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Development of bioplastic from wheat Janeng starch for food packaging

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Abstract. Agricultural and industrial products need a high performance of packaging that can preserve its properties in a long period. A high-performance bioplastic was developed in this study from wheat Janeng starch. The bioplastics were prepared by casting on the glass plate and formed by phase inversion method. Bioplastics are made from a mixture of starch and glycerol provides transparent films with high tensile strength and elongation value. The optimum bioplastics compositions were 12 % (w/w) of starch and 5 % (w/w) of glycerol as plasticizer. Glycerol was used as a plasticizer to modify its mechanical properties. The addition of glycerol with the concentration of 5 % (w/w) produced a bioplastic with a high tensile strength of 20.95 kgf/mm² and 42.69 % of elongation. The bioplastics are made from janeng starch can be used for packaging apples and tomatoes slice with a high protective barrier.

1. Introduction

The high desire of consumers to obtain high-quality groceries and fresh durable has attracted the interest of researchers to develop a packaging system that is a multi-function[1]. The packaging system is based on the development of bioplastics by using biopolymers are biodegradable such as polysaccharides, proteins, fat, or a combination of these compounds. The biopolymer-based plastics have been widely applied as a protective or barrier for the transfer of fat, moisture, air, and smell for fresh fruits and vegetables, frozen foods, meat, and sweets [2,3].

Bioplastics biopolymers as base material attracted the interest of many researchers and industry because it is environmental friendly and is a substitute packaging material derived from petroleum raw materials such as polystyrene and polyethylene which is not decomposed material [4]. This non-biodegradable plastics are uses in a short time, after which discharged into the environment as waste. Waste from petroleum-based plastic waste is one of the factors that cause environmental pollution. Processing or recycling process generally requires a high cost. Besides, recycled plastic products are lack of thermal and mechanical properties as original polymer plastic.

Therefore, the developments of biodegradable bioplastics are focused by researcher for food packaging materials. One of the organic compounds that can be a source of biodegradable plastic is a polysaccharide [5] which is widely available. Janeng starch is an alternative source for the provision of polysaccharides in which this material is easily made, easily processed, and easily obtained with low production costs of *Dioscorea spp* [6]. In Aceh, *D. hispida* is known as the Janeng. Utilization of

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carbohydrate from janeng as food is minimal due to toxic compounds containing in janeng bulb such as dioscorine, diosgenine and a precursor cyanide compound causes neurological disorders. However, these all chemical compounds are polar compounds that it is easily removed by washing with water.

Janeng also has advantages compared to other root crops, which can be grown in all types of soil, either latosol, alluvial, and podzolic [7]. Another advantage janeng is a high carbohydrate content, which is about 56-78% of the dry weight of janeng starch [6]. The janeng starch is an interesting source of carbohydrate-based; base on its the physical and chemical properties has the potential to use as bioplastics. In this study, bioplastic-manufacturing processes have been studied from raw material janeng starch. The bioplastic quality is influenced by starch concentration and glycerol as plasticizer. The addition of plasticizers can reduce stiffness and improve the mechanical properties and thermal resistance of the bioplastic. The final bioplastics are expected to be applied for packaging of tomato and apple slice.

2. Materials and Methods

Janeng (*Dioscorea hispida*) samples were collected in Aceh Besar and used for starch production. chemicals are purchased from supplier company used in experiments in pro analysis grade. Tomato and apple are collected from a local market. The equipment used in this study include knives, blender, hot plate, micrometer, analytical balance, magnetic stirrer, a stopwatch, a pH meter, vacuum pump, UV-VIS spectrophotometer, and infrared spectrophotometer.

Isolation of starch janeng

A total of 2 kg janeng tuber peeled and cleaned. Furthermore, tubers cut into small pieces and rinsed with distilled water. Then the tuber pieces are blended at low speed with a sodium bisulfite solution (1.12 g / L) for 5 minutes. The homogenate was rinsed with distilled water and squeezed using a soft porous fabric. Extortion is repeated several times until the juice is clear. Juice left in place for about a day and night is obtained the precipitate. The precipitate is washed with distilled water and filtered with a Buchner filter to remove dioscorine, and HCN contained in the precipitate. The qualitative test is done by using a solution of 0.5 M AgNO₃. Furthermore, the white precipitate obtained is dried in an oven of 70 ° C for 24 hours. Finally, the dried white powder is crushed and sifted with a 100 mesh sieve and referred to as wheat janeng flour.

