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The Effect of Glycerol Concentration on The Characteristics of Edible Film of Kimpul Starch (*Xanthosoma sagittifolium*)

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Abstract :
Edible film is a thin layer that has the function of packaging or coating food that can be consumed directly with the packaged product. Edible film made from starch has the disadvantage that it is fragile and easy to use. The aim of this research is to determine the effect of glycerol concentration on the characteristics of edible film from kimpul tuber starch. The experiment was carried out using a completely randomized design (CRD), with 4 treatments with glycerol concentrations of 0.5%, 1.0%, 1.5% and 2.0%, each treatment was repeated 4 times. The results showed that the solubility, thickness, wvtr, and elongation values increased with increasing glycerol concentration used. A glycerol concentration of 2.0% produces the highest solubility value of 58.33%, thickness of 0.174mm, wvtr 33.38g/m2.hour, and elongation is found at a glycerol concentration of 1.0% with a value of 21.397%. However, on the contrary, the transparency, compressive strength, and tensile strength of edible film decrease with increasing glycerol concentration. Glycerol concentration has a significant effect on the values of solubility, thickness, transparency, compressive strength, tensile strength and elongation, but does not have a significant effect on the value of the water vapor transmission rate (WVTR). A glycerol concentration of 1% produces the best edible film with a solubility value of 38.33%, thickness of 0.125mm, transparency of 18.656%/mm, WVTR of 28.25g/m2.hour, compressive strength of 103.56N/m2, Tensile Strength of 2.9428MPa, and Elongation 21.397%.

Keywords: Edible film, Glycerol, Tuber Kimpul

1. Introduction

Edible film is a thin layer made from edible ingredients such as proteins, lipids and polysaccharides which are coated on or between the surfaces of food products by dipping, spraying and packaging. Edible film is an alternative packaging material that does not cause environmental problems. The main advantage of edible film is that it has biodegradable properties, so it does not cause environmental pollution like synthetic packaging materials (Pangesti et al., 2014). The main polysaccharides used in making edible films are chitosan, starch, carrageenan, alginate, modified cellulose, and pectin (Dhanapal et al., 2012). Proteins that can be used as basic ingredients for making edible films are gelatin, casein, soy protein, wheat gluten, whey protein and corn protein (Krochta et al., 1994). The basic lipid ingredients that are often used as edible films are wax, fatty acids, monoglycerides and resin (Hui, 2006).

Tubers are one of the ingredients that are often used in making edible films, because tubers have a fairly high starch content compared to other plant parts. Kimpul tubers (Xanthosoma sagittifolium) are one of the tubers that have not been utilized optimally. Kimpul tubers belong to the Aracea family, are classified as flowering plants and the fruit has closed seeds (Angiospermae) and one piece (Monoctylae). Kimpul tubers can grow in places that are not muddy or require sufficient irrigation (Lingga, 1995). Xanthosoma sagittifolium can be differentiated from Colocasia esculenta by the characteristics of the shape of the tuber, the shape of the leaves, and the location of the leaf stalks.

Suismono (2011), states that tuber flour can be used as raw material for making edible films, either in the form of tuber flour and starch or mixed flour. Starch is a homopolymer of glucose with α-1, 4-glycosidic bonds, starch granules are composed of two polymers, namely amylose and amylopectin

(Haryadi, 1993). Based on nutritional content data in the Food Composition List (DKBM), the nutritional value contained in 100g of fresh kimpul includes 1.90 protein, 0.20 fat and 23.70 carbohydrates (Mahmud et al., 2000).

Starch 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. Making starch-based edible film basically uses the principle of gelatinization, by adding a certain amount of water and heating it to a high temperature, gelatinization will occur. Gelatinization causes the amylose bonds to tend to be close to each other due to the presence of hydrogen bonds. The drying process will result in shrinkage as a result of the release of water, so that the gel will form a stable film (Karnawidjaja, 2009).

The use of starch in edible film can determine the physical properties of the edible film. The physical properties that can be determined are thickness, elongation percentage and tensile strength. Thickness can determine the resistance of edible film to the rate of transfer of water vapor, gas and other volatile compounds (Pangella et al., 2002).

