

Characteristics of Edible Film Made from Bitter Cassava Starch with Glycerol

Karakteristik Edible Film dari Pati Singkong Beracun dengan Penambahan Gliserol

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ABSTRACT

The purpose of this study was to see how different glycerol concentrations affected the physical, mechanical, and barrier properties of an edible tapioca starch film. This study explored glycerol concentration using a completely randomized experimental design with four treatment levels, particularly regarding 10, 15, 20, and 25% (w/w). The tensile strength, elongation, solubility, and water vapor transmission rate of the films were all measured. Tensile strength has been 7.71 to 15.94 MPa, elongation was 13.33 to 20.00%, solubility was 15.81 to 24.81%, and water vapour transmission rate was 39.72 to 70.65 g/m².h. Glycerol increased tensile strength whereas the decreasing elongation, solubility, and water vapour transmission rate.

Keywords: Biodegradable film; cassava starch; elongation; glycerol; tensile strength; solubility

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ABSTRAK

Tujuan penelitian ini adalah untuk mempelajari pengaruh penambahan beberapa konsentrasi gliserol pada pembuatan *edible film* dari pati singkong beracun terhadap sifat fisik, mekanik dan barrier *film*. Rancangan yang digunakan adalah rancangan acak lengkap non factorial dengan perlakuan empat taraf konsentrasi gliserol yaitu: 10, 15, 20 dan 25 % (b/b). Peubah yang diamati adalah *tensile strength*, elongasi, daya larut, dan laju transmisi uap air. Karakteristik *edible film* yang dihasilkan meliputi *tensile strength* adalah 7,71 - 15,94 MPa, elongasi 13,33 - 29,00 %, daya larut 15,81 - 24,81 %, dan laju transmisi uap air 39,72-70,65 g/m².jam. Penambahan gliserol menyebabkan elongasi, daya larut, dan laju transmisi uap air meningkat, tetapi *tensile strength* menurun.

Kata kunci: Daya larut; *edible film*; elongasi; gliserol; pati singkong beracun; tensile strength

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INTRODUCTION

Food product packaging is a packaging process with appropriate packaging materials to maintain and protect food in the hands of consumers so that its quality and safety can be maintained (Kusumawati & Putri, 2013). Food packaging uses a lot of plastic as packaging or basic material. Plastic materials are widely used because they have superior properties, including light, transparency, and waterproofing, and the price is relatively low and affordable for all people. Plastic doesn't break down easily in the environment, not even when it rains or gets hot, and neither do the microbes that live in the soil.

This means that plastic can cause new problems, like pollution of the environment (Katili *et al.*, 2013).

One way to overcome this problem is to use biodegradable food packaging. This biodegradable packaging is made from natural ingredients, such as soybeans, cassava, etc. This biodegradable packaging is included in edible film because, based on its mechanical properties, it can replace non-biodegradable plastic (Sinaga *et al.*, 2013). The edible film is a packaging material that is biodegradable and in the form of a thin layer of non-toxic natural materials so that it can be eaten and placed as a coating between food components that functions as a barrier in controlling the transfer

of oxygen, water vapor, lipids, and volatile components in food ingredients (Setiani *et al.*, 2013). The components that make up edible films are divided into three groups: hydrocolloids, fats, and composites (a combination of hydrocolloids and fats) (Zibaei *et al.*, 2021). One of the basic ingredients used in the manufacture of biodegradable plastics is starch (Alobi *et al.*, 2017; Teseme, 2020).

Starch is one of the polymers that can be used to manufacture biodegradable plastics. Using starch as a basic material for making biodegradable plastics is a good alternative because starch is one of the polysaccharides from plants that are abundantly available in nature and is biodegradable, easy to obtain, and inexpensive (Winarti *et al.*, 2013). Because it is reasonably priced, sustainable, and has beneficial physical properties, starch is commonly utilized in the food industry as a biodegradable alternative to plastic polymeric materials to reduce environmental pollution (Muller *et al.*, 2017).

One of the starch-producing tubers is cassava. The type of cassava used is bitter cassava, also commonly called bitter cassava. It is called bitter cassava because it contains a compound known as cyanide acid, or HCN (hydrogen cyanide). According to de Araujo *et al.* (2019), a high dose of HCN causes the taste of cassava to be more bitter. Bitter cassava starch is never used and is only wasted when the cassava is processed for certain foods. The waste of bitter cassava starch during processing can be used for other purposes. The increased starch content in bitter cassava makes it suitable for manufacture in edible films. Still, an edible film can't be made into a continuous elastic layer without a plasticizer.

