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Original Research Article

Biodegradable Plastic from Taro Tuber (*Xanthosoma sagittifolium*) and Chitosan

Toto Rusianto[1*], Murni Yuniwati[2], Hary Wibowo[1], Lusi Akrowiah[2]
[1]Department of Mechanical Engineering, Institut Sains & Teknologi AKPRIND, Jl. Kalisahak No.28, Balapan, Klitren, Gondokusuman, Kota Yogyakarta, Daerah Istimewa Yogyakarta 55222, Indonesia
[2]Department of Chemical Engineering, Institut Sains & Teknologi AKPRIND, Jl. Kalisahak No.28, Balapan, Klitren, Gondokusuman, Kota Yogyakarta, Daerah Istimewa Yogyakarta 55222, Indonesia

***Corresponding author:** Toto Rusianto
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Abstract

Plastic synthetic is widely used in various purposes, ranging from household to industrial purposes. However, in spite of its superior, conventional plastic has several weaknesses, which the plastic waste can pollute the environment. It is important reason for replacing the use of conventional plastic with degradable plastics. Biodegradable plastic is a plastic that can be decomposed naturally by bacteria. The biodegradable plastic can be made from agricultural products such as cellulose and starch. Biodegradable plastic in this report was made from starch of purple taro tuber (*Xanthosoma sagittifolium*) and chitosan. The materials was perform using variables i.e. temperature, times and ratio of chitosan and starch. The mechanical and physical properties of biodegradable plastic were investigated by tensile strength testing, plastic degradation test by soaking in EM4 (Effective Microorganism) solution, and Fourier Transform Infra-Red (FTIR) was used to identify the chemical structure in biodegradable plastics. The specimens of the research were made by using starch of purple taro tuber with a weight of 10 g, 100 ml of 0.5% acetic acid, 2.5 ml of glycerin, a ratio of starch and chitosan of 0.075, with a temperature of 80 ºC, stirring speed of 300 rpm and a processing time of 75 minute. The result of the research showed a tensile strength of 2.32 MPa with elongation of 44.62%. The biodegradable plastic from the starch of purple taro tuber and chitosan can be degraded with the of EM4 solution until of 35 days. The investigated by using FTIR showed chemical structures of OH phenolic alcohols, C=O carbonyls, and CO esters, that can be easy decomposed. Thus, the plastic from the starch of purple taro tuber is environmentally friendly plastic.
Keywords: Plastic, biodegradable, purple taro tuber, chitosan.

Introduction

The intensity of the use of plastic as packaging is increasing. This is due to the many advantages of plastic compared to other packaging materials. Plastics are much lighter than glass or metal and are not easily broken. The plastic material can be shaped according to the desired design and size. The use of conventional plastics as packaging materials has serious environmental problems. Conventional plastics are resistant to degradation and consequently, their disposal an international encourage for the development of biodegradable plastics [1]. Plastic cannot be naturally decomposed by microorganisms on the soil, resulting in accumulation of waste, which causes pollution and environmental damage. Another disadvantage is a plastic base material from petroleum, whose existence is limited and not renewable. Along with this problem, packaging material research is directed to organic matter, which can be naturally decomposed and easily obtained [2]. Biodegradable plastic packaging technology is one of the efforts to get out of the problem of using conventional plastic packaging that cannot be degraded. Indonesia as a country rich natural resources has the potential to produce various biopolymer materials, therefore, that biodegradable plastic packaging technology has good prospects [3].

Biodegradable plastic is a plastic that can be naturally broken down by microorganisms into environmentally friendly compounds [4]. Previously, the biodegradable plastic was made from corn, chitosan, sweet potato, and cassava as the basic ingredients, the main content was starch or chitin, however, this plastic has low elasticity and low strength [5]. Therefore, this study was performed the manufacture of biodegradable plastics from purple taro tubers with the addition of chitosan as a strengthening.

