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Modification of Yellow Yam Starch (*Dioscorea alata*) Using Various Solvent Ratio and Its Application for Edible Film

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Abstract :
Edible films from native starch have some weaknesses, one of which is the water vapor transmission rate is still high. To lower the rate of water vapor transmission may be used starch composites starch. This study aimed to obtain ethanol volumes that can produce modified starch with the smallest size, produce composite starch for edible film and to determine the characteristics of edible film made out of natural starch and edible film from composite starch (natural starch and modified starch). This research was conducted in 3 stages, namely: extraction of yam starch, modification of yam starch by precipitation method and production of edible films from natural starch and composite starch. This study was designed to produce modified starch using 5 levels of ratio between starch paste volume and ethanol volume 1:5, 1:7.5, 1:10, 1:12.5, 1:15. The results showed that the treatment of ratio 1:15 (1500 ml ethanol) produced the smallest particle size of starch 3,417 x 5,945 µm up to 15,038 x 16,708 µm with starch yield of 80%. Edible films made from composite starch have different characteristics than natural starch. Edible film from composite starch produces higher thickness values of 0.156 ± 0.006 mm, lower solubility of 27.385 ± 3.808%, lower transparency of 10.657 ± 0.278% /mm and lower water vapor transmission rate (WVTR) of 18.423 g / m2 hour, and compressive strength of 841.8 ± 6,823 gF than natural starch edible film.

Keywords: Edible film, precipitation, starch composite, volume, yam starch

1. Introduction

Yam tubers (Dioscorea spp.) are a type of tuber that grows widely in Indonesia. There are more than 600 species of the genus Dioscorea spp. The nutritional value of cassava tubers is 75% water, 19.8%-31.8% carbohydrates, 0.6%-2.0% protein, 0.2% fat, minerals (Calcium 45 mg/100 gr, Phosphorus 280 mg /100 gr, Iron 1.8 mg/100 gr) and vitamins (B1 0.10 mg/100gr, C 9 mg/100gr) (Prawiranegara, 1996 in Winarti et al., 2011).

Dioscorea is a bulbous plant that is rich in starch content which has not been widely used. Starch is a polymer that can be used and is often used in the food industry as a biodegradable film to replace plastic polymers because it is economical, renewable and provides good physical characteristics (Bourtoom, 2007). Yam contains carbohydrates with high amylose levels, namely 26.98-31.02% (Jayakody et al., 2007). Films from starch with high amylose content produce stronger films than starch containing less amylose (Palviainen et al., 2001 in Kusumawati, 2013).

Natural starch-based edible films have weaknesses, namely their resistance to water is low and their barrier properties against water vapor are also low due to the hydrophilic nature of starch (Garcia et al., 2011). Edible film from yam starch produces the physical characteristics of edible film, namely having transparency between 13.245%-12.421%, thickness between 0.124mm–0.132mm, water vapor transmission rate (WVTR) 41.932-38.954 g/cm2/24 hours, compressive strength 49.5– 48.1 N/m2 and solubility 16.7%–15.3% (Maryana, 2018). Compared with edible film standards referring to JIS 1975 in Santoso et al. (2012) stated the standard for making edible film, plastic film for food packaging as the standard for making edible film with a maximum WVTR (water vapor transmission rate) value of 5 g/m2/day, a minimum compressive strength of 100 N, and a thickness of 0.25 mm. , so improvements need to be made so that the values obtained are better and in accordance with standards.

Improving the characteristics of edible film from yam starch can be done by using composite starch, namely a mixture of natural starch and modified starch which has smaller particles that function as filler in a matrix. Composites show new properties that are superior to the original material (Park et al., 2013 in Pamuji, 2014). Farrag et al. (2018) who made edible films from corn starch composites with modified corn starch and pea starch composites with modified pea starch can reduce the water vapor transmission rate, namely from 217.81 g/m2day to 196.38 g/m2day for starch. corn, and 200.01 g/m2day to 160.31 g/m2day in pea starch where modified corn starch and modified pea starch were produced using the gelatinization technique followed by precipitation using ethanol. Pengwu, et al. (2018) stated that starch which has a smaller size can be used as a filler for natural rubber and can increase the tensile strength of natural rubber. Setiawan (2018) stated that the addition of nanosilica from rice husks to cassava peel-based bioplastic composites can significantly increase the thickness and tensile strength of bioplastics.

