Biodegradable Plastic from Cassava Waste using Sorbitol as Plasticizer

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Abstract

Cassava waste can be utilized as raw material for biodegradable plastics. This research studied the influence of sorbitol, carboxymethyl cellulose (CMC) and the gelatinization temperature in the preparation of biodegradable plastic from cassava waste. 12 gram of starch from cassava waste was stired with 68.2 gram of water-ethanol solution at 75 rpm and is fixed during this study. While the amount of sorbitol, CMC and gelatinization temperature are varied. The best results are showed at 44.90% in water absorption, 101.4 MPa in tensile strength, 76.57% in elongation, 4.17 MPa in Young's modulus, and decomposition time are 64, 67, and 79 days.

Key words: cassava waste, starch, sorbitol, CMC, gelatinization temperature

Introduction

Biodegradable plastics can be made from crops that contain starch such as cassava and sago (Darni and Herti, 2010; Mali et al., 2005). In the tapioca production process, from one ton of cassava can produce 250 kilograms cassava flour and 114 kilograms of cassava solid waste which still contains 45-65% of starch (Tarmudji, 2004; Sefriana, 2012)

The processing of cassava solid waste into biodegradable plastics is an alternative to dealing with waste buildup and to increase the value of waste. Biodegradable plastics made from starch is safe for health and environment, but its color is not clear, has low mechanical properties, and also susceptible to bacteria and water. To improve the mechanical properties of biodegradable plastics the addition of additives, plasticizers, and setting the conditions to obtain the qualified biodegradable plastic are required (Darni and Herti, 2010). Glycerol, gelatin and sorbitol are commonly used as plasticizer in the production of biodegradable plastics. Sorbitol has an advantage compared with other plasticizers because of its ability to stabilize pH (Susilo et al., 2005).

This research was carried out by mixing starch obtained from cassava waste, plasticizer, and additives in a stirred tank. The solution was heated at a gelatinization temperature which is varied at 65 ºC and 70 ºC, followed by casting and drying to obtain a plastic film. The produced plastic film was tested its elongation and tensile strength characteristics, water absorption and biodegradability. Plasticizers and additives used in this study was sorbitol and carboxymethyl cellulose (CMC). The purpose of this research was to determine the the effect of the concentration of sorbitol and CMC and also gelatinization temperature on the formation of biodegradable plastics. Then the process variables were evaluated to obtain biodegradable plastics with good quality.

Materials and Methods
Procedure

Cassava waste was soaked in 0.3% sodium metabisulfite followed by crushing until it becomes pulp. Then, pulp was dissolved in water at a ratio of 1:1 and then stirred and filtered. Filtrate allowed to stand for 3 hours. The filtrate was separated from the precipitated starch. Starch was dried in an oven at 40°C for 48 hours. Then, the dried starch was crushed and sieved with a 100 mesh sieve.

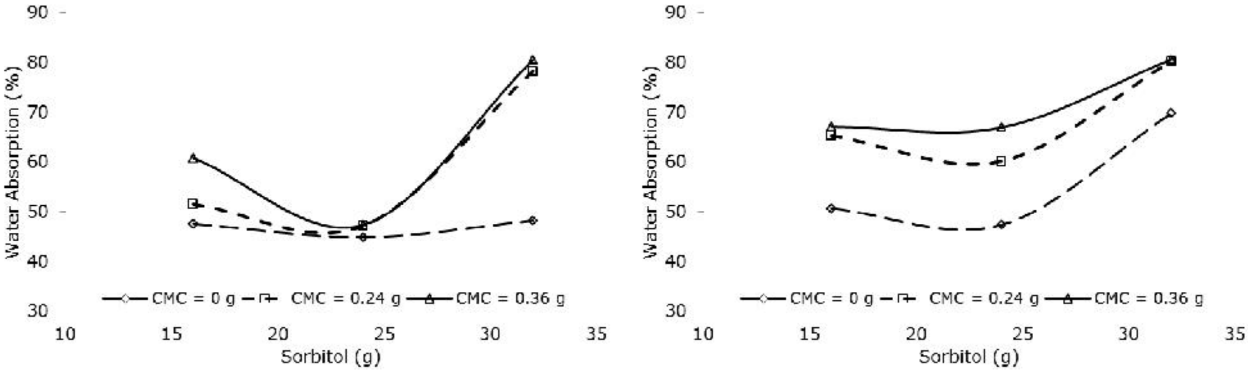
12 g of extracted starch from cassava waste was dissolved into 68.2 g of solvent (distilled water+ethanol (10:3.5)). The solution then was put into erlenmeyer and stirred with a magnetic stirrer for 15 minutes with a stirring speed of 75 rpm. Various concentrations of CMC solution at 0 g, 0.24 g, 0.36 g which was dissolved at a temperature of 60°C in 3.8 g of alcohol was added in to the starch solution. Then, sorbitol was added at variation of 16 g, 24 g and 36 g. Hereafthere, the solution was heated at a temperature of 65 °C and 70 °C while stirring until gelatinized. The gelatinized solution was allowed to cold until the temperature drops to 30 °C, then added 1.3 g ascorbic acid and stir until homogeneous.

