;4(1):192-201.

46. Nugraheni B, Cahyani IM, Herlyanti K. Effect of porang tuber glucomannan (AmorphophallusoncophyllusPrain ex Hook. f.) on total blood cholesterol levels of mice fed a fat diet. Journal of Pharmacy and Clinical Pharmacy. 2014;11(2):32-36.

47. Yuwana AMP, Putri DN, Harini N. The relationship between sensory attributes and the quality of cane brown sugar: the effect of pH and caramelization conditions. Media Information and Scientific Communication of Agricultural Technology. 2022;13(1):54-66.

48. Hasnirwan, Arifin B, Putra FN. Isolation and characterization of flavonoid compounds from ginseng leaves (Talinumtriangulare (Jacq. W). Proceedings of Chemistry. 2015;304-311.

49. Aris SE, Jumiono A, Akil S. 2020. Identification of critical points for gelatin halalness. Halal Food Scientific Journal. 2020;2(1):17-22.

50. Savitri I, Suhendra L, Wartini NM. Effect of solvent type on maceration method terhadap characteristics of Sargassumpolycystum extract. Journal of Agroindustry Engineering and Management. 2017;5(3):93-101.

51. Demasta EK, Al-Baarri AN, Legowo AM. Study of discoloration of apples (MalusdomesticaBorkh.) treated with hypoiodous acid (hio). Journal of Food Technology. 2020;4(2):149-152.

52. Etxabide A, Uranga J, Guerrero P, Caba KDL. Improvement of barrier properties of fish gelatin films promoted by gelatin glycation with lactose at high temperatures. Lebensmittel-Wissenschaft& Technology - Food Science and Technology. 2015;63(1):315-321.

53. Nilasari OW, Susanto WH, Maligan JM. The effect of temperature and cooking time on the characteristics of pumpkin lemur (gourd). Journal of Food and Agroindustry. 2017;5(3):15-26.

54. Razavi SMA, Amini AM, Zahedi Y. Characterization of a new biodegradable edible film based on sage seed gum: influence of plasticiser type and concentration. Food Hydrocolloids. 2015;43(1):290-298.

55. Amanto BS, Siswanti, Angga A. Drying kinetics of Intersection giring (Curcuma heyneanaValeton& van Ziip) using a cabinet dryer with pre-treatment of blanching. Journal of Agricultural Product Technology. 2015;8(2):107-114.

56. Li C, Wang L, Xue F. Effects of conjugation between proteins and polysaccharides on the physical properties of emulsion-based edible films. Journal of the American Oil Chemists' Society. 2019;96(1): 1249-1263.

57. Ginting NA, Rusmarilin H, Nainggolan R. The effect of the ratio of red guava to lemon and the concentration of gelatin on the quality of red guava marshmallows. Journal of Food and Agricultural Engineering. 2014;2(3):16-21.

58. Trilaksani W, Nurilmala M, Setiawati IH. Extraction of red snapper skin gelatin (Lutjanus sp.) by acid treatment process. Journal of Processing of Indonesian Fishery Products. 2012;15(3):240-251.

59. Saberi B, Thakur R, Vuong QV, Chockchaisawasdee S, Golding JB, Scarlett CJ, Stathopoulos CE. Optimization of physical and optical properties of biodegradable edible films based on pea starch and guar gum. Industrial Crops and Products. 2016;86(1):342-352.