Starch consists of amylose and amylopectin components. Rodriguez (2006), said that amylose is generally used to make strong films and gels. Garcia et al., (2000), reported that a high amylose content will make the film more compact because amylose is responsible for the formation of the film matrix. Krochta and Johnston (1997), reported that 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 in starch is classified into four groups, namely very low amylose content <10%, low amylose content 10-19%, moderate amylose content 20-24%, and high amylose content >25% (Aliawati, 2003).

The amylose and amylopectin levels of cassava starch are 20.12% dk and 71.03% dk (Anggi, 2011). The amylose content of kimpul flour ranges from 20.95% to 24.61%, while the amylopectin content of kimpul flour ranges from 27.93% to 40.04% (Puspitasari, 2015). According to Estiasih et al., (2017), kimpul starch has an amylose content of 15-25% and has a gelatinization temperature ranging from 68-95oC.

The mechanism for gel formation in edible film is that heating will weaken the hydrogen bonds of amylose resulting in swelling of the amylose molecules in the presence of water. Swelling continues by forming a three-dimensional network by amylose. Amylose will absorb water and form an amorphous area due to heating and stirring during solution preparation. When drying, the amorphous area will dry out and form a thin layer (film) (Carriedo, 1994).

Krisna (2011), stated that making edible film from red bean starch with the influence of regelatination and hydrothermal modification obtained the best results, namely with 1 hour regelatination and 1.5 hour MH with the highest tensile strength value of 5.49 MPa. It is known that the elongation value is found to be still low. Based on research by Herawan (2015), when making edible film plasticizer compounds are usually added. According to Krochta et al., (1994), the addition of plasticizers is useful for overcoming brittle, easily broken and less elastic properties. Plasticizers can reduce intermolecular forces and increase film flexibility by widening the empty space of molecules and weakening the hydrogen bonds of polymer chains. The plasticizers most commonly used in making edible films are sorbitol, glycerol, because of their hydrophilic properties (Suppakul, 2006).

Plasticizers that can be used in making edible films are glycerol, palmitic acid, polyethylene glycol (PEG) and sorbitol. Based on research by Julianto et al., (2011), the addition of palmitic acid plasticizer can reduce the solubility of edible film made from red indigo gelatin, but is not effective in reducing the value of the water vapor transmission rate. The use of polyethylene glycol (PEG) functions to reduce the brittleness of edible film, but it results in only starch being degraded, whereas synthetic polymers are difficult to degrade (Septiana, 2017). The use of glycerol in edible films greatly affects the material compared to sorbitol, glycerol is more profitable because it is easily mixed into the film solution and dissolves in water (Coniawati et al., 2014). In this study the author used glycerol as a plasticizer because glycerol has advantages compared to other plasticizers, namely that glycerol is easily soluble in water (hydrophilic), has a small molecular weight so it is able to reduce intermolecular forces along the polymer chain which causes the starch film to be flexible, plastic, and easy when bent (Rodriguez, 2006).

The use of different concentrations of glycerol will of course produce different characteristics in the edible film. The lower the concentration of glycerol added to the edible film formulation, the less amylose will bind to the glycerol in the edible film, so that the resulting film is tougher. The more polysaccharide components in the edible film formulation will increase the stretching strength so that the ability to stretch is greater. This is caused by the amylose contained in the edible film solution forming hydrogen bonds so that the resulting film is stronger (Fatnasari, 2018).

The higher the concentration of glycerol used in the formulation of the edible film solution, the more glycerol molecules that bind to starch molecules so that more polymers make up the film matrix (Fatnasari, 2018). Anker et al., (2009), stated that starch is a hydrophilic polymer and glycerol is also hydrophilic. There is an increase in the hydrophilic properties of edible film with the increase in OH groups from glycerol, which will further increase the amount of water bound. Winarno (2002), added that the addition of higher levels of glycerol will increase the cohesive properties between the glycerol molecules, so that the amount of water bound to the hydrocolloid (starch) will increase, causing the water content to be higher. According to Namet et al., (2010), glycerol is a type of plasticizer that is hydrophilic, adds polar properties and dissolves easily in water, so that the higher the concentration of glycerol used, the film's permeability to water vapor will increase. According to Baretto et al., (2003), adding glycerol that is too high will reduce the tension between the molecules that make up the film matrix so that the edible film becomes weaker against higher mechanical treatment, this is because adding a higher proportion of glycerol will reduce its stability. dispersion system of solids resulting in weaker physical properties of edible film.