The homogenized solution was poured into a casting glass with 15cmx15cmx2.5mm size and then was dried at room temperature for 3x24 hours. The formed film was removed from the glass plate and analyzed its elongation and tensile strength, water absorption and biodegradability.

Results and Discussion
The effect of sorbitol, CMC and gelatinization temperature on water absorption

This test was conducted to determine the level of water absorbed by the biodegradable plastic and to estimate its stability to water. The amount of water absorbed by sample is directly proportional to the amount of sorbitol and CMC that were added. Figure 1 shows that the amount of water absorbed is higher with the addition of more sorbitol and CMC. With the addition of 0.36 g CMC and sorbitol varied at 16, 24 and 32 g the amount of water absorbed by plastics are 67.14, 66.94 and 80.62% while on treatment without the addition of CMC the amount of water absorbed are 47.61, 44.9 and 48.24%. This is because sorbitol and CMC is hydrophilic and reduces the adhesive properties of plastics (Widjayani, 2008).

Gelatinization temperatures also affects the amount of water can be absorbed by plastic sample. At a higher gelatinization temperature solvent will evaporate more. This resulted in plastic sample will be hydrophilic and absorbs water in larger quantities (Utomo et al., 2013). Based on the experimental results, the plastic sample at gelatinization temperature 65 °C water give water absorption percentage of 80.53%. While at the gelatinization temperature 70 °C water absorption percentage is 80.62%.



(a) (b)

Figure 1. The amount of water absorbed as function of sorbitol, CMC and gelatinization temperature. (a) Gelatinization temperature 65 °C; (b) Gelatinization temperature 70 °C

The effect of sorbitol, CMC and gelatinization temperature on biodegradability

Decomposition test was conducted to determine the level of damage on plastic by the activity of microorganisms, such as bacteria and fungi. Figure 2 shows at the larger the concentration of CMC the decomposition time of plastic becomes increasingly longer. The fastest time of the plastic decomposition occurs at CMC concentrations 0.36 g in all concentration of sorbitol ie as long as 58 days. While the longest decomposition time occurs for plastic without the addition of CMC.

Gelatinization temperature also affects the decomposition time. Higher gelatinization temperature will have consequences on longer decomposition time. This is because when all the material is heated the particles of the material will undergo physical and chemical changes. So that the structure will be more dense and homogeneous, microbes will take longer to break down plastic sample (Utomo et al., 2013). Experiments on the plastic samples with a concentration of 32 g sorbitol without CMC at a temperature of 65 ^oC gelatinisasi decomposes at day 61. While the gelatinization temperature 70 ^oC decomposes plastic samples on day 64.