There are 3 ways to reduce particle size, namely acid hydrolysis, enzymatic and mechanical treatment (Le Corre et al., 2010). Reducing the size of starch particles by mechanical treatment can be achieved through precipitation with organic solvents. At this stage, the destruction of the amylose and amylopectin fractions occurs. The precipitated fraction is a starch solution that has been completely gelatinized, resulting in starch particles that are separated from the solvent. The use of organic solvents such as ethanol is certainly one of the advantages of the precipitation method compared to other methods such as acid and enzymatic hydrolysis because this material is polar, can bind water quite well so that during the precipitation process the gelatinized starch can be separated from the water, and easy to get and not dangerous. Apart from that, the precipitation method is not too complicated and does not require equipment that is too sophisticated, although it requires a slightly long process time (Winarti et al., 2011).

In the modification process using the precipitation method, the amount of anti-solvent reagent used is one of the factors that can influence the modification results. According to research conducted by Qin et al. (2016) regarding modification of tapioca starch was carried out using a solvent and anti-solvent ratio of 1:10 which produced a particle size of 30 nm to 110 nm. Another research, namely modification of sago starch using the precipitation method, was carried out by adding ethanol to the paste solution with a ratio of 1:20 and produced particle sizes of 300 nm and 400 nm (Chin et al., 2011). This research aims to obtain the solvent volume ratio that can produce modified starch with the smallest size and determine the characteristics of edible film made from composite starch, namely natural starch plus modified starch of smaller size.

2. Research Methods

Material

The materials used in this research were yellow yam tubers, distilled water, glycerol, 96% technical ethanol, and absolute ethanol, while the materials used for analysis included Mg(NO3)2, NaCl, and CaCl2.

The tools used in this research are analytical scales, blenders, sieves, 200 and 60 mesh sieves, basins, baking sheets, knives, cutting boards, electric ovens, measuring cups, beakers, stirring rods, magnetic stirrers, centrifuges, vortexes, indicators. pH and plastic clips as well as analysis tools in the form of a scanning electron microscope, spectrophotometer (UV-vis), screw micrometer, thermometer, screw tube, Petri dish and desiccator

Research Design

This research was carried out using 5 different ratios between the volume of starch paste and the volume of anti-solvent (ethanol) as follows:

P0 = Control (native starch without modification)
P1 = volume of paste : volume of ethanol = 1:5
P2 = volume of paste : volume of ethanol = 1:7.5
P3 = volume of paste : volume of ethanol = 1:10
P4 = volume of paste : volume of ethanol = 1:12.5
P5 = volume of paste : volume of ethanol = 1:15

Yam Starch Extraction (Ulyarti et al., 2016)

Yam is cleaned, washed, peeled, washed again and then sliced 2 mm to 3 mm thick. Mucus is removed by soaking the slices in 15% salt solution (NaCl) for 30 minutes and washing again 3 times. The yam slices are ground with a blender, until the pulp can pass through a 200 mesh sieve. The suspension obtained was deposited for 6 hours. The precipitate was then dissolved in distilled water again to purify starch. The starch was dried in the oven at 50 ºC for 6 hours. The dried starch was ground using a 60 mesh sieve and packed in a closed container and stored at room temperature.

Starch Modification by Precipitation Method (Qin et al., 2016) with modifications

A total of 1 gram of starch is dissolved in 100 ml of distilled water. The mixture was then heated on a hot plate at 100ºC for 30 minutes with constant stirring. Then the solution is cooled and ethanol is added according to the treatment, namely 500 - 750, 1000, 1250 and 1500 ml little by little while continuing to stir. Next, the solution was left for 8 hours at room temperature while continuing to stir constantly. The solution was then centrifuged at 2500 g for 15 minutes. Then the precipitate was washed with absolute ethanol 3 times. After that, the precipitate was dried using a drying process without heat (cold air drying). The modified starch was stored in polyethylene plastic at room temperature.

Preparation of Edible film (Gonzalez, 2015)

There are two types of edible films made in the research, namely edible films from natural yellow cassava starch and edible films from composite starch. The composite starch in question is a mixture of natural yellow yam starch and modified yellow yam starch with the smallest particle size. Both edible films were made using similar procedures with the difference that there was the addition of modified cassava starch at the end of the process of making edible films from composite starch.