Several previous studies have used glycerol, namely in Cornelia's (2012) research, making edible film from yam starch and tapioca mixture obtained the best glycerol concentration, namely in the 0.5% treatment with a tensile strength value of 19.73 Mpa and an elongation value of 2.21%. . Research by Irawan (2010), the best use of glycerol in the chitosan base material is 0.2 mL with the resulting tensile strength value being 146.92 kgf/mm2, elongation 4.2% and water vapor transmission rate 226,240 g/m2/24 hours. Andriyani's research (2018), the best characteristics of edible film in making white uwi starch edible film are with a glycerol concentration of 0.67% with a compressive strength value of 56.88 N/m, thickness of 0.15 mm, solubility of 18.68%, transparency 12.05% and a water vapor transmission value of 48.68 g/m2/24 hours.

2. Research Methods

Material

The materials used in this research were kimpul tubers (Xanthosoma sagittifolium), plasticizer (glycerol), sodium chloride (NaCl) 7.5%, and distilled water. The tools used in this research are analytical scales, blenders, sieves, 100 mesh sieves, basins, baking sheets, knives, cutting boards, measuring cups, beakers, stirring rods, magnetic stirrers, plastic clips, petridishes, electric ovens, hot plates, thermometers. , test tubes, as well as analytical equipment in the form of a desiccator, micrometer, filter paper, RH meter, LFRA Texture Analyzer, Universal Testing Machine Auto Strain, and spectrophotometer..

Research Design

The research was carried out using a completely randomized design (CRD) with 4 treatments, namely:

P1: Glycerol concentration 0.5%
P2: Glycerol concentration 1.0%
P3: Glycerol concentration 1.5%
P4: Glycerol concentration 2.0%

Each treatment was repeated 4 times to obtain 16 experimental units.

Table 1. Formulation of ingredients for making edible film solutions

Material	Glycerol 0.5%	Glycerol 1.0%	Glycerol 1.5%	Glycerol 2.0%
Kimpul Tuber Starch (g)	4	4	4	4
Aquades (g)	145,25	144,5	143,75	143
Glycerol (g)	0,75	1,5	2,25	3
Total (g)	150	150	150	150

Data Analysis

The data obtained were analyzed statistically using analysis of variance at the 1% and 5% levels. If the difference is significant then proceed with Duncan's New Multiple Range Test (DNMRT) at the 5% level. Tensile strength and elongation data were analyzed descriptively by displaying research data presented in the form of curves/graphs.

3. Results and Discussion

The Solubility of Edible Film

The solubility of edible film is expressed as the percentage of the part of the edible film that dissolves in water after soaking for 24 hours (Gontard et al., 1993). The aim of measuring solubility is to determine the ability of edible film to dissolve in water and to retain water. Analysis of variance shows that the glycerol concentration has a very significant effect on the solubility value in each treatment. The average solubility value of edible film with various glycerol concentrations can be seen in Table 2.

Table 2. Solubility of edible film from kimpul tuber starch with various glycerol concentrations.

No	Glycerol (%)	Solubility (%)
1	0.5	23.75± 2.50[a]
2	1.0	38.33± 3.33[b]
3	1.5	54.91± 6.07[c]
4	2.0	58.33±11.25[c]

Note: Numbers followed by the same lowercase letters in the same column are not significantly different at the 5% level according to the DNMRT test.

Table 2 shows that the solubility value increases with the higher the glycerol concentration treatment used. The highest solubility value was found at a glycerol concentration of 2.0%, namely 58.33%, and the lowest value was at a glycerol concentration of 0.5%, namely 23.75%. The higher the concentration of glycerol used, the higher the solubility value produced in the edible film. The increase in solubility value is caused by glycerol which is hydrophilic so that the more glycerol added, the more easily the resulting edible film will dissolve in water. In accordance with the opinion of Mehyar and Han (2004) that solubility increases as the hydrophilic components of the film increase.

