



The effect of banana starch concentration on the properties of chitosan-starch bioplastics

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ABSTRACT

The use of plastic films has been increasing due to their versatility and wide range of applications. They have been used mainly for wrapping and packaging. However, they are not easily degraded thus increasing the environmental problem. Bioplastics have been developed to substitute the petroleum based plastics. In this research, chitosan based bioplastics were made by blending chitosan with various banana starch concentrations from 10 to 30%. The bioplastics were prepared using casting method with the addition of 30% glycerol as the plasticizer. The resulting bioplastics were characterised for their mechanical properties, swelling behavior, and biodegradability. The increase of starch concentration decreased the tensile strengths while the elongation percentage, swelling, and biodegradability were enhanced. The incorporation of starch into chitosan based bioplastics reduced the film brittleness and in overall improved the desirable properties.

Keywords: bioplastics, chitosan, banana, tensile strength, biodegradability

INTRODUCTION

Plastics have become an integral part of human life due to their convenience and versatility. They have been used for a wide range of applications as home appliances, electrical equipments, medical instruments, construction, automobiles, and packaging [1-3]. However, it has been known that petroleum based plastics were hardly degraded and they have been causing environmental problems. There have been many research attempts on the development of bioplastics due to increasing demands on environmental-friendly plastics packaging materials [4-6]. Bio based plastics from renewable resources such as those derived from chitosan or starch are easily degraded thus environmentally safe.

Chitosan has been intensively studied to be used as bioplastics due to its premium film-forming ability, strong mechanical strength and flexibility, biodegradable nature and anti-bacterial characteristics [4]. It has been quite extensively used as scaffold materials in tissue engineering [7]. Starch has been chosen as one of the green packaging materials due to its availability, relatively low cost, sustainability and rapid biodegradable nature [4]. However, pure starch is sensitive to moisture [4] which greatly limit the utilization of starch-based biodegradable materials. Therefore, it was expected that the resulting composite chitosan-starch bioplastics would have improved mechanical properties (better strength and flexibility), lower water permeability and antibacterial properties [4,6] but still biodegradable. In this research, the effect of starch concentration on the overall properties of chitosan-starch bioplastics including mechanical properties, swelling behavior, and biodegradability in the present of 30% glycerol as plasticizer was thoroughly studied.

EXPERIMENTAL SECTION

Materials

Banana starch was isolated from green saba banana with amylase : amylopectin ratio of (37:63) (w/w) and moisture content of ~8%. Glycerol was used as plasticizer and purchased from PT. Brataco (Surabaya, Indonesia). Chitosan flakes were purchased from Institut Pertanian Bogor (Bogor, Indonesia). It was derived from shrimp shell and was pale yellow in color. Its viscosity was 20 cps and de-acetylation degree was 88.5%. NaOH flakes technical was purchased from PT. Brataco (Surabaya, Indonesia). Glacial acetic acid was purchased from PT. Merck Tbk (Indonesia). EM4 (Effective Microorganisms 4) solution containing mixed microbial cultures (Lactobacillus 8.7×10^5 ; phosphate solubilising bacteria 7.5×10^6 ; yeast 8.5×10^6 ; some actinomycetes and photosynthetic bacteria in mineral containing solution) was purchased from PT. Songgolangit Persada (Jakarta, Indonesia). Deionised water was used during the experiments.

Methods

Preparation of chitosan-starch bioplastics

Chitosan was used as the backbone of bioplastics while starch functioned as the filler. Chitosan-starch bioplastics were prepared with chitosan:starch ratios of (100:0; 90:10; 80:20; 70:30) (v/v). At first, chitosan solution was prepared by solubilising 2.8 g chitosan in 70 ml 1% (v/v) acetic acid solution and then mixed. Gas bubbles had to be removed out prior to use. Secondly, starch slurry was prepared by suspending 1.2 g banana starch into 30 ml 1% (v/v) acetic acid solution. The slurry was then heated to 55°C while stirring. Afterwards, both mixtures were mixed and 30 ml of glycerol was added in order to have chitosan-starch:glycerol ratio of 100:30 (v/v) or 30% (v/v) glycerol relative to the polymer mixtures. Finally, bioplastics casting were conducted by pouring the final mixture into a petri dish. Having been dried, bioplastics were soaked with 4% (b/v) NaOH solution until they had been easily removed out. The bioplastics were then rinsed under flowing water and dried at room temperature prior to analysis.

