Physical And Mechanical Properties Of Bioplastic From Pectin, Arrowroot Starch With The Addition Of Chitosan And Glycerol

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**Abstract.** One alternative to conventional plastics, such as biodegradable plastics, is bioplastic packaging. Bioplastic is made from materials that come from nature and naturally degrades easily. The purpose of this research was to obtain the optimal composition and analyze the characteristics of bioplastic produced from apple peel pectin, arrowroot starch, glycerol and chitosan. The production of bioplastic using raw materials of apple peel pectin and arrowroot starch, with variations of glycerol (1.5 mL and 2 mL), and chitosan (1 mL, 2 mL, and 3 mL). The implementation of this research began with the production of pectin from apple peel, and then the manufacture of bioplastic, followed by by testing the characteristics of bioplastic and analyzing the variance of the test results data using two-way ANOVA. The results showed that the optimal composition of apple peel pectin and arrowroot starch bioplastic is achieved at 1.5 mL glycerol and 2 mL chitosan. The optimal composition has a thickness value of 0.348 mm, tensile strength of 6.19 MPa, elongation percentage of 28.25%, elasticity of 0.219 MPa, and degradation percentage of 60.83% with an estimated degradation time of about 23 days. The addition of glycerol in the production of bioplastic has significant effect on tensile strength, and degradation.

Keywords: edible film, apple pectin, chitosan, arrowroot starch

# Introduction

Plastic packaging is a prevalent choice for food products due to its malleability, elasticity, transparency, accessibility, durability, unbreakability, and affordability. However, its inherent difficulty in degradation, poses a potential contamination risk through the transmission of monomers to the packaged products, which could lead to health problems. There is an increasing demand for the development and production of environmentally friendly substitutes for food packaging materials. In recent years, there have been significant advancements in food packaging technology, resulting in the production of preservative-free, environmentally sustainable, and biodegradable products. [1]. The biodegradable biofilm can be produced from sustainable biomass sources, including starch and cellulose [2]. Biofilm is a plastic-like packaging material that is environmentally friendly due to its natural composition and biodegradability. Biofilm is a common primary packaging material used for food products. Furthermore, biofilm serves as a barrier for products that inhibits mass transfer (oxygen, moisture, soluble substances, and fats). Two polysaccharides that are frequently used in the production of bioplastic are starch and pectin.

Fruit wastes, such as peels, can be used in the extraction of pectin from fruit pulp, flowers, and other fruit-derived materials [3]. The yield of pectin from orange peel was 25.5% [4] while banana peel yielded between 15.89% and 24.08% [5]. Due to its low cost and non-toxicity, pectin is considered an ideal film-forming agent with potential applications. Edible film from pectin with chitosan at proportions of 50:50 increased the tensile strength, reduced the water solubility, water vapor permeability, and the oxygen permeability [6]. The smooth surface of pectin biofilm is beneficial, but it has a slight disadvantage regarding its mechanical properties and poor moisture barrier, which limits its suitability for high moisture foods [7]. Therefore, it is necessary to add additives, including filler and plasticizers to enhance the mechanical properties of bioplastic.

Chitosan is a biodegradable, non-toxic material with antimicrobial, antifungal, and antibacterial activities, which can extend the shelf life of food products [8]. The film made from the pectin and chitosan chains is stabilized by hydrogen bonds and electrostatic interactions [6]. Chitosan also easily binds with other substrate polymers, such as tapioca starch. Furthermore, its high amylose content (16%–27%) enables the formation of a continuous matrix, resulting in films with optimal functional properties [9].

In this study, the bioplastic was made from apple peel pectin with the addition of arrowroot starch, glycerol, and chitosan in order to produce a mixture of film as packaging materials. The aim of this study was to analyze the mechanical and physical characteristics of the bioplastic made from apple peel pectin, arrowroot starch, glycerol, and chitosan.

# Method

## Materials

The materials utilized in this study include apple peel pectin, arrowroot starch, glycerol (technical), acetic acid (Merck), chitosan (Biotech Surindo), and distilled water. The instruments utilized in this study include laboratory glassware, hotplate stirrer, analytical balance (Fujitsu), thermometer, desiccator, oven (Memmert), micrometer (Mitotuyo), Universal Testing Machines (Housfield).

## Production of Film

The production of biofilm utilized apple pectin, arrowroot tuber starch and 1% chitosan with varying concentrations (1 ml; 2 ml; 3 ml) and glycerol (1.5 ml; and 2 ml). The composition of the biofilm material is shown in Table 1.

