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The Effect of Gelatin Concentration on the Characteristics of Edible Film from Yam (*Dioscorea alata*) Starch

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Abstract :
Edible film made out of starch is known to have bad mechanical property such as compressive strength. This study aimed to determine the effect of adding gelatin to edible films from yam starch. This study used a Completely Randomized Design (CRD) with 6 treatments and repeated 3 times. The addition of gelatin was done at several concentration: 0%, 1%, 1.5%, 2%, 2.5%, and 3%. The study shows the addition of gelatin concentration significantly affects transparency, thickness and compressive strength but did not significant affect the water vapor transmission rate (WVTR) and solubility. The best treatment of gelatin concentration is 1% which produced edible film with WVTR 154.24 ± 44.50 g/m^2.24h, transparency of 8.98 ± 1.27 %/mm, solubility 24.41 ± 4.65 %, thickness of 0.17 ± 0.026 mm and compressive strength of 47.73 ± 3.50 N/m^2.

Keywords: edible film, gelatin, starch, yam

1. Introduction

Yam (*Dioscorea alata*) is a tropical plant that grows widely and can be found in almost all regions in Indonesia (Winarti and Saputro, 2013). Yam tuber contains high carbohydrate content, vitamins, protein and minerals. Yam tuber is rich in starch accounts 75-84% (Hoover 2001). Starch can be used as a basic ingredient for making edible films because it is easy to obtain, can also be consumed and is thermoplastic (Mali et al., 2005). Edible film is a thin layer made from edible materials, formed to coat food (coating) or placed between food components (film) which functions as a barrier against mass transfer, for example moisture, oxygen, lipids and dissolved substances (Krochta, 1997). In addition, edible film functions to extend the shelf life of food (Hasdar et al., 2011), protect food from water vapor and oxygen (Liu and Han, 2005) and prevent water loss in food (Krochta et al., 1994). Edible film is environmentally friendly packaging (biodegradable) because it can be broken down by microorganisms (Kim and Ustunol, 2001; Simelane and Ustunol, 2005).

The main components of edible film can be hydrocolloids (proteins, polysaccharides, alginate), lipids (fatty acids, acyl glycerol, wax) and composites or mixtures of hydrocolloids and lipids (Fennema et al., 1994). According to Krochta et al., (1994) hydrocolloids are used as edible films for food products that are not sensitive to water vapor. Hydrocolloids can prevent damaging reactions in food products by inhibiting reactive gases, especially oxygen and carbon dioxide. This material is also resistant to fat because of its polar nature.

Edible films made from starch have been widely used, including corn starch (Kusumawati and Putri, 2013), sago starch (Said, 2005) and yam starch (Mali et al., 2005). Starch is small grains (granules) that have round, oval, truncated oval and polygonal shapes (Hoover, 2001). Starch is composed of two main polymer units, namely amylose and amylopectin (Adebowale and Lewal, 2003). According to Garcia et al., (1998) in Krisna (2011) and Rodrigues (2006), a high amylose content will make the film more compact because amylose is responsible for the formation of the film matrix. According to Krochta (1997), amylose is a fraction that plays a role in gel formation and can produce a thin layer (film) that is better than amylopectin. The amylose content of yam starch is 24.6% (Harzau and Estiasih, 2013). Edible film made from starch has the advantage that the film has a compact structure and low solubility (McHugh and Krochta, 1994). One of the weaknesses of edible films made from starch is that they are brittle and stiff (Mali et al., 2005), so efforts are needed to overcome these obstacles such as adding lipids (Amrinarsih, 2000), adding plasticizers for example glycerol (Mali et al., 2005) modification of starch (Said, 2005) or addition of ingredients that can increase elasticity properties, namely gelatin. Based on previous research, making edible film from yam starch with a concentration of 3.33% without gelatin produces an edible film whose properties do not yet meet the standards of good edible film with a thickness of 0.13 mm, transparency of 12.51%/mm, water vapor transmission rate of 42. 66 g/cm^2.day, compressive strength 53.0 N/m^2 and solubility 13.01% (Maryana, 2018).

Gelatin is a type of protein that is commonly used in making edible films because it has the ability to change reversibly from sol to gel form, swell or expand in cold water and is able to form films (Schrieber and Gareis, 2007). Gelatin has hydrocolloid properties, can form a thin elastic layer, forms a transparent and strong film, and has high digestibility (Murtini et al., 2009). Edible film made from gelatin has good gas retaining properties but is not a good water barrier because of its hydrophilic nature (Andreuccetti et al., 2009; Arvanitoyannis, 2002). Krochta (1992) in Payung Layuk (2001) states that edible film which has hydrophilic properties is very sensitive to water absorption. Films containing proteins such as gelatin have good mechanical characteristics but are hydrophilic so they have a low water barrier (Syarifuddin et al., 2017). Edible films using starch and protein have good barrier properties against aroma, O_2, CO_2 and fat and have more transparent film performance (Janjarasskul and Kroctha 2010). Due to the hydrophilic nature of edible film, it should be used as primary packaging, so that it does not come into direct contact with outside air and the product does not spoil quickly. Hydrophilic edible film can be applied to food products with low water content, namely as instant noodle seasoning packaging so that it can be decomposed by microorganisms and reduces plastic waste.