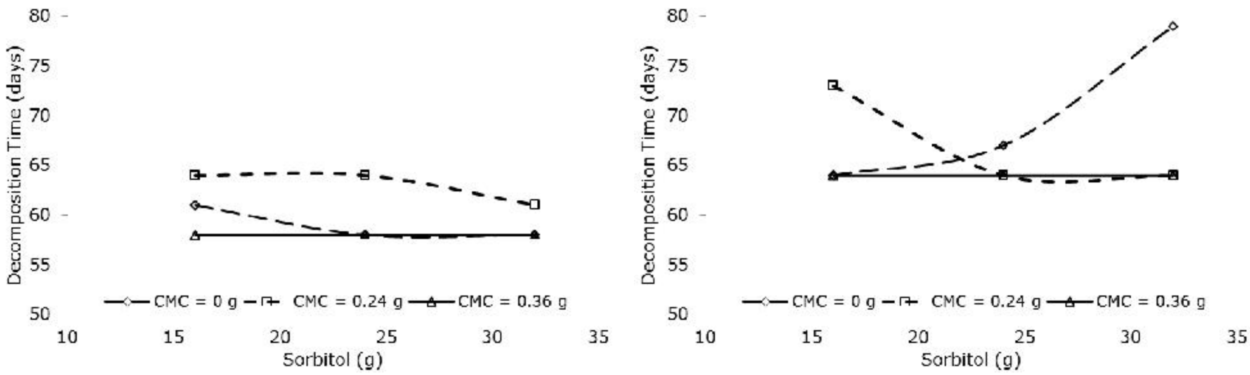
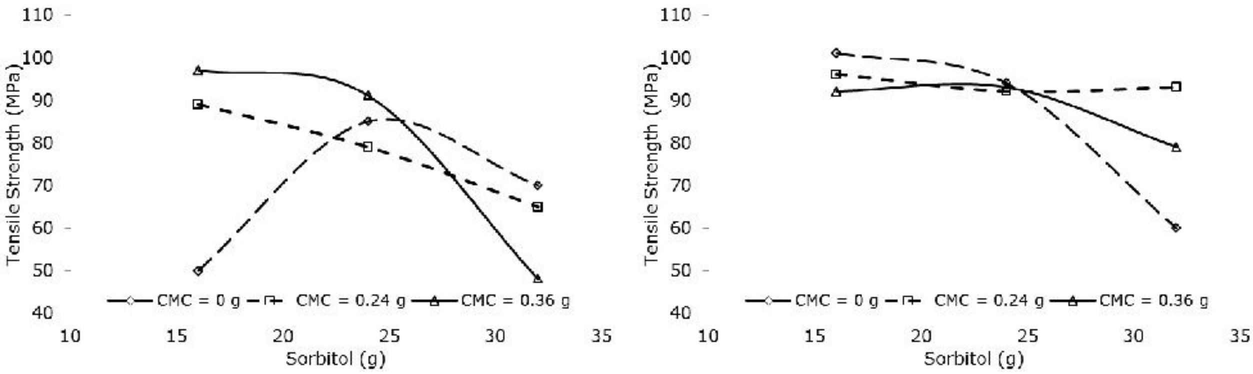


Figure 2. The decomposition time as function of sorbitol, CMC and gelatinization temperature. (a) Gelatinization temperature 65 ^oC; (b) Gelatinization temperature 70 ^oC

The effect of sorbitol, CMC and gelatinization temperature on tensile strength and elongation of biodegradable plastic

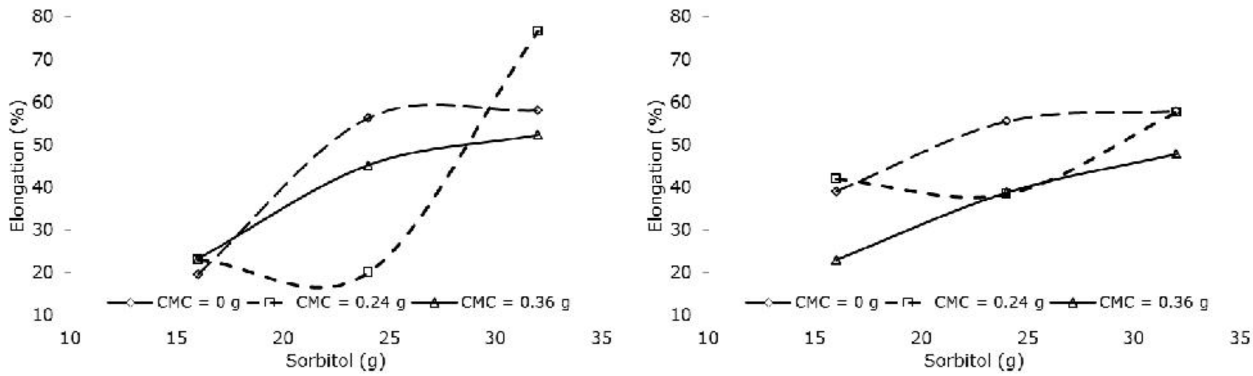
Figure 3 shows the downward trend in the value of tensile strength plastic with increasing concentrations of plasticizer sorbitol. The highest value of tensile strength plastic 101.14 MPa was obtained on the sample with the composition of 12 g of starch, 16 g of sorbitol and without additives CMC. Sorbitol will interact between the structure of the polymer chain resulting in reduced movement of the polymer chain. However, if the concentration of sorbitol is increased, starch is unable to bind sorbitol, so the excess sorbitol are in the phase out of polymer phase. This causes the value of the tensile strength decreased (Maghfiroh et al., 2013). For samples without CMC with at concentration of sorbitol 16, 24 and 32 g plastic tensile strength values decrease at 101.14 MPa, 94.08 MPa and 60.04 MPa respectively.