**TABLE 1.** The composition of the materials

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Name** | **Glycerol**  **(mL)** | **Chitosan**  **(g)** | **Pectin**  **(g)** | **Arrowroot starch**  **(g)** |
| G1CO | 1.5 | 0 | 2 | 2 |
| G1C1 | 1.5 | 1 | 2 | 2 |
| G1C2 | 1.5 | 2 | 2 | 2 |
| G1C3 | 1.5 | 3 | 2 | 2 |
| G2C0 | 2 | 0 | 2 | 2 |
| G2C1 | 2 | 1 | 2 | 2 |
| G2C2 | 2 | 2 | 2 | 2 |
| G2C3 | 2 | 3 | 2 | 2 |

The production of biofilm started by dissolving 2 g of arrowroot starch and 2 g of apple pectin in 100 mL of distilled water, which was then heating at 70°C using a hot plate stirrer. Next, glycerol solution (1.5 mL; 2 mL) and chitosan (0; 1 mL; 2 mL; and 3 mL) were added to the mixture, which was then stirred using a hot plate stirrer for 20 minutes at 70°C. Thereafter, the mixture was cooled to room temperature for 10 minutes and mold on a petri dish. Finally, the film was dried in an oven at 70°C for 12 hours.

## The Characterization Testing of Edible Film

The thickness test was carried out according to the ASTM D-1005 method using the micrometer. The tensile strength and elongation test were carried out according to the ASTM-D882 method using the Hounsfield Universal Testing Machine. Elongation is defined as the rate of change in the length of the bioplastic film when it is stretched until it breaks or the ability of the bioplastic film to elongate before breaking. The elongation test was carried out using the Universal Testing Machine according to the ASTM D-882 method. The elasticity test is a measurement carried out on the resulting film to determine its stiffness value. The elasticity value is derived from a comparison of tensile strength and elongation. The degradation test was carried out using the soil burial method. The sample was cut into a size of 20 x 20 mm, then dried in a desiccator for 30 minutes and weighed before burial (Wo). Each sample was buried in 100 g of soil at a burial depth of approximately 5 cm for 44 days to determine the mass reduction of the film. The degradation rate was expressed as weight loss percentage and calculated using the following equation:

(1)

Where:

W = Sample weight after burial (g)

Wo = Initial sample weight (g)

# Results and Discussion

## Tensile Strength Testing

The tensile strength test results are shown in Fig. 1.

**FIGURE 1.** Tensile strength of edible film

The tensile strength test results indicated that the highest tensile strength value was 6.19 Mpa and obtained in the treatment with a composition of 1.5 ml glycerol and 2 ml chitosan (G1C2), while the lowest tensile strength value was 2MPa 1.5 ml glycerol and 1 ml chitosan. (G1C1)

This is due to the fact that as chitosan concentration increased, the inter and intra molecular interaction between polymer (chitosan and pectin) chains also increases, leading to the more hydrogen bonds are formed in solution. This ultimately results in stronger film that are difficult to break [10]. Nevertheless, there is a decrease in tensile strength with an increase in chitosan by more than 1% [11]. The addition of chitosan beyond the optimal value caused a decrease in tensile strength, as it reaches a saturation point where molecular bonds are in close proximity.

The tensile strength value for each treatment meets the Japanese Industrial Standard (JIS) standard, namely more than 0.3 MPa. The optimum tensile strength value of the biofilm is 6.19 Mpa, this value is higher than previous research, namely 3.99 Mpa and 3.7 Mpa. The analysis results showed that the treatment with the addition of chitosan and glycerol had a significant effect on the tensile strength of the biofilm from apple peel pectin and arrowroot starch, as indicated by the obtained significance value, which was less than 0.05 (p < 0.05). This is consistent with the findings of previous study [12] on edible film made from sago and glycerol as a plasticizer, which stated that the addition of glycerol at concentrations ranging from 1% to 3.75% had a significant influence on the mechanical characteristics of the edible film produced.

## Elongation Testing

The elongation test results are shown in Fig. 2. The elongation test results indicated that the highest elongation rate was 55.29% and obtained in the treatment with a composition of 2 mL glycerol and 2 mL chitosan (G2C2), while the lowest elongation rate was 24.95% and obtained in the treatment with a composition of 1.5 mL glycerol and 1 mL chitosan (G1C1). The elongation rates of the 1.5 mL glycerol and chitosan with variations of 2 mL and 3 mL, were 28.25% and 28.33%, respectively, which were higher than the elongation rate of the 1.5 mL glycerol and 1 mL chitosan, which was 24.95%. The elongation rate increased with the increasing glycerol concentration, but decreased with the increasing chitosan concentration. The higher the concentration of glycerol added, the higher the elongation rate. This is because during the formation of the biopolymer film matrix, the hydrogen bonds formed between starch and plasticizer may disrupt the polymer structure and transforming it into a flexible, irregular structure. This restructuring of the polymer matrix leads to an increase in elongation ability of the film [7].

