Development and characterization of the mechanical properties of edible film from ginger starch, chitosan with glycerin as plasticizer to food packaging

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Abstract. Packaging used edible film is one of the food preservation techniques. Many studies have proven that edible films can extend the shelf life and improve the quality of food products. Edible film from ginger starch and chitosan with glycerin as plasticizer has been successfully prepared and characterized. The purpose of this research was to produce and characterized of the mechanical properties of edible film from ginger starch, chitosan, and glycerin as plasticizer. Edible film was characterized by UTM, TGA, FTIR and Water Uptake Test. The results of tensile strength test of edible film is 0.67125 MPa and elongation up to 15.67%. The thermal degradation of material reached 176.9695 °C, water uptake of edible film up to 2.5%, and FTIR data shows an interaction between ginger starch, chitosan, and glycerin. It concluded that edible film from ginger starch, chitosan, and glycerin as plasticizer has good mechanical properties and has potential as a packaging.

Keywords: edible film; chitosan; ginger starch; glycerine; mechanical properties.

1. Introduction
Packaging plays an important role to save the quality of food and to protect food from harmful contaminants, so it can improve food preservation. Plastics as food packaging has a negative impact on the environment [1]. Edible films can be used for increasing the food shelf-life because it have a good barriers against oxygen [2]. Edible films are commonly produced using carbohydrates, lipids, and proteins. Carbohydrates are often used for edible films because they are abundant in nature [3]. Edible films from carbohydrates have good characteristics and can protect packaged products from damage [4]. The elasticity of edible film from starch can be increased by using plasticizer such as glycerin [5]. Chitosan has a good mechanical properties for edible film because it is able to form hydrogen bonds between chains with amylose and amylopectin in starch [6]. Chitosan is a natural preservative because it is antimicrobial, chitosan can inhibit bacterial growth [7]. Chitosan and oligomer are natural antimicrobials, anti-fungal[8], antitumor, function as hypocholesterolemic, insecticidal and fungicidal activity [9]. Ginger (Zingiber officinale Rosc.) is a medicinal plant that contains bioactive components such as gingerol, (6)-shogaol, diarilheptanoid and curcumin. Ginger rhizome contains phenolic compounds and antioxidant activity better than tocopherol[10]. Ginger is often used as an ingredient in herbal medicines [11]. This study to show determine the effect of the composition of chitosan and...
ginger starch on the mechanical properties of edible film with glycerin as plasticizer so that it can protect well-packed food.

2. Experimental methods

2.1. Materials
The material used to produce edible film is commercial chitosan (from shrimp) with a deacetylation degree up to 87.5%, ginger starch, acetic acid (70% Dixi Merck), commercial glycerin, aquades.

2.2. Instruments
The instrument to preparation of edible film includes hotplate and magnetic stirrer C-MAG HS 7, beaker glass 500 mL Pyrex, pipette volume 10 mL Pyrex. Mechanical test of edible film consists of functional groups to find out the results of synthesis, tensile strength test, water uptake, and degradation thermal. The instrument includes FTIR Merck Shimadzu (Type IRprestige21), Testometric materials testing machines (Wintest™ Analysis), and TGA-DTA Stanton Redcroft TG-500.

2.3. Edible film preparation
Ginger starch and chitosan are weighed with variations in the composition of ginger starch and chitosan (g/g), 1:9, 5:5, 9:1 with a total mass of ginger starch and chitosan is 2 gram. Ginger starch was dissolved using aquades and chitosan dissolved using acetic acid1% (Merck®, 100%) mixing for 30 minutes at 100°C. The two solution are mixed. The mixture was heating at 100°C and stirring for 25 minutes. After 25 minutes, the mixture is added 0.2 mL glycerin (10% from the solution) and stirred for 5 minutes or until thickened. The solution is taken 100 mL of the solution and placed it on the mold, then leave it in the open space until the mold dries. The film is released from the mold and ready to be analyzed.

2.4. Characterization of edible film
Characterization of edible film includes tensile strength and elongation tests using Testometric Materials Testing Machines. The sample was clamp with a testing machine. The start button on the computer is pressed and then the tool will pull the sample at a speed of 5000 mm/minute until the sample breaks. Tensile strength of edible film is calculated by the following equation.

\[
\tau = \frac{F_{\text{max}}}{A}
\]

Based on equation above, \( \tau \) indicated tensile strength (MPa), \( F_{\text{max}} \) shows voltage (N), and \( A \) shows broad cross-section transverse (mm²).

Measurement of elongation extention was carried with same method for tensile strength, with following equation:

\[
\text{Elongation (\%)} = \frac{\text{Strain isolate (mm)}}{\text{initial length (mm)}} \times 100\%
\]

While, for elasticity (modulus young) obtained from the comparison of tensile strength with elongation[12].