Preparation bioplastics

A total of 5 g starch janeng plus 95 g of distilled water and stir until blended. The mixture was heated on a hotplate at a temperature of 70-75 °C stirrer until gelatinization conditions are reached (this state is achieved about 10-15 minutes). Then the starch paste is cooled until it reaches 45-50 °C and then added plasticizer 2.5 g of glycerol and stir until homogeneous mixtures. Starch paste is cooled to room temperature and then casting was done on glass plates with a thickness of ± 0.3 mm. The thin layer is drying in the oven at the temperature of 30-35 °C for 24 hours. Finally, the films are carefully removed for further characterized and application. A variation of janeng starch concentration and glycerol concentration are investigated in the manufacturing of bioplastic. The various janeng starch concentration are 5, 7.5, 10, and 12% (w/w), and various concentrations of glycerol are 0, 2.5, 5, and 7.5% (w/w).

Characterization of bioplastics

Bioplastics obtained were characterized and tested for thickness, tensile strength, elongation, and water absorption and solubility. FTIR analysis was carried out to characterize the functional groups of bioplastics.

Application of bioplastics for fruits and vegetable packaging

Application of bioplastics for fruits packaging was performed by wrapping tomatoes and apple slices with bioplastics during storage for seven days and compared with the fruit without wrapping with

bioplastic. Ten selected panelists have observed the color change in the organoleptic test. The change of vitamin C concentration in tomatoes and apples before and after wrapping with bioplastic was determined using the spectrophotometric method. The fruits sample of 10 gram was homogenized in 25 ml of 4% solution $\text{H}_2\text{C}_2\text{O}_4$, and the mixture was filtered by vacuum filter. The obtained filtrate was diluted to 100 ml with a solution of 4% $\text{H}_2\text{C}_2\text{O}_4$. Then 1 ml of CuSO_4 solution pH of 6 is added to aliquots of the sample, and the absorbance read at 249 nm wavelength using a UV-Vis Spectrophotometer. A calibration curve was prepared with a standard solution of ascorbic acid in solution $\text{H}_2\text{C}_2\text{O}_4$ 4%.

3. Results and Discussion

Starch Janeng Isolation

D. hispida tubers contain a high dioscorine and HCN levels and should be removed during the isolation process and purification of starch. In previous studies reported that the levels of HCN in *D. hispida* reach 700 mg/kg of tubers [6]. Janeng starches were isolated utilizing depositing slurry of starch. By this way, the starch will be present in the filtrate, while the other non-starch component will be retained by refining filter. The obtained filtrate was deposited, and finally, the precipitate was washed repeatedly by aquadest. The washing step was performed repeatedly to remove all the content dioscorine and HCN. Janeng starch free of HCN is indicated by a negative qualitative reaction using AgNO_3 reagent. The obtained starch was reduced particles size by using a blender and sieved with a 100 mesh sieve. *D. hispida* tubers contain 15% (w/w) of dry starch.

Bioplastics preparation and characterization

Preparation of starch-based bioplastics is via phase inversion method. The casting solution is prepared by heating a suspension of starch reaches the gelatinization temperature of about 70-75 °C. The addition of other components is done at cooler temperatures and stirring until a homogeneous mixture. The casting solution is printed on glass plate and bioplastics will be formed after a solidification process by evaporation of the solvent. The quality of bioplastics from starch janeng influenced by the addition of plasticizers. Glycerol has been added in casting solution to improve physical and chemical properties of bioplastic. The use of glycerol as plasticizers was affected the elasticity of the film and also increase in water vapor and oxygen permeability.