A plasticizer is a material added to a film-forming material to increase its flexibility. It has the potential to significantly decrease intermolecular interactions along the polymeric chains, allowing the film to bend when stretched (Rodriguez *et al.*, 2006). Plasticizers increase elasticity by lowering the degree of hydrogen bonding and boosting the polymer's intermolecular distance. A plasticizer is required to be used as a softener because it is stable (inert). That is, it is not degraded by heat and light, does not change the color of the polymer, and does not cause corrosion. One type of plasticizer that has been widely used so far is glycerol. Because it has a low molecular weight, glycerol works well to improve the plasticity of films (Huri & Fitri, 2014).

According to Damat (2008), the physical characteristics of edible films are influenced by the type of material, the type and concentration of plasticizer. Plasticizers from the polyhydric alcohol or polyol group include glycerol and sorbitol. Glycerol is preferable to sorbitol as a plasticizer because the edible film produced is more flexible and does not break easily, and its mechanical properties and appearance do not change during storage (Oses *et al.*, 2009). According to Pak *et al.* (2020), glycerol is a suitable plasticizer to produce edible film. The role of glycerol as a plasticizer is to increase the film's flexibility and make the film's surface smoother. Besides, glycerol can increase the ability of edible films to reduce the water vapor transmission rate.

Several research results on the use of glycerol in edible films, among them by Basuki *et al.* (2014) regarding sweet potato starch edible films with starch concentrations (1, 2, and 3%) (w/v) and glycerol concentrations (5, 10, and 15%) (w/w starch), using the heating method without the gelatinization process, showed that the sweet potato starch edible film with the best characteristics was produced from the formulation of 3 g sweet potato starch and 15% glycerol (w/v) with a thickness value of 0.041 mm, tensile strength of 26.594 MPa, percent elongation of 56.59% and moisture content of 11.97%. Jaya & Sulistyawati (2010) showed that manufacturing edible films from corn flour using 1 mL glycerol and 1 mL sorbitol produced a tensile strength of 17.2765 N and a solubility of 0.0091 g/mL, and pressure drop (tensile strength) and stress at fracture (percent elongation).

The purpose of this study was to characterize bitter cassava starch edible films based on physical, mechanical, and barrier properties.

MATERIALS AND METHODS

Materials

The material used in this study was bitter cassava. Bitter cassava was obtained from local farmers in Passo village, Ambon City. Bitter cassava is cleaned and then taken to the laboratory to be extracted and prepared for the manufacture of edible films.

Extraction of Bitter Cassava Starch

The cassava was peeled, then washed with running water to clean up the remaining dirt.

Cassava pieces are crushed using a grater to form tuber pulp. The tuber pulp was filtered using a cloth to separate the pulp and the filtrate. The dregs are filtered again with the ratio of dregs: water (1:2). The filtrate is deposited for 3-5 hours with four items of washing. The resulting residue was separated from the water and dried at 60°C for 5 hours in a cabinet dryer. The dry starch was then crushed with a blender and sieved using a 100-mesh sieve to obtain fine granules of cassava starch.

Edible Film Preparation

The process of making edible films follows the method of Parra *et al.* (2004). Bitter cassava starch (6% w/v) was mixed with 80 mL of distilled water. Then the suspension was stirred for 1 minute at room temperature, then heated (95°C, 15 minutes) while stirring using a magnetic stirrer. After 15 minutes, glycerol was added with concentrations of 10, 15, 20, and 25% (w/w) and distilled water until it reached 100 mL. Heating was continued with stirring (95°C, 15 min). After completion, the solution was transferred to a mold plate with a size of 25 × 17 cm. The film solution was dried in an oven at 40°C for 24 hours. Before analysis, the film was stored in a container with a relative humidity of 50% at room temperature.

Edible Film Mechanical Properties Testing

Film thickness (mm) was measured using an IP-65 micrometers (Mitutoyo, JP) (Wattimena *et al.*, 2016). The film was placed between the micrometer, and the thickness was measured at three different places for each sample shape (circle and dimension I), then the average was calculated.

Tensile strength and elongation were measured using the Universal Testing Machine (Zwick Z.05 Texture Analyzer), as suggested by Saberi *et al.* (2016). The film samples were cut in I dimensions, with a film width of 5 mm, and the thickness was determined based on the average.