Dissolve 4 grams of yellow cauliflower starch in 143 grams of distilled water and stir for 10 minutes. Heated using a hot plate for 30 minutes at gelatinization temperature (80ºC) with stirring using a magnetic stirrer. Then the glycerol solution was added with a concentration of 2% (3 gr) at the 10th minute. Next, the solution was added with 15% (0.6 gr) modified starch and homogenized. The film solution was then printed using a petridish with a diameter of 9.2 cm and a height of 1.7 cm and dried at a temperature of 50ºC in an oven for 24 hours. Then, before being analyzed, the film was equilibrated for a minimum of 48 hours, the edible film was stored in a desiccator with RH 52% using saturated $Mg(NO_3)_2$. The resulting edible film was then analyzed for its physical and mechanical properties.

Modified Starch Yield

The yield is calculated by comparing the amount of modified starch produced with the initial amount of starch before modification using the following formula calculation:

$$\text{Yield (\%)} = B/A \times 100\ \%$$

Keterangan :
A = Starch weight before modification
B = Starch weight after modification

Morphology and Size of Starch Granule Particles (Juhana, 2018)

Modified yellow cassava starch was tested using a scanning electron microscope (model JEOL JSM 6510 LA) which had previously been dispersed using alcohol. The samples were placed on aluminum stabs using double-sided adhesive tape and coated with gold powder to avoid charging under the electron beam after the alcohol evaporated. Starch granules were observed at 250x and 1000x magnification. Starch granules were measured using the Image J version 1.5.2 application by measuring length and width.

Thickness (Warkoyo et al., 2014)
The samples were measured using a screw micrometer at 5 different places then the measurement results were averaged as a result of the film thickness.

Solubility (Gontard et al., 1993)
Weigh the dried filter paper. The film samples were cut into 2x2 cm pieces, put into 50 ml of distilled water and soaked for 24 hours while stirring periodically. The solution was then filtered and the filter paper dried at 1050C for 24 hours. The number of films that did not dissolve was then weighed. % Solubility can be calculated using the formula:

$$\% \text{ Solubility} = \frac{w2 - (w3 - w1)}{w2} \times 100\%$$

Keterangan:
w1 = Initial filter paper (g)
w2 = *Edible film* after (g)
w3 = Filter paper and insoluble edible film (g)

Transparency (Hernandez, 2017)
The film is cut square (50x10mm), placed in the spectrophotometer cell. Percent transmittance was measured with a UV-Vis spectrophotometer at a wavelength of 600 nm. Edible film transparency is calculated using the formula:

$$\text{Transparency} = \log T / \text{thickness}$$

Water Vapor Transmission Rate/WVTR (Hernandez, 2017)
A test tube containing calcium chloride is covered using film. The weight of the tube is then weighed. The tube was placed in a desiccator that was saturated using saturated sodium chloride (RH 75%). The change in tube weight is then recorded and plotted as a function of time. WVTR calculations can use the formula:

$$\text{WVTR} = \frac{\text{Slope}}{A}$$

Keterangan:
WVTR = Water vapour transmition (g/m^2/24jam)
Slope = Linear function of weight gain and time (g/d)
A = The area of the film (m^2)

Compressive Strength
Compressive strength was measured with a Brookfield brand LFRA Texture Analyzer.
1. Determine the type of probe that will be used for edible film, namely the TA 7 60 mm type and use a blade to test the compressive strength of edible film.
2. The LFRA Texture Analyzer tool is set to:
   Test : Cycle count
   Trigger : 2 g
   Distance : 2 mm
   Speed : 2mm/s
3. The probe is installed in place and the "start" button is pressed to start pressing the edible film.
4. A sample of edible film that has been cut to a size of 5 x 2 cm is placed under the probe and the probe will press the film until the magnitude of the probe force used appears on the screen.

3. Results and Discussion

Yield of Modified Starch

Starch yield is calculated by comparing the weight of starch after modification and the weight of starch before modification, the results of which can be seen in Table 1.