Tensile strength is one of the mechanical properties to measure the strength of the film is used as a packaging material. Bioplastic tensile strength values of pure starch obtained ranged between 0 -5 kgf/mm². The highest tensile strength values were obtained in pure starch bioplastic with a concentration of 12% (w/w). The addition of plasticizer influences the value of the tensile strength and elongation of the film. The optimum tensile strength of 20.95 kgf/mm² is obtained at 5 % (w/w) glycerol concentration as the plasticizer. The elongation increased from 10.83 % to 42.9 % by adding 5% (w/w) glycerol in the casting solution. The characteristics of bioplastics against water absorption and solubility are one of the essential indicators to show the level of loss of bioplastics in contact with water or water vapor. The water absorption of bioplastic was obtained 61.35 %, and the bioplastic solubility was 17.29 %. The amount of water that can be absorbed by bioplastics and the amount of bioplastic dissolved in the water is done by immersion test for 24 hours. The characteristics of bioplastics for water absorption and solubility of bioplastics are one of the important indicators to show the level of loss of bioplastic in contact with water or water vapor. The high amount of water absorbed is presumably because the nature of water and plasticizers are very polar so they tend to absorb more water. Water absorption capacity can also be linked to the chemical structure of materials that have a functional group (OH) that can absorb water [10]. Based on solubility, the solubility value of glycerol is near complete, which can dissolve as a whole in water.

The ability of bioplastics to regulate oxygen transport is largely determined by the basic structure and chemical properties of polymers as constituents of these bioplastics. The ability to pass gas particles is very dependent on the porosity of the film and the swelling degree of the film. Oxygen permeability in packaging films is useful for estimating the shelf life of packaged products. The value

of oxygen permeability of bioplastic starch janeng modified by the addition of glycerol obtained an average value of $5,883 \times 10^{-9}$ ($\text{cm}^3 \cdot \text{cm} / \text{cm}^2 \cdot \text{s} \cdot \text{cmHg}$). This lower oxygen permeability due to bioplastic janeng starch-glycerol has a denser structure and has a good interconnection in structure because the starch and glycerol have hydrogen bonds [11].

FTIR analysis

The results of measurements of the FTIR spectra of pure starch bioplastic and added plasticizer glycerol in Figure 1. Based on the spectra in Figure 1 can be informed some common functional groups contained in the starch molecule. The infrared spectrum of starch showed a significant absorption at wavenumbers 3000 to 3600 cm^{-1} indicates the stretching vibration of OH groups. Broad peak and a high intensity indicate the hydrogen bonds in the starch molecule. Peaks that appear in the region below 1450 cm^{-1} shows the bending vibration of the methylene group. -CH stretching vibration of alkanes indicated by the peak at 2884 cm^{-1} region. The existence of ether and alcohol C-O bond can be seen in the peak that appeared at the 1316 and 1024 cm^{-1} . FTIR spectra showed a band at 1639 cm^{-1} , which shows the carbonyl glucose from starch. FTIR spectra of the bioplastic that have been added plasticizer mixture show the difference in the width and intensity of the resulting peaks associated with pure compound and mixing ratio. Glycerol is a compound containing an OH group and the CH-alkanes. The spectra revealed that there is some specific interaction between the hydroxyl groups of starch and the hydrogen atom of the hydroxyl group from glycerol that cause the increase in the peak intensity and width of the stretching vibrations of the -OH group of bioplastic.