Fig-1: Cultivars with purple stems or leaves are also variously called purple taro, blue taro, or purple elephant's ear (*Xanthosoma sagittifolium*)

MATERIALS AND METHODS

The materials research in this study used purple taro tuber, glycerol, distilled water, acetic acid, and chitosan. The research performed a experimental method with variables process i.e. weight ratio of chitosan to starch of 2,5%, 5%, 7.5%, 10%, and 12.5%, at temperatures of 50 °C, 60 °C, 70 °C, 80 °C, and 90 °C, and processing times for 45 minutes, 60 minutes, 75 minutes, 90 minutes, and 105 minutes. The specimens of bioplastic were analyzed i.e. gravimetry to determine water content in starch, percentages elongation, tensile strength, biodegradation, and Fourier transform infra-Red spectroscopy /FT-IR to identify chemical structure. The purple taro tuber was peeled and washed and then was grated to get fine crumble and added water with a ratio of 1: 2. The colloid was then filtered and squeezed to separate the pulp from the filtrate. The colloid was allowed to stand until the starch settles as deposit. Starch deposit was dried in an oven at 45 °C until it reached a fixed weight and then mashed.

The starch from purple taro tuber with a weight of 10 grams was added chitosan with a weight ratio varied. The mixture was put into a 250 ml beaker glass and was added of 100 ml with concentration of 0.5% acetic acid and 2.5 ml of glycerin to form a thick liquid. The thick liquid was heated on a hot plate with magnetic stirrer at varying temperatures and processing times. The thick liquid was poured on flat glass, cooled, and dried using an oven at 80 °C for 3 hours. Analysis of moisture in starch used the gravimetric method. The starch sample with an initial weight of 3 grams were heated in an oven with a temperature of 105 °C for 3 hours. Then the dry sample was measured again, the weight loss was the water content in the starch. Tensile tests were performed by means of a Universal Testing Instrument (UTI) machine with the crosshead speed was 1 mm/min by using ASTM D-1708 procedure. Tensile strength at failure and percentage elongation at breakage were determined using at least five specimens for each composition or treatment tested. Fourier Transform Infra-Red Spectrometer Spectrum was performed to pick up a spectrum from 4000 cm^{-1} to 450 cm^{-1} with the resolution was set at 4 cm^{-1}. Absorption bands recognized using a peak height algorithm within the Perkin Elmer software were taped and matched to absorption bands of each polymer reported in the literature and obtained from a spectral library [6]. A minimum of four corresponding absorption bands were taken for accepted identification of chemical structure. The ability of biodegradation was determined based on the duration of degradation by EM4 (Effective Microorganism). The biodegradation test was performed by placing a bioplastic specimen on a petri dish and then was soaked in10 ml EM4 until to degrade.

RESULTS AND DISCUSSION

Produce starch from purple taro tuber

The process production starch from purple taro tuber was obtained from the yield of 5.89% white starch powder. The produced plastic from white starch fine powder with variable temperature, time of the process, and mass ratio of chitosan to starch were obtained a yellow thin layer and slightly transparent. Figure-2 shows the starch from purple taro tuber and biodegradable plastic.

Fig-2: (a) Fine starch powder (b) biodegradable plastic

Moisture Content In Starch

The analysis of water content was done to determine amount of water contained in the starch. The analysis was obtained the results of water content on starch of 13.33%. Water content affects the shelf life of starch as a basic material for biodegradable plastic. The higher of the water content can effects the shorter the shelf life of the starch so that it will be more quickly contaminated by microbes. The value of water content in starch according to (Indonesia National Standard/SNI) number 01-3451-1994. The established standard a maximum water content of 15%, so the water content of starch produced was still in accordance with the standards.

Effect of processing temperature

The effect of the processing temperature on the tensile strength and elongation of the biodegradable plastic with temperature variations can be seen in Figure-3 and Figure-4. The other variables were fixed, namely the processing time of 90 minutes and the mass ratio of chitosan to starch of 10%.

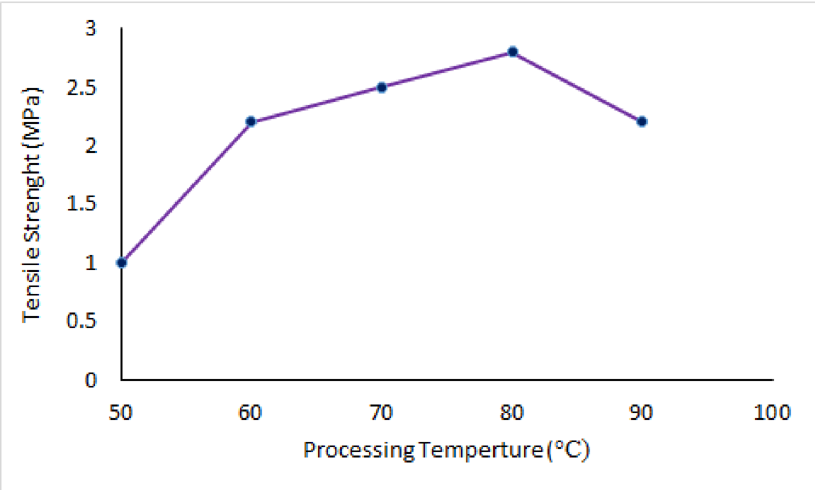

Fig- 3: Effect processing temperature to tensile strength of biodegradable plastic