The results of the analysis show that the solubility value ranges from 23.75% -58.33%, the results obtained are in accordance with research by Anandito (2012), regarding the effect of glycerol on edible film of jali flour (coix lacryma-jobi l.), the highest solubility value is at the addition of 40% glycerol, namely 48.15%, and the lowest with the addition of 20% glycerol, namely 41.87%, and research by Kawijia (2017), regarding the study of the characteristics of whole cassava starch based on edible film with modified cross-linking citric acid, the results of the analysis show that the highest solubility value was at a citric acid concentration of 30% with a value of 62.892% and the lowest was at a citric acid concentration of 0.52% with a value of 36.887%, this was caused by the influence of glycerol which is hydrophilic and starch is also hydrophilic, Bourtoom (2008), The solubility of edible film increases as the concentration of hydrophilic plasticizer increases, thus increasing the solubility of the film in water. According to Zulferiyenni (2014), glycerol and starch are components that dissolve in water, the higher the hydrophilic value of a material, the higher its solubility.

Edible Film Thickness

Edible film thickness is the thickness of the edible film produced after the drying process. The thickness of the edible film was measured using a screw micrometer with an accuracy of 0.01 mm. Measurements were made at five different points. The results of the analysis of variance show that the glycerol concentration has a very significant effect on the resulting thickness values. The average value of edible film thickness with various glycerol concentrations can be seen in Table 3.

Table 3. Thickness of edible film from kimpul tuber starch at various glycerol concentrations.

No	Glycerol (%)	Thickness (mm)
1	0,5	0,104±0,017[a]
2	1,0	0,125±0,008[b]
3	1,5	0,138±0,009[b]
4	2,0	0,174±0.011[c]

Note: Numbers followed by the same lowercase letters in the same column are not significantly different at the 5% level according to the DNMRT test.

From Table 3 it is known that the thickness value of edible film with various glycerol concentrations increases according to the glycerol concentration used. The highest thickness value is found at a glycerol concentration of 2%, namely 0.174mm, and the lowest value is at a glycerol concentration of 0.5%, namely 0.104mm. This is due to the nature of glycerol which is able to bind water so that the higher the concentration of glycerol used, the lower the water that experiences evaporation, in accordance with the opinion of Mc Hugh (1993), the factor that influences the thickness of edible film is the concentration of dissolved solids in the film forming solution, the higher it is. The concentration of dissolved solids, the higher the thickness of the edible film produced.

The results obtained are in accordance with standard quality requirements for edible film thickness. According to the Japanase industrial standard (JIS) (2019), the maximum thickness of edible film is 0.25mm. Maharani (2017), Edible film that is too thick or exceeds the maximum capacity limit will affect the packaged materials, such as changing the aroma, taste, etc. The thickness values obtained ranged from 0.104-0.174mm, which is in line with the results of research by Basuki (2014), regarding the characteristics of edible films from sweet potato starch and glycerol. The results of his research were the highest thickness values at a sweet potato starch concentration of 3% (w/v) and glycerol 15% (w/w) with a value of 0.041mm, and the lowest value at the concentration of sweet potato starch 1% (w/v) and glycerol 5% (w/w) with a value of 0.015mm, and research by Kawijia (2017), regarding Study of the characteristics of whole cassava starch based on edible film with modified citric acid cross-linking, obtained the highest thickness value at a 30% citric acid concentration with a value of 0.1812mm and the lowest at a 0% citric acid concentration with a value of 0.1017mm. This is influenced by the amount of glycerol which increases with treatment, resulting in an increasingly thick edible film. In accordance with the opinion of Irawan (2010), the more glycerol added, the thickness of the edible film increases because the total solids in the solution increases.

Transparency

Transparency is an analysis that describes the level of clarity of the film produced or the amount of light that can pass through the edible film. According to Bao et al., (2009), as the transparency value decreases, the degree of film clarity increases. The transparency value of edible film can be determined from the amount of light shot onto the edible film using a UV-Vis spectrophotometer with a wavelength of 600 nm and divided by the thickness of the edible film (Pineroz-Hernandez et al., 2017). The average transparency value of edible film at various glycerol concentrations can be seen in Table 4.

Table 4. Transparency of edible film from kimpul tuber starch at various glycerol concentrations.

No	Glycerol (%)	Transparency (%/mm)
1	0.5	23.019±3.711[c]
2	1.0	18.656±1.248[b]
3	1.5	17.078±1.093[b]
4	2.0	13.007±0.795[a]

Note: Numbers followed by the same lowercase letters in the same column are not significantly different at the 5% level according to the DNMRT test.