Table 1. Average yield and particle size of modified starch in various volumes of ethanol

Ethanol Volume (ml)	Modified Starch Yield (%)	Modified Starch Particle Size (μm)
500	80 ± 0,007	8,461 x 10,332 to 21,779 x 26,783
750	72 ± 0,007	6,232 x 10,419 to 15,493 x 35,861
1000	81 ± 0,014	8,360 x 10,761 to 25,416 x 26,458
1250	79 ± 0,028	4,512 x 7,223 to 13,717 x 17,492
1500	80 ± 0,007	3,417 x 5,945 to 15,038 x 16,708

Modification using the precipitation method begins with a gelatinization process. During gelatinization, the structure of the starch granules is destroyed. As the temperature increases, the starch will expand, this is because water molecules enter the starch granules and bind with amylose or amylopectin so that the hydrogen bonds connecting the amylose and amylopectin molecules weaken.

It can be seen in Table 1 that the yield value ranges between 72-81%. This shows that the volume of ethanol added produces a quite large yield value. This result is similar to research by Sauyana (2014) where the precipitation process using sago starch that had been lintnered for 6 hours produced a yield of 83.49-87.88%. Research conducted by Wulandari (2013) by modifying sago starch and tapioca starch using the precipitation method produced yields ranging from 92.84-94.54% for sago starch and 85.38-87.17% for tapioca. He suspects that the large yields produced were due to because during the precipitation process no further destruction of the amylose and amylopectin chains occurs so that the resulting yield is greater. Apart from that, the addition of ethanol in different volumes is thought to not affect the resulting yield value, because ethanol plays a role in attracting water which has bound to amylose or amylopectin, so that when water has bound with ethanol, amylose and amylopectin will re-bond with each other and undergo a retrogradation process and starch will precipitate.

Morphology of Starch

The changes and size of starch particles produced in the starch modification process using the precipitation method were analyzed using a scanning electron microscope (SEM). The changes and size of the starch granules produced can be seen in Table 1.

In Table 1, it can be seen that there are differences in the shape and size of the natural yam starch granules and the yam starch that has been modified using the precipitation method. In natural starch, it can be seen that the starch granules still look intact with their oval shape, which shows that the granules in natural yam starch have not experienced damage to their granular structure. Apart from that, natural starch granules still have a smooth and intact surface. This is in accordance with Faridah et al. (2011) and Nadia (2013) that starch granules that have not undergone a modification process will have a smooth and intact surface and have various shapes such as round, oval, elliptical and polygonal with uneven thickness.

Starch granules were measured using the image J application. The size of the granules was obtained by measuring the long and wide sides of the starch granules. The measurement results can be seen in Table 8. Using SEM (scanning electron microscope) magnification of 250 and 1000x, natural starch granules have sizes between 10.089 x 11.696 µm to 25.896 x 28.177 µm. This is in accordance with Huang et al. (2006) in their research explained that yam starch granules have a predominantly large size, namely between 20-40µm, and according to An-nuha (2018) yam starch granules have a size of 10-30 µm.

According to Le Corre et al. (2010) the initial process of starch modification which produces a smaller size is by attacking the amorphous area. Amorphous areas have weaker hydrogen bonds, so they undergo chemical reactions more easily than crystalline areas. Reducing the size of starch particles can be achieved through precipitation with organic solvents. At this stage, the destruction of the amylose and amylopectin fractions occurs. The precipitated fraction is a starch solution that has been completely gelatinized, resulting in starch particles that are separated from the solvent. Reducing the size of starch particles occurs when starch is treated at high temperatures during the gelatinization process (Sauyana, 2014).

In Figure 1, it can be seen that the granules produced by starch modification have a shape that looks like it is dredged or folded, and have a reduced size. The treatment with an ethanol volume of 1500 ml produced the smallest size, namely 3.417 x 5.945 µm to 15.038 x 16.708 µm, this can be seen in the picture in the 500 ml to 1000 ml treatment the starch granules were still dominated by large sizes whereas in the 1250 ml treatment and 1500 ml small granule sizes have begun to appear with increasing numbers as the volume of ethanol increases.