Mechanical properties measurement

The mechanical properties of bioplastics determined in these experiments included tensile strength and elongation percentage measured using an Autograph AG-10TE (Shimadzu, Japan). Bioplastics specimen dimension of 7 cm x 2 cm was prepared. The specimen thickness was measured using a thickness gauge instrument (Mitutoyo, Japan). Tensile strength was performed by elongating the specimen and measure the load carried by the specimen before breaking. It was calculated by dividing the maximum load by the original cross-sectional area of the specimen.

$$\text{tensile strength (MPa)} = \frac{F \text{ (kgF)}}{A \text{ (cm}^2\text{)}} \quad (1)$$

where F was measured load before breaking and A was cross-sectional area of the specimen (width x thickness).

Elongation was the percentage increase in length that occurred before the specimen was broken under tension.

$$\% \text{ elongation} = \frac{L-L_0}{L_0} \times 100\% \quad (2)$$

Where L was the final length of specimen before breaking and L_0 was the initial length of specimen.

Swelling behavior analysis

Bioplastics was immersed in water up to 10 minutes. The weight was recorded every 2 minutes. Swelling percentage could be calculated as

$$\% \text{ swelling} = \frac{W-W_0}{W_0} \times 100\% \quad (3)$$

Where W_0 = initial sample weight and W = final sample weight.

Biodegradability test

Bioplastics were cut into 2 cm x 2 cm and then were put into petri dishes. Afterwards, 20 ml microbial solution (EM4) which was previously diluted for 5 times was added. The degradation processes were monitored every 30 minutes.

RESULTS AND DISCUSSION

Chitosan-starch bioplastics were prepared by varying the concentration of banana starch (10-30%) with the presence of 30% glycerol as the plasticizer. The mechanical properties of the resulting bioplastics in terms of tensile strength and elongation were depicted in Fig. 1. It could be seen that the tensile strengths were decreased whereas the elongation percentages were increased as starch concentrations increased. The highest tensile strength of about 5 MPa was obtained when no starch was added into the mixtures. Tensile strength dropped by 50% when 30% banana starch was incorporated into the bioplastics. On the other hand, the elongation percentage increased two times from ~14% to ~28% by the addition of 30% starch. The decrease of tensile strength in the chitosan-starch bioplastics upon the addition of starch was due to the poorer mechanical properties of starch in comparison to chitosan. Chitosan showed strong mechanical properties due to its strong inter-molecular and intra-molecular bonding [8] whereas starch did not contain amylopectin fraction have a branched structure leading to a weaker molecular bonding. The increase in elongation was due to the presence of amylopectin in starch acting like the plasticizer which improved the molecular mobility of the polymer chains and reducing the brittleness of the chitosan based biopla