The results of the analysis of variance show that the resulting transparency values have very significant differences in edible films with various glycerol concentrations. Based on Table 4, it is known that the transparency value of edible film is inversely proportional to the glycerol used. The highest value is found at a glycerol concentration of 0.5%, namely 23.019%/mm and the lowest value is at a glycerol concentration of 2.0%, namely 13.007%/mm. This states that the higher the concentration of glycerol used in edible film, the lower the resulting transparency value, so it is known that the degree of clarity will increase. Bertuzzi et al., (2007), stated that low glycerol levels in the film (<15%) will produce high transparency.

The results of the analysis show that the transparency value ranges from 13.007-23.019%/mm which is higher than research by Wattimena et al., (2016), the results of the transparency analysis of edible film based on the type of sago starch treatment and glycerol concentration show that the highest value is at a glycerol concentration of 1.5%. namely 3.68% and the lowest at a glycerol concentration of 0.5%, namely 0.71%, caused by the influence of glycerol, and the influence of the color of the starch used, where the color of sago starch is dull white while the color of kimpul tuber starch is bright white, so that the resulting edible film has a higher transparency value. In accordance with the statement of Wattimena et al., (2016), the greater the concentration of glycerol added, the degree of clarity tends to increase (transparency decreases). Saragih (2016), starch that has high brightness will form a more transparent edible film.

Water Vapor Transmission Rate (WVTR)

Water Vapor Transmission Rate (WVTR) is the amount of water vapor that passes or passes through an edible film surface. Krochta et al. (1994), stated that the water vapor transmission rate value can be used to determine the shelf life of a product. If the water vapor transmission rate can be controlled, the product's shelf life can be extended. Based on the analysis of variance, it is known that the glycerol concentration treatment has no significant effect on the WVTR value of the edible film produced. The average WVTR value of edible film with various glycerol concentrations can be seen in Figure 1

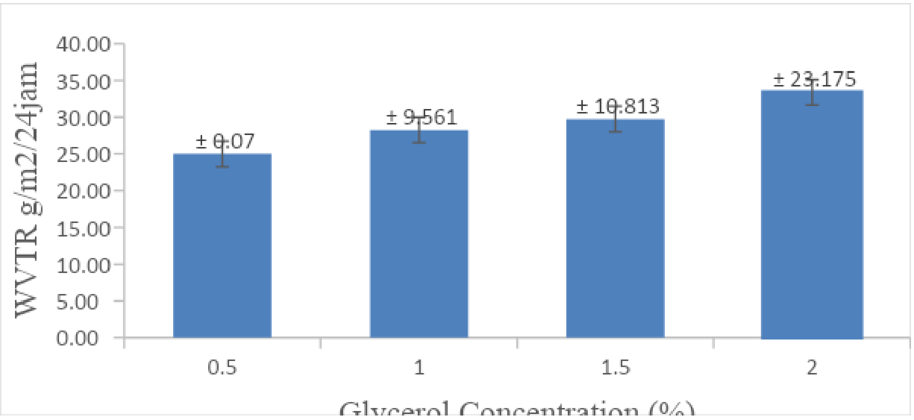

Figure 1. WVTR of edible film from kimpul tuber starch at various glycerol concentrations.

In Figure 1, it is known that the WVTR value of edible film with various glycerol concentrations is directly proportional to the value obtained. The highest WVTR value was at a glycerol concentration of 2.0% with a value of 33.38 g/m2.hour, and the lowest value was at a glycerol concentration of 0.5% with a value of 25.00 g/m2.hour. This is because the glycerol concentration used is not too far apart so that the resulting WVTR values are not significantly different. The results of all treatments have met the standard quality requirements for water vapor transmission rate according to the Japanase industrial standard (JIS) (2019) which meets grade 4, namely >20 g/m2. 24 hours and <100 g/m2. 24 hours.