Physical Properties Testing of Edible Film

Solubility shows the percentage of dry weight dissolved after being immersed in water for 24 hours, as stated by Wattimena *et al.* (2016). The film samples were cut to a size of 2 × 2 cm. The filter paper samples were dried at 105°C for 24 hours. The filter paper and the sample were weighed separately, then determined as the initial

weight (w_1). The sample was put into 50 mL of water containing 0.02% sodium azide solution and soaked for 24 hours, stirring periodically. Then filtering was carried out with filter paper, and the insoluble film was dried (at 105°C, for 24 hours). After that, the sample was weighed (w_2) to determine the dry matter that was insoluble in water.

Testing the Barrier Properties of Edible Film

WVTR ($\text{g H}_2\text{O}/\text{m}^2\cdot\text{h}$) was determined gravimetrically by modifying the method used by Saberi *et al.* (2016). The film sample to be tested was closed in a cup containing 10 g of silica gel (RH = 0%) and placed in a desiccator containing 40% (w/v) NaCl salt solution (RH = 75%) at 25 °C. The inner bowl diameter is 75 mm, and the height is 280 mm. The silica gel will absorb the water vapor that diffuses through the film will increase the weight of the silica gel. The weight of the cup was recorded every hour for 7 h. The data obtained is a linear regression equation, and the slope is determined. The equation determines WVTR:

WVTR = the slope of the increase in the weight of the cup (g/h) / film surface area (m^2)

Statistics analysis

This research employed a completely random design with three replications and was analyzed using Minitab 19 software. If the treatment affects the observed variables, the Tukey test is used to examine the difference in treatment means (α 0.05)

RESULTS AND DISCUSSION

The treatment of glycerol concentration had a significant effect on the edible film's mechanical, physical, and barrier properties ($p < 0.01$). The results of the analysis of the edible film are shown in Table 1.

Mechanical Properties of Edible Film

The tensile strength of edible films ranged from 7.71 to 15.94 MPa (Table 1). Based on the Tukey test for the treatment of 10% glycerol concentration, it showed the highest average tensile strength value and was significantly different from other concentrations (Table 1).

Table 1. Effect of glycerol concentration treatment on mechanical, physical, and barrier properties of bitter cassava starch edible film

Glycerol (% , b/b)	Mechanical properties		Solubilities (%)	WVTR (g H ₂ O/m ² .h)
	Tensile Strength (MPa)	Elongation (%)		
10	15.94 ± 0.33 ^a	13.33 ± 1.96 ^c	15.81 ± 1.08 ^c	39.72 ± 2.78 ^c
15	12.56 ± 0.77 ^b	18.47 ± 0.51 ^b	18.80 ± 1.89 ^{bc}	45.93 ± 0.75 ^{bc}
20	10.42 ± 0.65 ^c	22.95 ± 2.98 ^b	20.72 ± 1.48 ^{ab}	53.13 ± 0.34 ^b
25	7.71 ± 0.45 ^d	29.00 ± 1.44 ^a	24.81 ± 2.06 ^a	70.65 ± 7.02 ^a

Note: The numbers followed by the same letter in the same column show no significant difference based on Tukey's test ($\alpha = 0.05$).

Increasing glycerol concentration causes a decrease in the tensile strength of the edible film. The same result was also shown by Wattimena *et al.* (2016) and Saleh *et al.* (2007). The decrease in tensile strength of edible films is due to reduced internal hydrogen bonds, decreased intermolecular interaction forces, and increased intermolecular distances. Wattimena *et al.* (2016) stated that glycerol can reduce interactions between molecules and weaken the tensile strength of the edible film produced so that an elastic film will be obtained.

The elongation value of edible film based on the treatment of cassava starch and glycerol concentration ranged from 13.33 to 29.00 %. The treatment of glycerol concentration showed the average elongation value was 29.00%. Based on Tukey's test, each treatment of glycerol concentration showed significantly different values (Table 1). Increasing the concentration of glycerol affects the elongation of the edible film. Glycerol can change the nature of starch that has undergone gelatinization. Glycerol is hydrophilic (Mali *et al.*, 2005) and can reduce the edible film layer's brittleness and flexibility (Pérez *et al.*, 2016; Tarique *et al.*, 2021). Both properties can reduce intermolecular forces along the polymer chain by widening the distance between chains and increasing elasticity. Relatively similar results were shown by Wattimena *et al.* (2016) on the manufacture of sago starch edible films. According to him, glycerol produces more elastic edible films. Glycerol causes the mobility between molecular chains and the percentage of elongation in edible films to increase. Wattimena *et al.* (2016) also suggested that glycerol can cause the film matrix to become less dense, thus increasing the flexibility of the film.