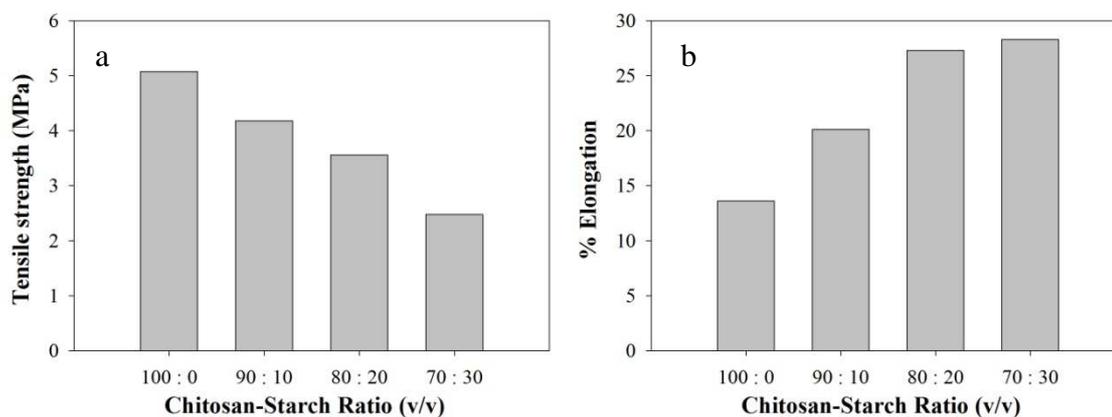


Figure 1. Mechanical properties of chitosan-starch bioplastics. a) Tensile Strength; b) % Elongation

The swelling behavior of chitosan-starch bioplastics were studied by immersing the bioplastics in water for up to 10 minutes. The weight increase of bioplastics indicated how much water penetrated the bioplastics reflected in the swelling percentage. Swelling percentages of chitosan-starch bioplastics with varying starch concentrations vs. time was depicted in Fig. 2. It could be seen that in general, swelling percentages were increased with time in all samples. Furthermore, swelling percentages were getting higher as starch concentrations were increasing. Starch was more sensitive to moisture compared to chitosan which is more hydrophobic. Water was easily moved into the amorphous region of starch during swelling. Swelling percentage increased from ~10% to ~14% upon addition of 30% starch in the presence of 30% glycerol.

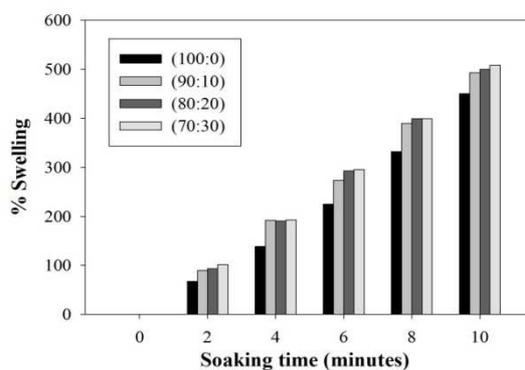
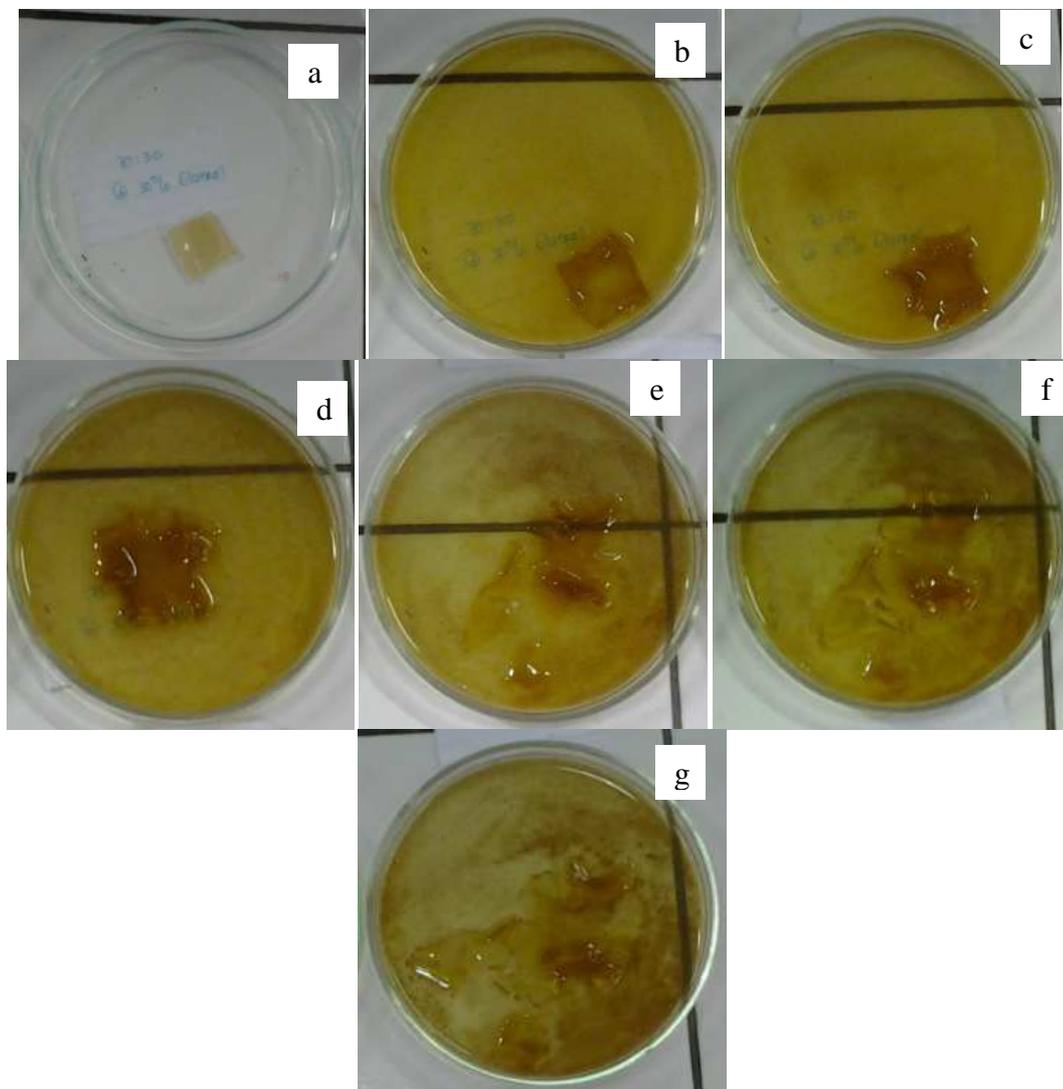