The WVTR value ranges from 25.00-33.38g/m2.hour, this result is higher than research by Huri (2014), regarding the effect of glycerol concentration and apple peel pulp extract on the physical and chemical characteristics of edible film, it is known that the value of the highest water vapor transmission rate namely at a glycerol concentration of 30% and apple peel pulp extract 6% (v/v total) namely 19.00 g/m2.24 hours and the lowest at a glycerol concentration of 10% and apple peel pulp extract 2% (v/v total) namely 15.00 g/m2.24 hours, and higher than the research results of Kawijia (2017), studying the characteristics of whole cassava starch based on edible film with modified citric acid cross-linking, the highest water vapor transmission rate was obtained in the 0% citric acid concentration treatment namely 11.4877 g/m2, and the lowest value was at a citric acid concentration of 30%, namely 9.9591 g/m2. The influencing factors are glycerol which is hydrophilic so it is unable to hold water vapor that comes out and the amylose content of kimpul tubers is higher. In accordance with the statement of Namet et al., (2010), the increase in the value of the water vapor transmission rate is thought to be caused by the nature of the plasticizer (glycerol).) which is hydrophilic and is able to reduce the tension between molecules in the edible film matrix which causes the space between the molecules to become larger so that water vapor can penetrate the edible film. Alves et al., (2007), in Warkoyo (2014), that the water vapor permeability value of the film will increase with the addition of more amylose. This is related to the higher number of free hydroxyl groups, can increase its interaction with water, and transmission. water vapor through the film.

Compressive Strength

Compressive strength describes the maximum compressive force that an edible film can withstand (Santoso, 2012). The higher the compressive strength value of the edible film, the better the edible film. The results of analysis of variance show that the concentration of glycerol has a significant effect on the compressive strength value of edible film. The average value of compressive strength of edible film with various glycerol concentrations can be seen in table 5.

Table 5. Compressive strength of edible film from kimpul tuber starch at various glycerol concentrations.

No	Glycerol (%)	Compressive Strength (N/m^2)
1	0.5	159.899±46.807 ^{b}
2	1.0	103.556±49.079 ^{ab}
3	1.5	143.507±18.353 ^{b}
4	2.0	69.444 ±6.846 ^{a}

Note: Numbers followed by the same superscript in the same column are not significantly different at the 5% level according to the DNMRT test.

In Table 5 it can be seen that the increase in glycerol concentration is inversely proportional to the resulting compressive strength value, the higher the glycerol concentration used in making edible film, the lower the compressive strength value. Based on the compressive strength value of kimpul tuber starch edible film, the highest value was obtained at a glycerol concentration of 0.5%, namely 159.899 N/m2, and the lowest value was at a glycerol concentration of 2.0%, namely 69.444 N/m2. This is because glycerol has a function as a plasticizer which can reduce the mechanical cohesive bonds between polymers and can change their rigidity properties so that the resulting edible film is more flexible. Rodriguez, (2006) stated that glycerol has a small molecular weight so it is able to reduce intermolecular forces along the polymer chains, which causes starch films to be flexible and easy to bend. At a glycerol concentration of 1.0%, the compressive strength value decreased, which is thought to be because the glycerol concentration used did not differ significantly so that the results obtained experienced a decrease.

The resulting compressive strength value ranges from 69.444 -159.899 N/m2, where this result is higher than research by Andriyani (2018), regarding the effect of glycerol on the characteristics of uwi edible film, the highest compressive strength value is found at a glycerol concentration of 0.67% with a value of 56. 88 N/m2 and the lowest value was found at a glycerol concentration of 1.67% with a value of 43.06 N/m2. The influencing factor is the concentration of glycerol used, the more glycerol used, the more flexible the edible film will be and have a lower compressive strength value, and vice versa. When glycerol is added to the film solution, various structural modifications occur in the starch network, the film matrix becomes less dense, the polymer chains move, and the flexibility of the film increases. The increasing addition of starch is accompanied by an increasing ratio of starch to glycerol, resulting in lower plastic properties of the film (Su et al., 2010).

Tensile Strength

Tensile strength is the maximum tensile strength to break an edible film. The purpose of measuring tensile strength is to determine the amount of force required to achieve maximum tensile strength on the film. Edible film which has a high tensile strength value is needed for use as food product packaging which has the function of protecting food ingredients in the handling, transportation and marketing processes (Pitak and Rakshit 2011). The tensile strength value can be seen in Figure 2:
Based on the data in Figure 2, it is known that the glycerol concentration influences the tensile strength value produced. The more glycerol concentration used, the lower the tensile strength value of an edible film. It is known that the highest tensile strength value is at a glycerol concentration of 0.5%, namely 6.8996 MPa and the lowest at a glycerol concentration of 2.0%, namely 1.2238 MPa. This decrease is due to the presence of empty space which occurs because the bonds between polysaccharides are broken by glycerol, so that the bonds in the plastic film become weaker as the glycerol is added (Intan and Wan Aizan, 2011). The tensile strength results show that all treatments have met the standards according to JIS 2019 (Japanesse Industrial Standard), namely at grade 5, namely <25 MPA.