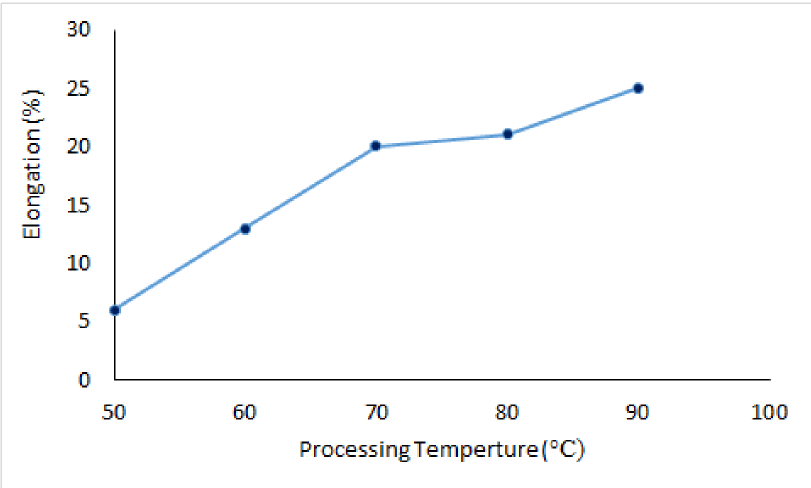

Fig-4: Effect processing temperature to elongation of biodegradable plastic

Figure-3 shows that the tensile strength of biodegradable plastic at processing temperature of 50 °C to 80 °C increases. It is cause the higher the temperature the faster the gelatinization process is achieved. At a temperature of 80 °C, the tensile strength reached 2.85 MPa, in this condition gelatinization has occurred perfectly so that optimum tensile strength can be obtained. At temperature below 80 °C, the gelatinization process has not run perfectly so it does not form plastic with a thick solution but it still a dilute solution, if it is dried in an oven the biodegradable plastic is easily cracked. This is because bioplastic particles have not been formed completely. While at the processing temperature above 80 °C the tensile strength of the plastic produced decreases. It is caused by using temperatures above 80 °C the perfect gelatinization process has been exceeded, then decomposition occurs. Figure-4 shows that the elongation increases with increasing the processing temperature. It is caused by the higher the processing temperature, the gelatinization process is perfect. The addition of 2.5 ml of glycerin also resulted in increased elongation, because at the higher temperature interaction process of glycerin bond with starch is stronger [7]. At a temperature of 90 °C, the highest percentage of elongation is 25%.

Effect of Processing Times

The study of effect of the processing times on the tensile strength and elongation of the biodegradable plastic can be seen in Figure 5 & 6. The other variables were fixed, namely the processing temperature of 80 °C and the mass ratio chitosan and starch of 10%.