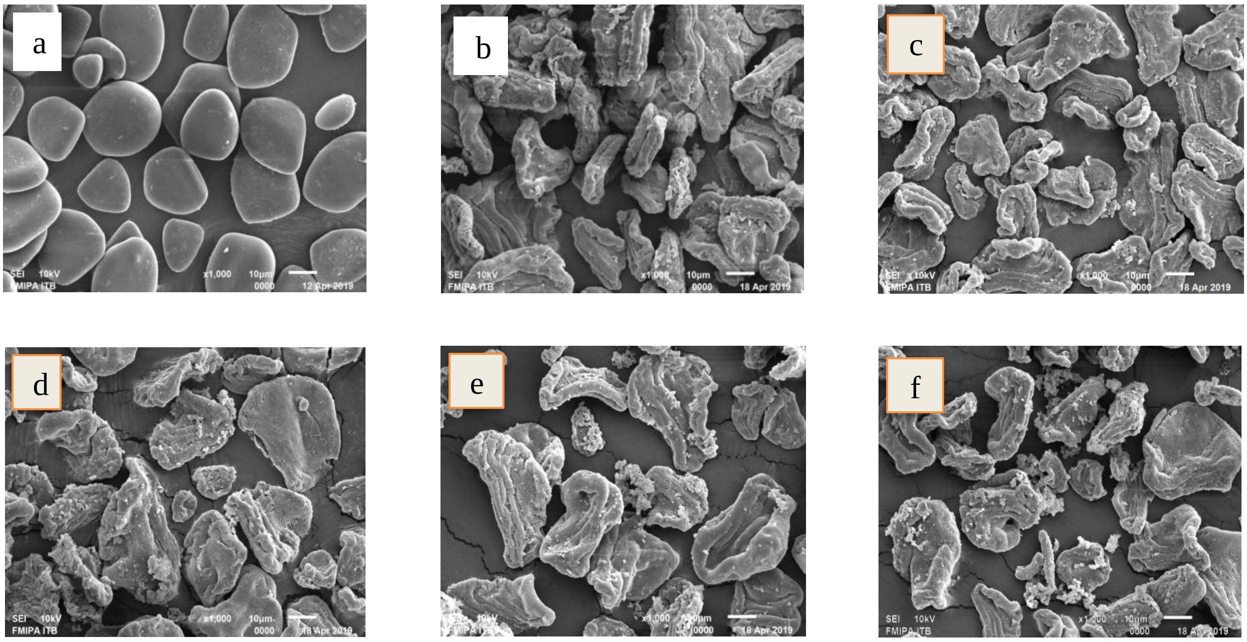

Figure 1. Scanning Electron Microscope Results (a) Natural starch of yellow yam; (b) Modified starch, ethanol volume 500 ml; (c) Modified starch, ethanol volume 750 ml; (d) Modified starch, ethanol volume 1000 ml; (e) Modified starch, ethanol volume 1250 ml; (f) Modified starch with ethanol volume of 1500 ml.

According to Saari et al. (2016), the ratio between starch paste solution and ethanol at 1:1 and 1:10 showed the same results and there was no significant difference in reducing particle size. According to Chin et al. (2011) at a ratio of starch paste and ethanol solution of 1:10 produces fiber-like starch particles, then the ratio is increased to 1:15 to produce starch particles that have a fiber-like shape but are elongated round, and when the ratio is 1:20 it produces a predominantly round shape. with a particle size of 300-400 nm, as the ethanol increases, the resulting small, round-shaped particles become increasingly visible. During the 8 hour stirring process, it causes further destruction of the starch granule structure so that small particles will form. At a volume of 500 ml of ethanol, destruction of the granule structure occurs only in the outermost area, namely amorphous, and causes the resulting starch granules to still have a predominantly large size. Increasing the volume of ethanol to 1500 ml, apart from destroying the amorphous area, will also damage the crystalline area, resulting in starch particles with a smaller size. This is in accordance with Sauyana (2014) that during the precipitation process there will be destruction of covalent and hydrogen bonds in the amylopectin double helix structure, resulting in the formation of smaller starch particle sizes. By destroying these bonds, starch granules will more easily form smaller particles. In the precipitation process, starch undergoes a rapid retrogradation process when ethanol is added slowly and stirred quickly.

Thickness

Edible film is a thin layer used as food packaging. In determining the quality of edible film, there are several parameters that can be used, including thickness, solubility, transparency, and water vapor transmission rate. Edible film thickness testing is obtained from the average of measurement results at five different points on the edible film using a screw micrometer. The average thickness value can be seen in Table 2.

Thickness is an important parameter in edible film, because it can influence its application to a product, besides that it can influence other parameters, such as solubility, water vapor transmission rate, transparency and compressive strength (Maryana, 2018).