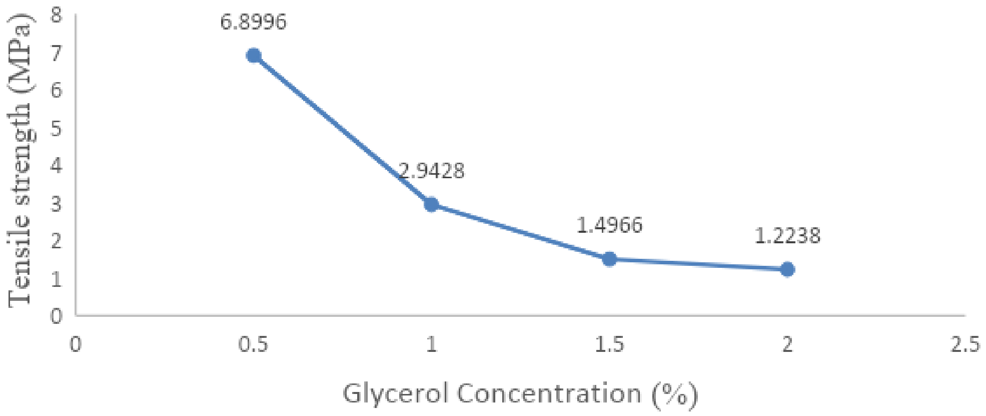

Figure 2. Tensile strength of edible film from kimpul tuber starch at various glycerol concentrations

In this study, tensile strength values were obtained ranging from 1.2238-6.8996 MPa, this value is higher than the results of research by Fatnasari, et al. (2018), regarding the effect of glycerol concentration on the characteristics of sweet potato starch edible film (Ipomoea batatas l.), the results of the research showed that the highest tensile strength resulted from treatment with a glycerol concentration of 10% (v/w starch), namely 0.75 N/mm2, while the lowest value resulted from treatment with a concentration of 25% glycerol (v/w starch), namely 0.07 N/ mm2, and higher than the research results of Lismawati (2017), regarding the effect of adding glycerol plasticizer on the characteristics of edible film from potato starch (Solanum tuberosum l.), the results of the research showed that the highest tensile strength value was at a glycerol concentration of 20% (v/v), namely 0.75 N/mm2, and the lowest at a concentration of 40% (v/v), namely 0.35 N/mm2. The factor that influences the tensile strength value is the higher concentration of glycerol and amylose in kimpul tuber starch. Chen (2008), the tensile strength of edible film decreases as the concentration of glycerol in edible film formulations increases, increasing the concentration of glycerol as a plasticizer results in interactions by forming hydrogen bonds in the bond chain between polymers, causing the bonds between biopolymer molecules to become increasingly reduced, this causes a decrease Tensile strength of edible film with the addition of plasticizer. According to Baretto et al., (2003), adding glycerol that is too high will reduce the tension between the molecules that make up the film matrix so that the edible film becomes weaker against higher mechanical treatment, this is because adding a higher proportion of glycerol will reduce its stability. dispersion system of solids resulting in weaker physical properties of edible film. Alves et al., (2007) in Warkoyo (2014), on cassava starch based films showed that the amylose content had a significant effect on the mechanical properties of the film produced, the addition of amylose of 18.7g/100g could increase the tensile strength of the edible film by 4, 8 MPa.

Elongation

Elongation is the length of the film which is calculated when the film is stretched until it breaks in percent units. The elongation value of kimpul tuber edible film with various glycerol concentrations can be seen in Figure 3.