Figure 4 shows the trend of increasing plastic elongation along when sorbitol concentration increased. For sample without CMC with sorbitol concentrations 16, 24 and 32 g, elongation percentage is increasing in the amount of 39.09%, 55.45% and 57.89%. The existence of sorbitol molecules in the polymer chain causes the polymer bond to be reduced and weakened so as to provide the flexible nature of the plastic (Purwanti, 2010). Plasticizer molecules will bind to the particles in empty space contained in the pores of the plastic, so that the bonds between the particles on plastic sheets will become increasingly meeting (Jannah et al., 2014). This will improve the flexural strength plastic.



(a) (b)

Figure 3. The tensile strength as function of sorbitol, CMC and gelatinization temperature. (a) Gelatinization temperature 65 ^oC; (b) Gelatinization temperature 70 ^oC



(a) (b)

Figure 4. The percent elongation as function of sorbitol, CMC and gelatinization temperature. (a) Gelatinization temperature 65 ^oC; (b) Gelatinization temperature 70 ^oC

Conclusions

Cassava waste can be utilized as raw material for biodegradable plastic. The addition of CMC as an additive during production will increase plastic water absorption. Plastic with the best water resistance obtained on the composition of the 12 g of starch, 24 g of sorbitol, without the addition of CMC, which amounted to 44.90%. The fastest decomposition time for 58 days occurs at variation of sorbitol 16, 24 and 32 g, with a concentration of 0.36 g CMC. While the longest decomposition found in plastics with 32 g sorbitol, without the addition of CMC, ie 79 days. The maximum tensile strength of 101.4 MPa obtained in condition with a composition of 12 g of starch, 16 g of sorbitol and without CMC. The highest percent of elongation is obtained on the sample with a composition of 12 g of starch, 24 g of sorbitol, and 0.24 g of CMC in the amount of 76.57%.

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References

Darni, Y., Herti, U. (2010). Studi Pembuatan dan Karakteristik Sifat Mekanik dan Hidrofobisitas Bioplastik dari Pati Sorgum. Jurnal Rekayasa Kimia dan Lingkungan, 7: 1-4.

Jannah, M., Ratnawulan, Gusnedi. (2014). Analisis Penambahan Gula Jagung Terhadap Karakteristik dan Degradasi Plastik Biodegradable Air Pati Ubi Kayu (Mannihot utilissima). Pillar of Physics Journal, 1: 2-6.

Maghfiroh, S., Susatyo, W, E. B. (2013). Sintesis dan Karakterisasi Edible Film Kitosan Termodifikasi PVA dan Sorbitol. Journal of Chemical Science, 2:1.

Mali, S., Sakanaka, L.S., Yamashita, F., Grossman, M.V.E. (2005). Water Sorption and Mechanical Properties of Cassava Starch Films and Their Relation to Plasticizing Effect. Carbohydrate Polymers Journal, 1: 1-2.

Purwanti, A. (2010). Analisis Kuat Tarik dan Elongasi Plastik Kitosan Terplastisasi Sorbitol. Jurusan Teknik Kimia, Institut Sains dan Teknologi AKPRIND, Jurnal Teknologi, 3: 5.

Sefriana, F. (2012). Variasi Nitrogen dan Hidrogen Enzimatis pada Produksi Beta Glukan Saccharomyces Cereviciae dengan Medium Onggok Ubi Kayu dan Onggok Umbi Garut. Fakultas Teknik, Teknik Kimia, Universitas Indonesia, Depok.

Soesilo, D., Santoso, R, E., Diyatri, I. (2005). Peranan Sorbitol dalam Mempertahankan Kestabilan pH Saliva pada Proses Pencegahan Karies. Jurnal Kedokteran Gigi (Dent. J), 1: 2-4.

Tarmudji, M, S. (2004). Pemanfaatan Onggok Untuk Pakan Ternak. Balai Penelitian Veteriner, Bogor.

Utomo, A, W., Argo, B, D., Hermanto, M, B. (2013). Pengaruh Suhu dan Pengeringan terhadap Karakteristik Fisikokimiawi Plastik Biodegradable dari Komposit Pati Lidah Buaya (Aloe vera) – Kitosan. Jurnal Bioproses Komoditas Tropis, 1: 6-7.

Widjayani, A., Ummah, K., Tjahjani, S. (2005). Karakterisasi Karboksimetil Selulosa (CMC) dari Eceng Gondok. Indonesia Journal of Chemistry, 3: 1-4.