In Table 2, it can be seen that the edible film from natural starch has a thickness of 0.102 mm and the thickness of the edible film from composite starch has increased to 0.156 mm. This shows that edible film added with composite starch can increase the thickness of the edible film. This is in accordance with research conducted by Shankar et al. (2015) where the results obtained showed an increase in the thickness of gelatin-based films with the addition of NP-ZnO. The thickness of the edible film produced is categorized as good edible film because it complies with the Japanese Industrial Standard (JIS), where the maximum thickness for film for food packaging is 0.25 mm (Saputra, 2015). The thickness of the edible film from composite starch can be caused by the increase in the total amount of solids and the increase in the polymer that makes up the edible film matrix so that the resulting edible film will be thicker. This is in accordance with the opinion of Barus (2002) and Murdianto (2005) who state that the increase in thickness is caused by an increase in the concentration of the film making material, this results in the total solids in the film after drying increasing and the polymers that make up the film matrix also increasing. .

Yulianti and Ginting (2012) stated that the thicker the edible film produced, the higher its ability to inhibit the flow of gas and water vapor, so that the product's shelf life will be longer. If it is too thick it will affect the appearance and taste or texture of the product when eaten. The thickness of the edible film must be adjusted to the product to be packaged.

Table 2. Average values for thickness, solubility, transparency and WVTR of edible films

Parameter	Native Starch	Composite Starch
Thickness (mm)	0,102 ± 0,010	0,156 ± 0,006
Solubility (%)	32,554 ± 9,035	27,385 ± 3,808
Transparency (%/mm)	17,721 ± 0,942	10,657 ± 0,278
WVTR (g/m^2jam)	42,111 ± 8,596	18,423 ± 5,264
Strong Press (gF)	632,53 ± 2,510	841,08 ± 6,823

Solubility

The solubility of the film in water is expressed as the percentage of the film that dissolves in water after soaking for 24 hours (Gontard et al., 1993). Solubility of edible film indicate the integrity of the edible film in a liquid environment. Edible film with high solubility indicates that the resistance of the edible film to water is lower, and also shows the hydrophilicity of the film (Ramadhon, 2018). Water resistance is an important property for films to have because of their application as food protectors (Imeson, 1999). The average solubility value can be seen in Table 2.

In Table 2, it can be seen that edible film made from composite starch has a lower solubility value compared to edible film made from natural starch, where natural starch has a solubility value of 32.55% while the solubility value of edible film made from composite starch is 27.38%. This is because composite starch is more hydrophobic, and causes the solubility value to decrease compared to natural starch. According to Murdianto et al. (2005) stated that the addition of hydrophobic components resulted in the film having low solubility. according to Anandito et al. (2012) the addition of hydrophilic components to edible film will cause an increase in the percentage of film solubility.

Edible films made from composite starch have a lower solubility value compared to natural starch, as in research conducted by Diova et al. (2013) by making a semi-refined carrageenan composite edible film which produced the best solubility value, namely 39.15%, and according to research by Liu et al. (2016) who made edible film from corn starch composite starch had a solubility of 22.33%. Edible film made from natural starch has a higher solubility value, such as research conducted by Wattimena (2016) regarding edible film made from sago starch with glycerol concentration treatment which has a solubility value of 33.44-42.43%, and according to Anandito et al. . (2012) edible film made from jali flour with the addition of glycerol produces a solubility value of 41-48%.

According to Diova et al. (2013) in his research, edible film with the lowest solubility was the best. This is because the lowest solubility value indicates that the edible film is the best because it plays a very important role when the film is packaged for products with high water content. This is in accordance with the opinion of Mc Hugh and Krochta (1994) that if the application of a film is desired as packaging that is suitable for eating, then high solubility is desired, and conversely, if edible film is applied to food with a high water content then a film that is not soluble in water is used.

Transparency

Transparency is the ability of a material to transmit light. According to Wattimena et al. (2016) transparency describes the level of clarity of the resulting film. A material can be said to have high transparency if its transparency value is also high.

In Table 2. It can be seen that the transparency value in edible film from natural starch is 17.7% and in edible film from composite starch it has a lower value than natural starch, namely 10.6%, this shows that the addition of modified starch can reduce transparency value in edible film. This is in accordance with the opinion of Shi et al., (2013) that when light passes through the film, the light cannot penetrate the gaps (interspaces) of the edible film because the gaps in the edible film have been filled with smaller starch. This will produce edible film with a low brightness level.