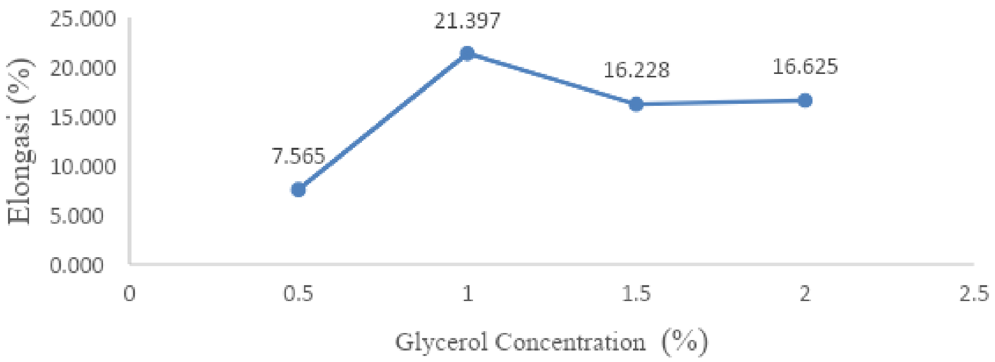

Figure 3. Elongation of edible film from kimpul tuber starch at various glycerol concentrations.

In Figure 3 it can be seen that the glycerol concentration influences the resulting elongation value, the higher the glycerol concentration, the more the elongation value increases, the highest elongation value is at a glycerol concentration of 1.0% with a value of 21.397%, and the lowest value is at a glycerol concentration of 0.5 % with a value of 7.565%. This is because glycerol can increase the stretching of the intermolecular space of the edible film matrix structure, thereby increasing flexibility and reducing the number of hydrogen bonds and reducing brittleness. In accordance with Huri and Nisa's (2014) statement, treatment with increasing glycerol concentration results in increased elongation of edible film, apart from that the addition of plasticizers is very important to overcome fragile films. It is also known that there is an increase in the elongation value at a glycerol concentration of 1.0%, due to a decrease in intermolecular forces along the polymer chain, thereby increasing film flexibility. This is in accordance with research conducted by Huri and Nisa (2014), the addition of glycerol resulted in the elongation value of edible film increasing drastically.

The results of the elongation analysis show that the elongation value ranges from 7.565-21.397%, where the highest value is found at a glycerol concentration of 1.0% with a value of 21.397%.) in Anggarini (2013)). Suryaningrum et al., (2005), stated that the elongation percentage of edible film is said to be poor if the value is less than 10% and said to be good if the value is more than 50%.

The research results obtained are in line with research by Fatnasari, et al., (2018), regarding the effect of glycerol concentration on the characteristics of sweet potato starch (Ipomoea batatas l.) edible film. It is known that the highest edible film elongation value was produced from treatment with a glycerol concentration of 25% (v/ b starch) namely 17.50%, while the lowest was produced from treatment with a glycerol concentration of 10% (v/w starch) namely 8.75%, and research by Lismawati (2017), regarding the effect of adding glycerol plasticizer on the characteristics of edible films from potato starch (Solanum tuberosum l.), the average elongation value of edible film produced by glycerol concentration treatment is 4.96% - 9.513%. This is influenced by the glycerol used and the amount of amylose contained in the starch, in accordance with the statement of Chiumarelli and Hubinger (2012), the percentage of elongation of edible film tends to increase with increasing cassava starch at a fixed amount of glycerol. Krocha, et al., (1994) in Huri (2014), glycerol can interact with starch by forming a starch-plasticizer bond where this bond will result in an increase in the elasticity of the suspension of both, the addition of plasticizer can also cause a decrease in intermolecular forces along the polymer chain so that increase flexibility. According to Katili et al., (2013), the resulting edible film is elastic due to the increase in the amount of glycerol, so that mobility between molecular chains increases and the percentage elongation of the edible film increases.

Conclusion

Glycerol concentrations of 0.5%, 1.0%, 1.5% and 2.0% significantly influence the values of solubility, thickness, transparency, compressive strength, tensile strength and elongation, but do not significantly influence the values water vapor transmission rate (WVTR). The WVTR values obtained were 25.00 g/m^2.hour, 28.25 g/m^2.hour, 29.75 g/m^2.hour, and 33.38 g/m^2.hour. Glycerol concentration that produces the best edible film is 1.0% glycerol concentration with a solubility value of 38.33%, thickness 0.125 mm, transparency 18.656%/mm, WVTR 28.25 g/m^2.hour, compressive strength 103.56 N/m^2, tensile strength 2.9428 MPa, and elongation 21.397%.

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