Functional group analysis with FTIR, sample placed into the set holder, then the appropriate spectrum is sought. The result will be obtained by diffractogram relationship between wave number and intensity. The FTIR spectrum was recorded using a spectrophotometer at room temperature.

Water resistance test using the absorption of water, namely by measurement initial mass of the sample to be tested (Wo), then inserted into a container includes aquades during 10 minutes[13]. The sample is taken from a receptacle containing aquades and water contained in the plastic surface removed with paper tissue, then measured the water absorbed by the sample is calculated through equations:
Based on equation above, W is wet edible film mass, Wo is dry edible film mass. TGA-DTA is a thermal analysis technique in a polymer. This technique is a dynamic method for recording sample mass under controlled or cooled conditions at a controlled rate as a function of time or temperature. Sample placed into the sample receptacle then heated, and seeking a spectrum that shows the reduced mass of the polymer changes in time or temperature due to the process of degradation or decomposition. Result will be obtained by diffractogram relationship between wave number and intensity.

3. Result and discussion

Testing the mechanical properties of edible films includes the strength test of tensile strength and elongation which from the test results shows the following data (Figure 1).

From these data indicate the maximum tensile strength is in the composition of chitosan: ginger starch 1:9 of 0.67125 MPa. This indicates that the more the amount of chitosan, the tensile strength of edible films decreases. This is probably due to the presence of chitosan which will interfere with the formation of the film matrix by the ginger starch polymer. This data is supported by elongation data from the following data (Figure 1b). where tensile strength is inversely proportional to elongation. An increase in elongation is affected by the presence of glycerin. Glycerin acts as a plasticizer that provides elastic properties to edible films. Glycerin has a small molecular weight so that it can enter into the intermolecular bond amylose with chitosan. The presence of plasticizers in the film can interrupt the formation of amylose with amylopectin branches, then reduce the interaction between amylose molecules and amylopectin, thereby increasing the flexibility of the film [14].

Figure 2. (a) FTIR spectra, (b) Interaction between ginger starch, chitosan and glycerin [15]
The interaction between ginger starch, chitosan and glycerin was shown through FTIR data in Figure 2. FTIR data shows the influence of the interaction between the –OH group on ginger starch, –NH group from chitosan and glycerin resulting in reduced free -OH group and amine group in the sample. Where uptake of the -OH group is around 3600 cm\(^{-1}\) 3200 cm\(^{-1}\), while the-NH group (amine) is at absorption of 3500 cm\(^{-1}\). From these interactions can be seen that the amine group from chitosan interacts with glycerin and ginger starch, resulting in reduced amine groups and free -OH groups, which supported by FTIR spectra, where in the edible spectra the resulting film has a lower -OH absorption and amine groups.

The water uptake test purpose to determine ability of edible film to absorb water. The smaller the ability to absorb water, the better the mechanical properties of the edible film. Edible films with well mechanical properties will able to protect well-packaged products. Water uptake of edible film data is shown in figure 3a.

![Figure 3](image.png)

**Figure 3.** (a) ability to absorb water, (b) thermal degradation

From these data (3a) shows the greater the composition of chitosan, then the lower the percentage of water absorption from the edible film. Because the greater the amount of starch, the more the pores of the edible film will increase the ability to absorb water [16]. The higher the absorption of water, the mechanical properties of edible film are getting worse, because the absorption of water will interfere with molecular chain interactions, which are followed by increased diffusivity and able to absorb water vapor from the air[17]. TGA testing purpose to determine the degraded thermal temperature of the edible film, from the TGA data showing that the edible film have the degradation temperature at 176.9695°C. Thermal degradation of edible film data is shown in figure 3b.

Edible film of ginger starch and chitosan with glycerin as a plasticizer there are 3 stages of degradation which is at a temperature of 30.3639°C-176.9695°C is the evaporation of water, and then at temperature of 176.9695°C–381.6855°C is the degradation of ginger starch, and at temperature of 381.6855°C–600.2126°C is the degradation temperature of chitosan[18].

4. Conclusion
Based on the above data, it can be concluded that:

1. Edible film of ginger starch chitosan with glycerin as plasticizer has good mechanical properties. Maximum tensile strength is 0.67125 MPa, the best elongation up to 15.67%, the best water absorption ability is 2.5%, the degradation temperature is 176.9695°C, and the FTIR test results show an interaction between ginger starch, chitosan and glycerin.
2. The more the amount of chitosan added, the mechanical properties of edible film tend increase, because chitosan is able to close the surface pores of edible film and can increase the mechanical strength of the sample.
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