Gelatin has high binding strength and can produce uniform granules in edible film with good compressibility and compactibility (Setyowati, 2009). Therefore, the affinity between gelatin and starch is higher, thereby strengthening the structure of the edible film (Gardjito, 1994). The characteristics of edible film produced from starch with the addition of gelatin produce a stronger edible film (Ongkowidodo, 2016). Edible film formed with a higher level of gelatin concentration will increase the interaction between bonds which ultimately affects the properties of the edible film with stronger protein molecular bonds (Gennadios et al., 2006). Based on research by Hendra (2015), using gelatin with more than a starch concentration will produce a stiff edible film.

2. Research Methods

Materials and Tools

The materials used in this research were yam starch, glycerol, gelatin and distilled water. Meanwhile, the materials for analysis are $Mg(NO_3)_2$, NaCl and CaCl. The tools used in this research were digital scales, blenders, beakers, stainless steel basins, test tubes, filter cloths, plastic clips, tissues, spatulas, cutting boards, dropper pipettes, 60 mesh filters, 200 mesh filters, baking pans, desiccators, glass funnel, beaker glass, measuring cup, magnetic stirrer, hot plate stirrer timer, petridish and electric oven. Meanwhile, the tools for analysis are texture analyzer, desiccator, screw micrometer and spectrophotometer.

Research Design and Statistical Analysis

The research was carried out using a Completely Randomized Design (CRD) with 6 treatments and 3 replications to obtain 18 experimental units. The treatments applied were gelatin concentrations of 0%, 1%, 1.5%, 2%, 2.5% and 3%.

Preparation of Starch

The yam tubers were cleaned of dirt and steamed at 100^{o}C for 5 minutes. Then the cassava tubers are peeled and sliced 0.5 cm thick. The yam slices are then soaked first in a salt solution for 30 minutes to remove the mucus in the yam flesh, after that they are crushed using a blender with the addition of 1:2 water (yam: water). The yam pulp is then filtered using a 200 mesh sieve, then the results of the filter are settled for 6 hours, after being settled for 6 hours, the water and the sediment are separated, then the sediment is washed with distilled water and then soaked in distilled water for 30 minutes until the precipitated water is clear. and throw back the water and sediment in the oven for 6 hours at a temperature of 50^{o}C.

Edible Films Preparation

Starch with a concentration of 3% is dissolved with distilled water in a beaker and stirred until dissolved without heating for 10 minutes and 3 grams of glycerol and gelatin are added at the 10th minute after heating according to the concentration determined in % until the total ingredients are 150 grams. Then heated on a hot plate until the temperature reaches 80°C and stirred using a magnetic stirrer until homogeneous. The homogenized edible film solution is then poured into a petri dish. Then the film on the petridish was dried in an oven at 50°C for 24 hours.

Parameter

The parameters are Equilibration (Manrich *et al*., 2017), Water Vapour Transmission Rate (Pineroz-Hernandez, 2017), transparency (Pineroz-Hernandez, 2017), solubility (Gontard *et al*., 1992), film thickness (Mendes *et al*., 2016), compressive strength (ASTM, 1997).

Data Analysis

The data obtained were analyzed using analysis of variance. Furthermore, if there is an effect of treatment, further tests will be carried out using the Duncan New Multiple Range Test at the 5% level.

3. Results and Discussion

Water Vapour Transmition Rate (WVTR)

WVTR accounts for the movement of water vapor that enters the edible film at a certain time, temperature and humidity. The WVTR value will indicate the film's ability to inhibit water vapor. The greater the WVTR value, the greater the rate of water vapor in the film, so the film's ability to inhibit water vapor is less good.