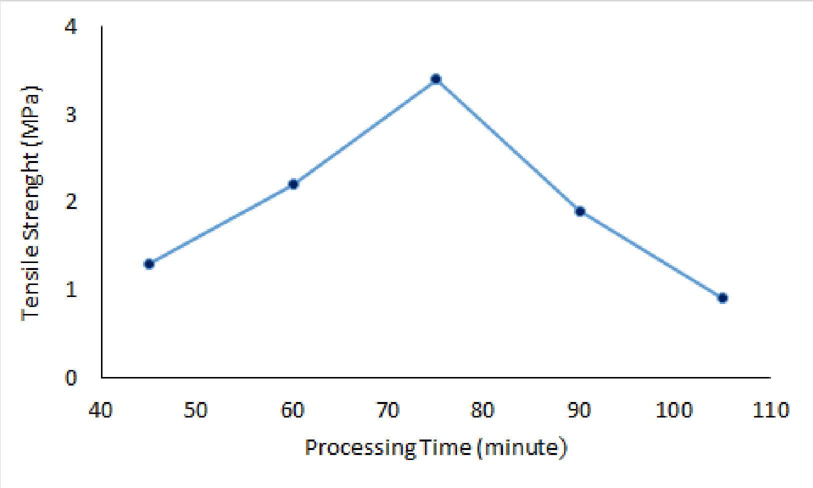

Fig-5: Effect processing times to the tensile strength of biodegradable plastic

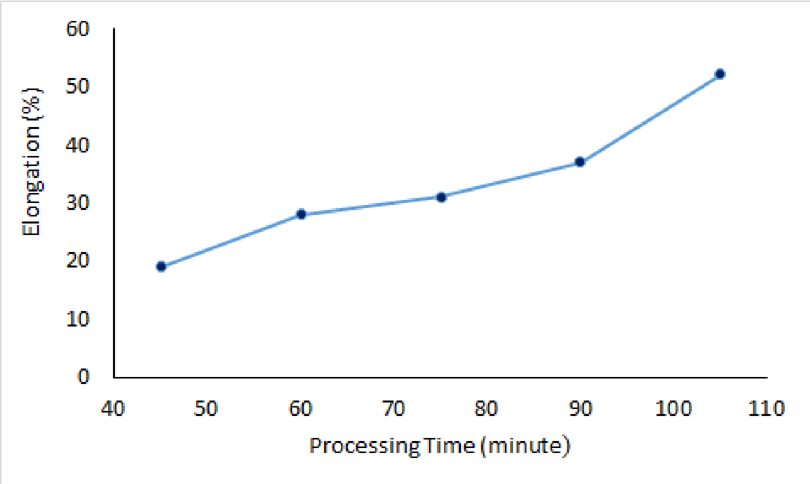

Fig-6: Effect processing times to the elongation of biodegradable plastic

Figure-5 shows the results of tensile strength testing that has been done on plastic specimens with a processing times of 45 minutes to 105 minutes. For long processing time, the gelatinization process can be achieved fastly, the more perfect the gelatinization process the tensile strength of the plastic produced is greater. At a processing time of 75 minutes the tensile strength reaches 3.40 MPa, in this condition gelatination occurs perfectly so that it can be obtained optimal tensile strength. However, if processing time more than 75 minutes the tensile strength decrease. It is cause that the processing time is too long and it has exceeded the gelatinization process and decomposition occurred so the tensile strength of the plastic decrease. This shows that after perfect gelatinization occurs the addition of time will cause decomposition, according to Winarno which states that the heating time affects the gelatin process [8]. Figure-6 shows that increases the processing time to increase the elongation of degradable plastic. It is caused that the longer the processing time of gelatinization process result plasticization produced completely. The addition of 2.5 ml glycerin result the increased elongation because the higher the temperature of the bonding process between glycerin and starch more stronger [8]. The processing time at 105 minutes shows the highest percentage of elongation is 52%.

Effect of mass ratio of chitosan to starch

The study effect mass ratio variation of chitosan to starch on the tensile strength and elongation plastic specimens can be seen in Figure 7 & 8. The biodegradable plastic process used mass ratio variation with constant variables are the processing temperature at 80 °C and the processing time of 75 minutes.

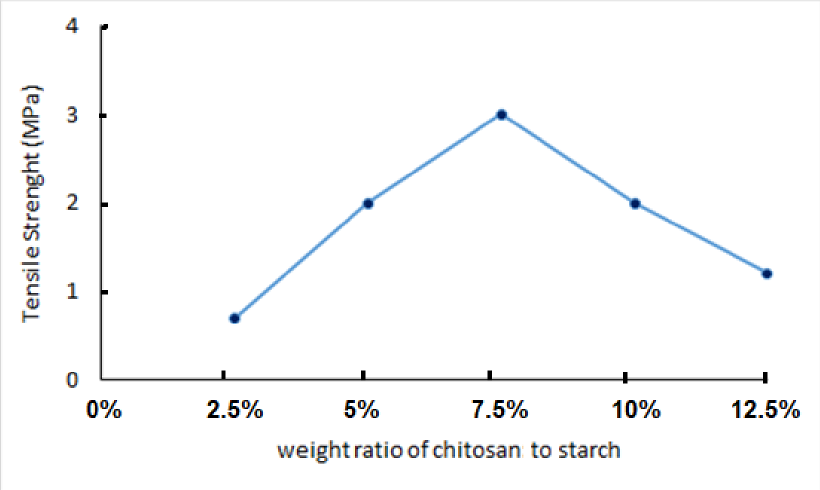

Fig-7: Effect mass ratio of chitosan to starch to the tensile strength of biodegradable plastic