Edible Film Solubility

The solubility analysis of edible films based on the treatment of glycerol concentrations ranged from 15.81 to 24.81%. The glycerol treatment showed a higher average solubility value and was significantly different based on the Tukey test compared to the treatment with a glycerol concentration of <20% (Table 1).

Increasing the concentration of glycerol increases the solubility of the edible film. Increasing glycerol added to the film solution causes weak interactions between starch molecules, thereby reducing molecular density and forming free space in the film matrix to increase solubility. Wattimena *et al.* (2016) showed that the solubility of edible films from sago starch increased with increasing glycerol concentration.

Water Vapor Transmission Rate

The analysis of the water vapor transmission rate of the edible film based on the glycerol concentration treatment ranged from 39.72 to 70.65 g H₂O/m².h. Based on the Tukey test, each treatment with a 25% glycerol concentration showed a significantly different value than the other treatment levels.

The water vapor transmission rate of the edible film increases with increasing glycerol concentration. This is because glycerol weakens the interaction between starch molecules, so its density decreases and free space is formed in the film matrix. This condition can facilitate the diffusion of water vapor. This is in line with Amaliya & Putri (2014) and Wattimena *et al.* (2016) that hydrophilic plasticizers can reduce the intermolecular tension in the edible film matrix and cause the space between molecules to increase so that water vapor can penetrate the edible film. In

addition, the hydrophilicity of glycerol also increases the water vapor transmission rate of the film. Some researchers argue that the lower the WVTR value, the better the edible film will be (Amaliya & Putri, 2014; Wattimena *et al.*, 2016).

CONCLUSION

When glycerol is added to edible films, their elongation, solubility, and water vapor transmission rate increase, but their tensile strength decreases.

REFERENCES

- Alobi, N. O., Sunday, E. A., Magu, T. O., Oloko, G. O., & Nyong, B. E. (2017). Analysis of starch from non-edible root and tubers as sources of raw materials for the synthesis of biodegradable starch plastics. *Journal Basic Appl. Res.*, 3(1), 27-32. <https://ssrn.com/abstract=3291118>
- Amaliya, R. R. & Putri, W. D. R. (2014). Characterization edible film of corn starch with the addition of white saffron filtrate as antibacterial. *Jurnal Pangan dan Agroindustri*, 2(3), 43–53.
- Basuki, E. K. S., Jariyah, & Hartati, D. D. (2014). Characteristic of edible film from sweet potato starch and glycerol. *Jurnal Rekapangan*, 8(2), 128-135.
- Damat. (2008). Efek jenis dan konsentrasi plasticizer terhadap karakteristik *edible film* dari pati garut butir. *Jurnal Agritek*, 16(3), 333–339.
- de Araújo, F. d. C. B., Moura, E. F., Cunha, R. L., de Farias Neto, J. T. and de Souza Silva, R. (2019). Chemical root traits differentiate ‘bitter’ and ‘sweet’ cassava accessions from the Amazon. *Crop Breeding and Applied Biotechnology*, 19, 77-85. <http://dx.doi.org/10.1590/1984-70332019v19n1a11>
- Huri, D. & Nisa, F. C. (2014). The effect of glycerol and apple peel waste extract concentration on physical and chemical characteristic of edible film. *Jurnal Pangan dan Agroindustri*, 2(4), 29–40.
- Jaya, D., & Sulistyawa, E. (2010). Pembuatan edible film dari tepung jagung. *Eksergi*, 10(2), 5–10. <https://doi.org/10.31315/e.v10i2.333>
- Katili, S., Harsunu, B.T. & Irawan, S. (2013). Pengaruh konsentrasi *plasticizer* gliserol dan komposisi khitosa dalam zat pelarut terhadap sifat fisik *edible film* dari khitosan. *Jurnal Teknologi*, 6(1), 29-38.
- Kusumawati, D. H., & Putri, W. D. R. (2013). Physical and chemical characteristic of corn starch edible film that incorporated with pink and blue ginger extract. *Jurnal Pangan dan Agroindustri*, 1(1), 90-100.
- Muller, J., Gonzalez-Martinez, C., & Chiralt, A. (2017). Combination of poly(lactic) acid and starch for biodegradable food packaging. *Materials*, 10, 952. <https://doi.org/10.3390/ma10080952>
- Oses, J., Fernandez-Pan, I., Mendoza, M., & Mate, J. I. (2009). Stability of the mechanical properties of edible films based on whey protein isolate during storage at different relative humidity. *Food Hydrocolloids*, 23(1), 125-131. <https://doi.org/10.1016/j.foodhyd.2007.12.003>
- Pak, E. S., Ghaghelestani, S. N., & Najafi, M. A. (2020). Preparation and characterization of a new edible film based on Persian gum with glycerol plasticizer. *Journal of Food Science and Technology*, 57(9), 3284-3294. <https://doi.org/10.1007/s13197-020-04361-1>
- Parra, D.F., Tadini, C.C., Ponce, P. & Lugalo, A.B. (2004). Mechanical properties and water vapor transmission in some blends of cassava starch *edible film*. *Carbohydrate Polymers*, 58(4), 475-481. <https://doi.org/10.1016/j.carbpol.2004.08.021>
- Pérez, L.M., Piccirilli, G.N., Delorenzi, N.J., & Verdini, R.A. (2016). Effect of different combinations of glycerol and/or trehalose on physical and structural properties of whey protein concentrate-based edible films. *Food Hydrocolloids*, 56, 352-359. <https://doi.org/10.1016/j.foodhyd.2015.12.037>
- Saberi, B., Vuong, Q. V., Chockchaisawasdee, S., Golding, J. B., Scarlett, C. J., Stathopoulos, C. E. (2016). Mechanical and physical properties of pea starch edible films in the presence of glycerol. *Journal of Food Processing and Preservation*, 40(6), 1339-1351, <http://dx.doi.org/10.1111/jfpp.12719>
- Saleh, F. H. M., Nugroho, A.Y., & Juliantama, M. R. (2017). Pembuatan *edible film* dari pati singkong sebagai pengemas makanan. *Teknoin*, 23(1), 43-48.