Table 1. The characteristics of edible film with several concentration of gelatin

Gelatin (%)	WVTR (g/m^2.day)	Transparency (%/mm)	Solubility (%)	Thickness (mm)	Compressive strength (N/m^2)
0	256.06 ± 71.47^a	14.59 ± 2.59^c	15.56 ± 1.24^a	0.12 ± 0.020^a	35.60 ± 1.87^a
1	154.24 ± 44.50^a	8.98 ± 1.27^b	24.41 ± 4.65^a	$0.17 \pm 0{,}026^{ab}$	47.73 ± 3.50^b
1.5	172.42 ± 18.68^a	5.67 ± 0.94^a	23.67 ± 4.15^a	0.22 ± 0.026^{bc}	61.37 ± 1.44^c
2	180.91 ± 174.72^a	6.54 ± 0.44^a	26.15 ± 2.57^a	0.22 ± 0.026^{bc}	69.10 ± 2.42^d
2.5	180.61 ± 26.60^a	5.47 ± 0.19^a	17.95 ± 5.78^a	0.25 ± 0.005^{cd}	80.10 ± 5.36^e
3	153.94 ± 97.11^a	5.14 ± 0.87^a	17.21 ± 5.16^a	0.30 ± 0.055^d	88.90 ± 1.53^f

Note: numbers followed by the same lower case letter are not significantly different at the 5% level in the DNMRT test

WVTR of edible film with the influence of gelatin concentration produces an average of 153.94 ± 97.11 - 256.06 ± 71.47 g/m2 24 hours. The results of this research produced a higher water vapor transmission rate compared to research by Abdurrahman (2018) on optimizing the synthesis of edible film from sweet sorghum protein which produced a water vapor transmission rate of 78 - 85.2 g/m2 24 hours. The results of this research produced a higher water vapor transmission rate compared to research by Maryana (2018) on edible film with a concentration of 3.33% white cassava starch without gelatin which produced a water vapor transmission rate of 42.66 g/m2 24 hours.

Edible films at various gelatin concentrations produce quite high water vapor transmission rates due to the hydrophilic nature of the materials used in making edible films. According to McHugh and Krochta (1994), protein-based edible films usually have relatively high water vapor permeability due to the hydrophilic properties of protein. Glycerol also has hydrophilic properties which cause an increase in the rate of water vapor transmission. This is in line with the statement by McHugh et al., (1994) that glycerol has a high ability to bind water, resulting in a high water vapor transmission rate value.

According to the standards set by JIS Z 1707 (1997) in Abdurahman (2018), edible film can be said to be a food packaging material if the transmission rate of water vapor through the film is no more than 168 g/m2 24 hours. Based on the data that has been obtained, it appears that edible film produces a water vapor transmission rate ranging from 153.94 ± 97.11 - 256.06 ± 71.47 g/m2 24 hours and does not meet the standards set by JIS.

Transparency

Transparency describes the clarity of edible film. The light from the UV-Vis Spectrophotometer passes through the edible film so that the transmittance value can be obtained. The results of the variance test showed that the gelatin concentration was very significantly different ($p < 0.05$) to the transparency of the cassava starch edible film. The transparency value of edible film can be seen in **Table 1.**

Based on the addition of gelatin concentration, the average transparency of edible film was between 5.14 ± 0.87 – 14.59 ± 2.59 %/mm. This result is lower than research by Maryana (2018) on edible film with a concentration of white cassava starch of 3.33% without gelatin with a transparency value of 12.51%/mm. These results are in line with Ramadhon's (2018) research on making cassava starch edible film with the addition of gelatin which produces a transparency value of 4.13 – 10.68%/mm.

Based on the research results, it can be seen that the gelatin concentration causes the transparency value to decrease with each treatment. Increasing the gelatin concentration will increase the viscosity level of the film solution, causing the film forming polymer to increase in quantity as a result, the film thickness will increase. This was stated by Golsberg and Williams (2003) that increasing viscosity will have an effect on increasing the thickness of the edible film so that its brightness will decrease.

Solubility

Solubility is the percentage of edible film that dissolves in water when soaked for 24 hours. Film solubility is an important factor in determining the biodegradability of edible film when used as packaging. Based on analysis of variance, it showed that gelatin concentration had no significant effect ($p > 0.05$) on the solubility of cassava starch edible film.

Edible film which has high solubility is very good for use in ready-to-eat food products because it dissolves easily when consumed. On the other hand, low solubility is one of the important requirements for edible film as food packaging that comes into contact with water and acts as a protector for food products. The average solubility value of edible film can be seen in Table 1.

Based on research results, various gelatin concentrations produce varying solubility in the range of 15.56 ± 1.24 – 26.15 ± 2.57%. According to Negara and Simpen (2014), the addition of plasticizer (glycerol) to edible film results in an increase in C, H and O atoms or an increase in the number (content) of constituents in the structure. Glycerol as a plasticizer has completely entered the gelatin structure to form a new structure of edible film. As a result, changes in physico-chemical properties also occur, including solubility in water.

The results of this research produced a higher solubility value compared to research by Maryana (2018) on edible film with a concentration of white cassava starch of 3.33% without gelatin, namely 13.01%. It is desired that the film has a high level of solubility or vice versa depending on the type of product being packaged (Nurjannah, 2004). Films made from starch tend to be hydrophilic, so they dissolve easily in water.