**FIGURE 2.** The elongation percentage of edible film

As the concentration of chitosan increases, the elongation rate decreases [13, 14], inversely proportional to the tensile strength. This finding is supported by previous study [15] which demonstrated an inverse correlation between elongation and tensile strength in edible film made from canna starch and ginger extract with the addition of sorbitol and chitosan. The analysis results showed that the addition of chitosan and glycerol had no significant effect on the elongation of the biofilm made from apple peel pectin and arrowroot starch, as indicated by the significance value obtained of 0.322, which was greater than 0.05 (α > 0.05).

## Elasticity (Modulus Young) Testing

The elasticity test results are shown in Fig. 3.

**FIGURE 3.** The elasticity of edible film

The elasticity test results indicated that the highest elasticity value was 0.230 MPa, which was obtained in the treatment with a composition of 1.5 mL glycerol and 1 mL and 2 mL chitosan (G1C2), while the lowest elasticity value was 0.04 MPa, which was obtained in the treatment with a composition of 2 mL glycerol and 2 mL chitosan (G2C2). A direct proportional correlation exists between elasticity and tensile strength. Glycerol functions as a plasticizer, which reduces the forces between molecules and increases the polymer chain movement [14, 16]. The elasticity value decreased with the increasing chitosan concentration. The optimal elasticity in this study was 0.23 MPa, which was lower than the previously reported value of 0.376 MPa. The analysis results showed that the addition of chitosan and glycerol had no significant effect on the elasticity of the biofilm made from apple peel pectin and arrowroot starch, as indicated by the significance value obtained of 0.508, which was greater than 0.05 (α > 0.05).

## Thickness

The thickness test results are shown in Fig. 4.

**FIGURE 4.** The thickness of edible film

The thickness values of the biofilm for all treatments does not meet the Japanese Industrial Standards (JIS), where the applicable thickness standard is less than or equal to 0.25 mm. The thickness test results indicated that the highest thickness value was 0.377 MPa, which was obtained in the treatment with a composition of 2 mL glycerol and 2 mL chitosan, while the lowest thickness value was 0.329 MPa, which was obtained in the treatment with a composition of 1.5 mL glycerol and 1 mL chitosan. The biofilm thickness increased with the addition of glycerol, which is hydrophilic due to its high water absorption capacity. This finding is supported by previous study [17] which stated that the biofilm thickness is directly proportional to the addition of plasticizers, resulting in a thicker biofilm. Bioplastic derived from starch and pectin has hydrocolloid properties and the ability to absorb water in biofilm solution to form a solid structure. Glycerol, which acts as a plasticizer, is able to interact with starch to form a starch plasticizer polymer matrix [18].This leads to an increase in the total solids of the film solution. The analysis results showed that the addition of chitosan and glycerol had no significant effect on the thickness of the biofilm made from apple peel pectin and arrowroot starch, as indicated by the significance value obtained of 0.100, which was greater than 0.05 (α > 0.05). This is because the production of biofilm using the manual casting method causes uneven pouring and molding of biofilm.

## Biodegradability

The biodegradability test results are shown in Fig. 5.

**FIGURE 5.** The biodegradability of bioplastic

The biodegradation test results indicated that the highest biodegradation rate was 77.79%, which was obtained in the treatment with a composition of 2 mL glycerol and 1 mL chitosan (G2C1), while the lowest biodegradation rate was 53.16%, which was obtained in the treatment with a composition of 1.5 mL glycerol and 3 mL chitosan (G1C3). Increasing the glycerol concentration and decreasing the chitosan concentration resulted in faster degradation of the film [19, 20}.The film started to dry on the 4th day, and the mass of the film decreased until the 14th day. The biodegradation rate of the film remained constant at 0.01 mg/day. The time required for complete degradation of the film is between 18 and 23 days. The analysis results showed that the addition of chitosan and glycerol had no significant effect on the biodegradation of the biofilm made from apple peel pectin and arrowroot starch, as indicated by the significance value obtained of 0.508, which was greater than 0.05 (α > 0.05).

Further research is needed to improve the mechanical properties of the biofilm by varying the concentration of different materials so that the resulting biofilm can be applied as packaging material for food products.

# Conclusions

The addition of glycerol and chitosan in the production of bioplastic has significant effect on tensile strength, and degradation. However, it had no significant effect on the thickness, and elongation, elasticity properties The optimal concentration for the production of edible film from apple pectin, arrowroot starch, glycerol and chitosan was obtained in the treatment of 1,5 mL glycerol and 2 mL chitosan, (G1C2).

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