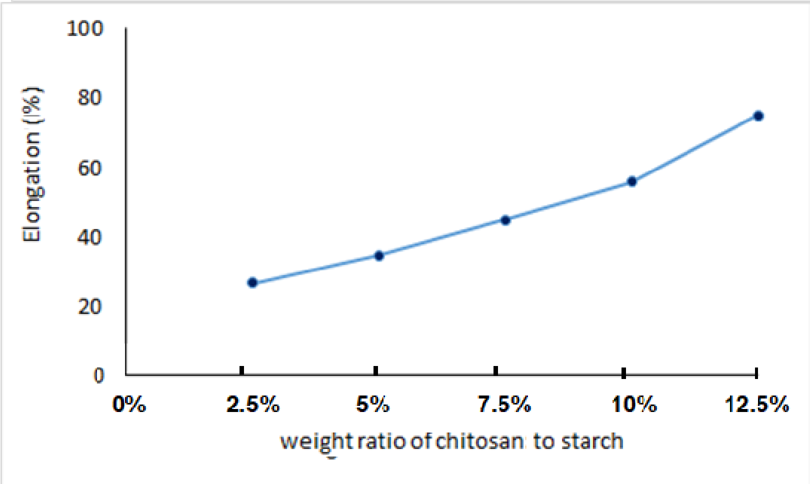

Fig-8: Effect mass ratio of chitosan to starch to the elongation of biodegradable plastic

Figure-7 shows that the mass ratio of chitosan to starch of 7.5% is the result of optimal tensile strength, which is 2.32 MPa. While the lowest tensile strength value is 0.68MPa, with a mass ratio of chitosan to starch 2.5%. The value of bioplastic tensile strength increased with increasing mass ratio of chitosan to starch from 2.5% to 7.5%. However, on the addition of mass ratio of chitosan to starch above 7.5% tensile strength decrease. It is due to the addition of mass ratio of chitosan to starch above 7.5% in plastic cause the composition between starch macromolecules and chitosan macromolecules to be in complete balance. Furthermore, when comparison mass ratio of chitosan to starch is high, it will reduce the value of tensile strength because chitosan has a linear polymer chain structure. The linear chain structures tend to form crystalline phases because they are able to arrange regular polymer molecules. The crystalline phase can provide strength, stiffness and hardness that can cause plastics to break easily [9]. Figure-8 shows that the mass ratio of chitosan to starch to elongation is highest in the mass ratio of chitosan to starch of 12.5% with an elongation percentage of 75%. It can be seen that the value of elongation is getting higher. The hydrogen bond between chitosan and starch and hydrogen bonds between chitosan and glycerol is increasing. So the bioplastics will be more elastic and elongation tends to increase.

Fourier transform infra-Red spectroscopy analysis

FT-IR analysis aims to find out the chemical compounds that is contained in the material and can also be used as an indicator that the plastic produced can still be degenerated with pick up a spectrum from 4000 cm^{-1} to 450 cm^{-1}. From the results of functional groups in organic chemical analysis using FT-IR technique, FT-IR spectrum was obtained as shown in Figure-9.