The solubility level of edible film is caused by the increased content of soluble solids originating from the basic ingredients for making edible film, namely starch, gelatin and glycerol which are hydrophilic. According to Bourtoom (2007), edible films that use starch as raw material will have hydrophilic properties. Krochta et al., (1992) films made from hydrocolloids plus glycerol can have hydrophilic properties.

Thickness

Thickness is an important parameter that influences the application of the film to the product to be packaged, besides that it can also influence the parameters of transparency, tensile strength and rate of steam or gas transmission in the film (Sinaga et al., 2013). The edible film thickness value was taken from the average at 5 different film points using a screw micrometer.

The thickness value of the resulting edible film can be seen in Table 1 which shows that the gelatin concentration treatment has a significant effect ($p < 0.05$) on the thickness of the edible film. The higher the gelatin concentration, the higher the thickness value of the edible film. This is in accordance with the opinion of Nugroho et al., (2013) who stated that increasing the amount of solids in the solution results in more polymers making up the edible film matrix.

Apart from the total solids in the solution, the factor that the edible film becomes thicker is influenced by the viscosity and polymer content of its constituents. The water absorption ability of each material will affect the viscosity of the edible film solution. Zavala et al., (2008) stated that the use of polysaccharides as a basic ingredient for edible films will provide thickness because they have high viscosity. Viscosity affects the amount of solids in the solution. The higher the viscosity, the greater the amount of solids in the solution. Furthermore, Wang et al., (2006) stated that the thickness of edible film is influenced by the nature and content of the polymer that makes it up.

Edible film with the influence of gelatin concentration produces good edible film thickness because according to Japanesse Industrial Standards (JIS), plastic film for films categorized as food packaging has a maximum thickness of 0.25 mm (Saputra, 2015). The thickness of the edible film in this study was in the range of 0.12 ± 0.020 - 0.30 ± 0.055 mm, which means that the thickness of the edible film meets food packaging film standards. The results of this research are in line with research by Ramadhon (2018) on edible cassava starch film with the addition of gelatin which has a thickness value of 0.18 - 0.41 mm. The results of this research are higher than research by Maryana (2018) on edible film with a concentration of white cassava starch of 3.33% without gelatin with a thickness value of 0.13 mm. According to Yulianti and Ginting (2012), the thicker the edible film, the higher the ability of the edible film to inhibit the flow of water, so the product's shelf life will be longer. However, if it is too thick it will affect the taste of the product when eaten, so the thickness of the edible film must be adjusted to the product being packaged.

Compressive Strength

Compressive strength is the maximum compressive strength that can be achieved until the edible film remains intact before breaking/tearing. Compressive strength is a mechanical property of edible film. The greater the compressive strength, the better the edible film is at resisting mechanical damage.

Based on analysis of variations, gelatin concentration has a very significant effect on cassava starch edible film as seen in Table 1. The higher the gelatin concentration, the higher the compressive strength value produced. The compressive strength in this study is in line with research by Chambi and Grosso (2006) who reported that edible films made from gelatin and casein increased due to an increase in collagen concentration in gelatin. This is because the plasticizer can interact with gelatin, thereby forming a gelatin-plasticizer bond, where this bond can form increased elasticity (Julianto et al, 2011).

The average value of compressive strength of edible film is 35.60 ± 1.87 – 88.90 ± 1.53 N/m^2. The results of this research produced a higher compressive strength compared to the results of Maryana's (2018) research on edible film with a white cassava starch concentration of 3.33% without the addition of gelatin, which was 53.6 N/m2. Based on JIS Z 1707: 1975 in Santoso *et al*, (2012) Plastic film for food packaging has a minimum compressive strength value of 0.49 N/m^2.

Arvanitoyannis *et al*., (1997) stated that the amount of compressive strength is determined by the tissue structure, namely the shape of the weave and the protein content in collagen in gelatin-based edible films. Meanwhile, according to (Poeloengasih and Marseno, 2003) film matrix instability occurs due to an increase in the hydrophilic protein component of gelatin in the edible film structure. The greater the strength of the gel, the more abundant and dense the matrix formed on the film, so that when a compressive force is applied the film will produce a greater compressive strength.

Conclusion

The concentrations of gelatin have a significant effect on transparency, thickness and compressive strength of edible film but do not have a significant effect on WVTR and solubility. Edible film with 1% gelatin concentration produces the best edible film with characteristics of WVTR 154.24 ± 44.50 g/m^2 day, transparency 8.98 ± 1.27 %/mm, solubility 24.41 ± 4.65 %, thickness 0.17 ± 0.026 mm and compressive strength 47.73 ± 3.50 N/m^2.

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