Increasing the concentration of ingredients causes the transparency value to also decrease, as in research conducted by Maryana (2018) in making edible film with various concentrations of purple starch, the transparency value decreased along with increasing starch concentration, namely at a starch concentration of 1.33% it had a value of 16.39%. and at a starch concentration of 3.33% it has a value of 12.05%. This is in accordance with the opinion of Setiani (2013) that the more ingredients that are added to making edible film, the transparency value of the edible film will tend to decrease and the whiter the starch used, the more transparent the resulting edible film will be (Setiani, 2013).

WVTR (Water Vapor Transmission Rate)

Water vapor transmission rate shows the speed at which water vapor penetrates (per gram per second) per unit area of edible film or the ability of edible film to inhibit water transmission (Ramadhon, 2018). One of the functions of edible film is to resist the migration of water vapor, so its permeability to water vapor must be as low as possible (Gontard et al., 1993).

The value of the water vapor transmission rate can be seen in Table 2. That edible film made from composite starch has decreased compared to edible film made from natural starch. Edible film made from natural starch has a water vapor transmission rate value of 42.111 g/m2 hour and edible film made from composite starch has a value of 18.423 g/m2 hour. This is in line with research conducted by Farrag et al., (2018) that the WVTR value of edible films made from natural corn starch decreased in edible films made from composite starch, namely from 9.075 g/m2 hour to 8.182 g/m2 hour. The use of composite starch will produce edible film with smaller pores because the empty spaces will be filled with smaller starch so that incoming water vapor becomes more difficult to penetrate the surface of the edible film. Smaller starch has more hydrophobic properties compared to natural starch so that the hydrophobic properties of edible film increase. Barus (2002) stated that water vapor migration generally occurs in the hydrophilic part of the film. Thus, the ratio between the hydrophilic and hydrophobic parts of the film components will influence the value of the film's water vapor transmission rate. The greater the hydrophobicity of the film, the lower the value of the film's water vapor transmission rate. So it can also be concluded that the greater the hydrophilicity of the film, the higher the value of the film's water vapor transmission rate.

The water vapor transmission rate is also influenced by the thickness of the film being tested. The thicker the film, the lower the WVTR value will be (Moulia, 2018). The hydrogen bonds formed in the edible film manufacturing process result in an increase in the amount of film matrix formed, thus reducing the water vapor transmission value of the edible film. Some researchers are of the opinion that the lower the value of the water vapor transmission rate, the better the edible film will be, making it suitable for packaging products that have high humidity (Amaliya and Putri, 2014).

Compressive Strength

Compressive strength is one of the important mechanical properties of edible film, because it is related to the ability of the edible film to protect the product it coats (Ramadhon, 2018). Compressive strength describes the maximum compressive force that can be withstood by an edible film (Santoso, 2011). The compressive strength value of edible film can be seen in Table 13.

In Table 13, it can be seen that the compressive strength value of edible film made from composite starch has an increased value compared to edible film made from natural starch. Edible film made from natural starch has a compressive strength value of 632.53 gF, then edible film made from composite starch has increased to 841.08 gF.

Herawati (2018) stated that the higher the concentration of ingredients added in making edible film, the higher the compressive strength value of the edible film. According to Wiriyanata (2016), a greater value indicates that the resistance to damage due to stretching and pressure is greater, so the resulting physical quality is better. Polysaccharides, one of which is starch, in edible film formulas function as matrix builders and provide cohesive properties. The type of forming material and cohesion properties will determine the mechanical strength of the edible film (Gontard et al., 1993)

Conclusion

Based on the results of the research that has been carried out, it can be concluded that ratio of 1:15 (1500 mL ethanol) produces the smallest starch granule size, namely 3.417 x 5.945 µm to 15.038 x 16.708 µm. Composite starch consisting of native starch and modified starch with the smallest particle size can be used as raw material in making edible films. Edible film made from composite starch with the addition of 15% smaller starch has different characteristics from edible film made from natural starch alone. Edible film from composite starch produces a higher thickness value of 0.156 ± 0.006 mm, lower solubility 27.385 ± 3.808 %, lower transparency 10.657 ± 0.278 %/mm, lower water vapor transmission rate (WVTR) 18.423 g/ m2.hour, and a higher compressive strength of 841.8 ± 6.823 gF than edible film from natural starch.

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