Figure 2. Swelling behavior of chitosan-starch bioplastics

Finally, biodegradability tests were conducted on the bioplastics. Biodegradability rates increased as the starch concentrations in chitosan-starch bioplastics were increased as could be seen in Table 1 dan Fig. 3.

Table 1. Biodegradability tests of chitosan-starch bioplastics

Chitosan : Starch (v/v)	Degradation time (minutes)	Remaining specimen (%)
100 : 0	150	0
90 : 10	> 180	± 80
80 : 20	> 180	± 30
70 : 30	> 180	± 20

**Figure 3. Biodegradability test of Chitosan-starch bioplastics (70:30) with the presence of 30% glycerol monitored every 30 minutes (0 – 180 minutes)**

Interestingly, pure chitosan bioplastics degraded readily within 150 minutes whereas the chitosan-starch composite bioplastics degradation took a longer time. This might be due to some interaction occurred between starch and glycerol molecules via hydrogen bonding slowing down the biodegradation rates. This turned out that the addition of starch into chitosan based bioplastics could accelerate the biodegradation process thus reducing the accumulation of plastics wastes that was harmful to the environment. The mechanical properties of chitosan-starch bioplastics in terms of tensile strength could be further improved by the additions of some additives, such as ZnO or clay [9]. In overall, chitosan-starch bioplastics looked promising to be used as the substitute of the non-biodegradable conventional plastics in response to the increasing demands on environmental friendly packaging materials.

CONCLUSION

Concentration of starch was varied from 10 to 30% within the chitosan based bioplastics in the presence of 30% glycerol. It turned out that the increase of starch concentration decreased the tensile strength but increased the elongation percentage. Swelling percentage and biodegradability was also increased with the increase in starch

concentration. However, the biodegradability of pure chitosan bioplastics is the lowest. This indicated some interactions that might occur between starch and glycerol molecules retarding the biodegradation process. In summary, blending chitosan with starch has improved the overall desirable properties. It looked promising to use bioplastics as the substitute of conventional plastics though their high cost in order to improve environmental sustainability and for saving this planet for the future generation.

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