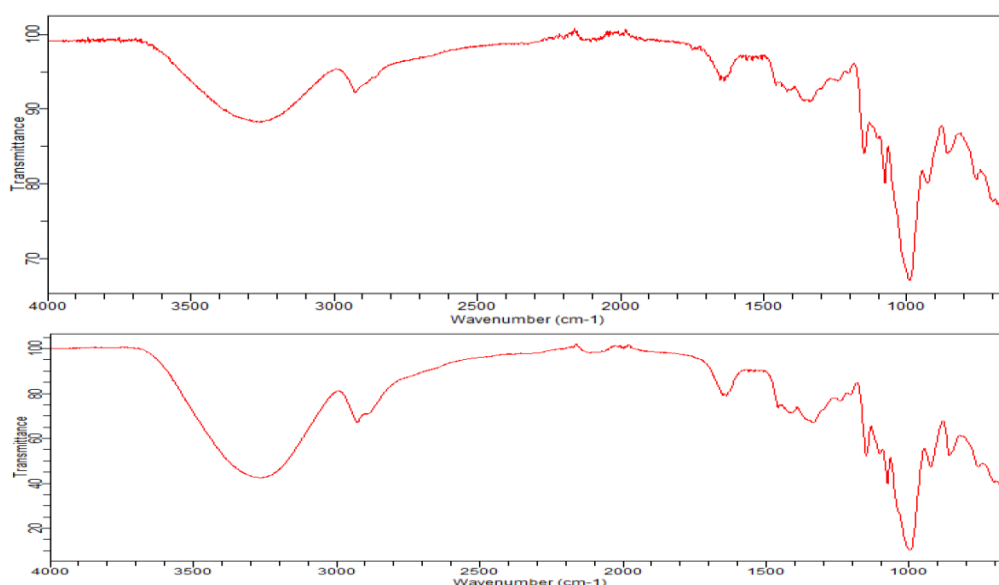


Figure 1 FTIR spectra of starch bioplastic and the addition of glycerol

Application of bioplastics for fruits and vegetable packaging

Application of bioplastics for fruits packaging was performed by wrapping tomatoes and apple slices by looking at the color change with the bioplastics wrapped pieces of fruit without wrapping. Pure starch bioplastics, glycerol modified starch bioplastics, and commercial wrapping plastic were illustrated their ability in protecting tomatoes and apple slices. The protecting barrier ability of plastics was observed for storage period seven days. Packaging is done by wrapping and storage is done for seven days at room temperature (27°C - 29°C), as shown in Figure 2. Tests were also conducted on the plastic wrapping commercial as a comparison (control).



Figure 2. Visual illustration of the testing process as bioplastic packaging pieces of apples and tomatoes (Left: first day and Right: after seven days)

Ten selected panelists have observed the color change in the organoleptic test. From the results of data analysis, it was found that the storage of tomatoes and slices of apple on the seventh day showed the color of the fruit wrapped in bioplastics was significantly different from the fruit that was not wrapped at a 95% confidence level. The fruit that is not wrapped in bioplastics has turned dark on day three while the fruits wrapped in bioplastic starch, especially those modified with glycerol, have not been significantly different after seven days. From these results, indicate that bioplastics as packaging can protect the fruit.

Vitamin C content in tomatoes and apple slices wrapped starch bioplastics, commercial plastic wrap and tomatoes not wrapped (control) are shown in Figure 3. Figure 3. confirmed that the vitamin C content of apples wrapped in bioplastics higher than the apple that is not wrapped. This agrees with the literature, the content of vitamin C in apples obtained by 5 mg in 100 g of fruit. The tomatoes wrapped with bioplastic was also proved that the vitamin C content maintained and higher than unwrapped tomatoes. In 100 g fresh tomatoes vitamin C levels obtained by 9 mg. From the results show that vitamin C in slices apple and tomatoes wrapped with bioplastic are comparable and more protected level content of Vitamin C.

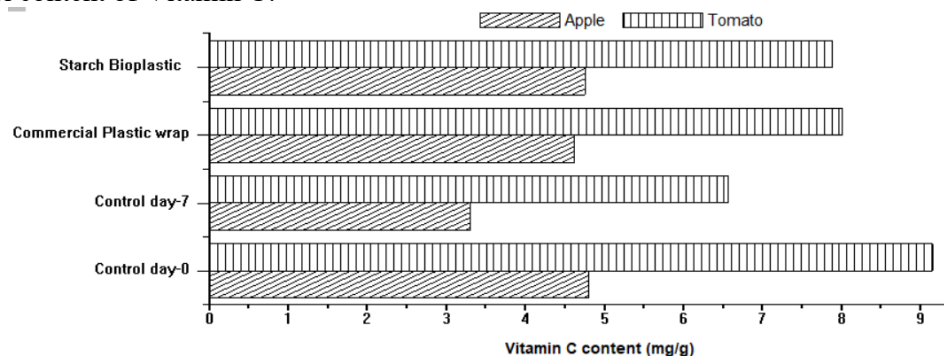


Figure 3. The test results of vitamin C on apple slices and tomatoes

4. Conclusions

Janeng starch is obtained from the isolation of tuber janeng has been used for the manufacture of bioplastics. Bioplastics can be made using the phase inversion method by drying and evaporation of solvent printing solution at room temperature. Bioplastics are made from a mixture of starch and glycerol provide transparent film, the value of tensile strength and high elongation. The bioplastics have a high value of the tensile test is equal to 20.95 kgf / mm² and the elongation of 42.69%. Bioplastics are made from starch janeng can be used for packaging apples and tomatoes.

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