- <https://doi.org/10.20885/teknoin.vol23.iss1.a5>
- Setiani, W., Sudiarti, T., & Rahmidar, L. (2013). Preparasi dan karakterisasi *edible film* dari poliblend pati sukun-kitosan. *Valensi*, 3(2), 100-109.
<https://doi.org/10.15408/jkv.v3i2.506>
- Sinaga, L. L., Rejenika, M.S.S. & Sinaga, M.S. (2013). Karakteristik *edible film* dari ekstrak kacang kedelai dengan penambahan tepung tapioka dan gliserol sebagai bahan pengemas makanan. *Jurnal Teknik Kimia USU*, 2(4), 12-16.
<https://doi.org/10.32734/jtk.v2i4.1485>
- Tarique, J., Sapuan, S. M., & Khalina, A. (2021). Effect of glycerol plasticizer loading on the physical, mechanical, thermal, and barrier properties of arrowroot (*Maranta arundinacea*) starch biopolymers. *Scientific Reports*, 11, 13900.
<https://doi.org/10.1038/s41598-021-93094-y>
- Teseme, W. B. (2020). Review on the manufacturing of biodegradable plastic packaging film from root and tuber starches. *American Journal of Nano Research and Applications*, 8(1), 1-8.
<https://doi.org/10.11648/j.nano.20200801.11>
- Winarti, C., Miskiyah, & Widaningrum. (2013). Production technology and application of starch based antimicrobial edible package. *Jurnal Penelitian dan Pengembangan Pertanian*, 31(3), 85-93.
- Wattimena, D., Ega, L. & Polnaya, F.J. (2016). Characteristics of edible film from native and phosphate sago starches with the addition of glycerol. *Agritech*, 36(3), 247-252. <https://doi.org/10.22146/agritech.16661>
- Zhu, X., Zhang, Y., Deng, J., Luo, X. (2018). Effect of glycerol on the properties of the cross-linked polyvinyl alcohol hydrogel beads. *Chemistry Select*, 3(2), 467-470.
<https://doi.org/10.1002/slct.201701975>
- Zibaei, R., Hasanvand, S., Hashami, Z., Roshandel, Z., Rouhi, M., de Toledo Guimarães, J., Mortazavian, A. M., Sarlak, Z., & Mohammadi, R. (2021). Applications of emerging botanical hydrocolloids for edible films: A review. *Carbohydrate Polymers*, 256, 117554.
<https://doi.org/10.1016/j.carbpol.2020.117554>

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