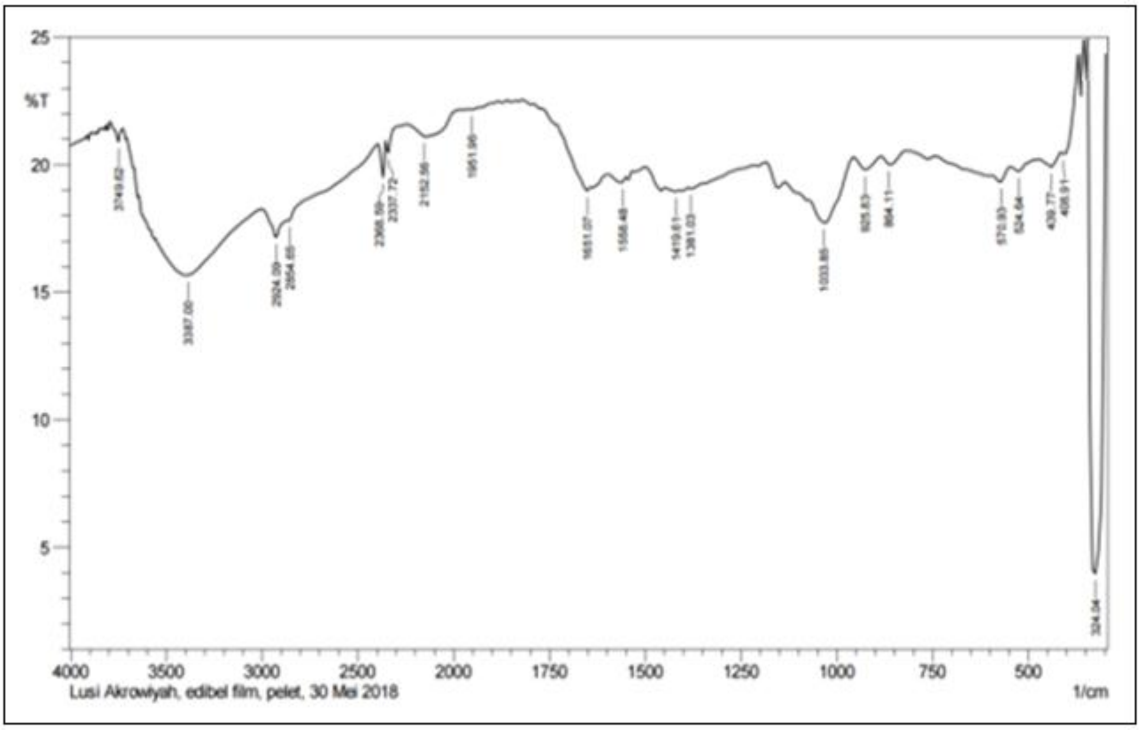

Fig-9: Plastic FT-IR spectra of purple taro tuber starch

Figure-9 shows the absorption of O-H groups at 3387 cm^{-1} spindle numbers at wave numbers of 864.11, 925.83, 1381.03, 1419.61, 2854.65, and 2924.09 cm^{-1}. It shows the uptake of C-H groups, C = 0 at wave number of 1651.07 cm^{-1}, C-O at wave number of 1033.85 cm^{-1}. According, that in addition to other hydroxide groups (OH) the functional groups contained in biodegradable plastic films are carbonyl (CO) and ester functional groups, so that with the FT-IR test conducted in this study obtain functional groups OH, CO and ester. It indicate that the plastic film produced is categorized as degradable materials [10]. From the results of the FT-IR test shows that all the groups obtained in the plastic produced can be degenerated.

Biodegradation Test

Biodegradation test was conducted to determine the degradation of plastic by using EM4 bacteria (Effective Microorganism). EM4 is a micro mixed culture consisting of Lactobacillus, Actinomyces, Streptomyces, yeast fungi and photogenic bacteria which work in mutual support in decomposition of organic matter [11]. The process of decomposition of organic matter with EM4 molecules takes place in fermentation both in aerobic and anaerobic conditions. These bacteria will degrade starch containing bioplastics by breaking the polymer chain into its monomers through an enzyme produced from the bacteria. This process will produce organic compounds in the form of amino acids, lactic acid, sugar, alcohol, vitamins, proteins, and other organic compounds that are safe for the environment. Figure-10 show bioplastic is degraded by micro-organisms.

Fig-10. Plastic before being given EM4 (left), after being given EM4 (middle), and after 35 days of degeneration (right)

The specimen of bioplastic is soaked in EM4 with volume of 10 ml and it is let for few days. The result of examination shows that within 35 days the biodegradable plastic from the purple taro tuber starch begins to degrade. It is indicated by rotten and torn on surface of the bioplastic film. From this result, biodegradable plastic from tuber and chitosan starch can be said to be environmentally friendly plastic.

CONCLUSION

The optimum tensile strength of biodegradable plastic is achieved at a processing temperature of 80 °C. At a processing time of 75 minutes to produce bioplastic, in this condition gelatination occurs perfectly so that it can be obtained optimal tensile strength of 3.40 MPa. At a processing time exceeds 75 minutes the tensile strength decreased. The higher mass ratio of chitosan to starch cause the greater the tensile strength, but in the mass ratio of chitosan to starch which exceeds 7.5% the tensile strength decreases. The elongation of degradable plastic specimens with variable processing temperature, processing time and mass ratio of chitosan to starch all of increase. The FT-IR analysis conducted in this study shows functional groups OH, CO and ester. It indicate that the plastic film produced is categorized as degradable materials. The biodegradable plastic from the purple taro tuber starch begins to degrade on 35th day. The plastic can be said to be environmentally friendly plastic.

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