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Preparation and Characterization of Biodegradable Plastic from Corn Starch

Bo Bo Thet*

Abstract

Starch is used in the production of biodegradable packaging materials as an attractive alternative to synthetic polymers because it is a natural biopolymer and renewable source. In this research, biodegradable plastic was made from corn starch to reduce the soil pollution problem. For the production of starch-based plastic, glycerol was added for the gelatinization of starch during thermal processing. Biodegradable plastic was made by varying the amount of ingredients such as water (6ml, 7ml, 8ml, 9ml) and glycerine (0.25g, 0.5g, 0.75g, 1g). The characteristics of prepared biodegradable plastic were evaluated by biodegradability test, water absorption test, moisture absorption test and solubility test. Corn starch 1.5g, vinegar 1ml, glycerine 0.5g and distilled water 7ml were the most suitable conditions for the preparation of biodegradable plastic.

Keywords: packaging materials, biopolymer, corn starch, soil pollution, biodegradable plastic

Introduction

This is an increasing interest in plastics biodegradation because of the environmental pollution. Plastics are mainly made of carbon, hydrogen, nitrogen, oxygen, chlorine and bromine are used in automobile production, space exploration, irrigation, agriculture, health and other industries (Gautam., et.al.,2008 and Mohee R.,et.al.,2007). Generally 2 to 3 million tons of plastics are used each year in agricultural applications (Mohee R.,et.al.,2007). Plastics made from nonrenewable oil products last for thousands of years in our environment because they do not break down or disintegrate.

Methods normally used to destroy other types of waste such as burning and burying are not suitable for plastic destruction. When some types of plastics are burnt, they can release dangerous gases into the atmosphere while burying plastics in soil cannot destroy plastics because they are not biodegradable. Degradation at high temperature, such as in pyrolysis (burning) tends to cause emission of toxic fumes. Plastic accumulation in the environment thus creates tremendous problems for the world, presently and in the future. Environmental problems caused by plastics include changes to the carbon dioxide cycle, problems in composting, and increased toxic emissions. Stimulated by environmental concerns, scientists are now concentrating on the ways to develop plastics that will be used more efficiently. Two simple strategies are to "recycle" (reuse), or to produce plastics that will degrade when no longer required. Degradable plastics are grouped by the American society for Testing and Materials as: (a) Photodegradable plastics – a degradable plastic in which the degradation results from the action of natural daylight; (b) Oxidatively degradable plastics – a degradable plastic in which the degradation results from oxidation; (c) Hydrolytically degradable plastics – a degradable plastic in which the degradation results from hydrolysis; and (d) Biodegradable plastics - a degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi and algae. The main environmental disadvantage of plastic materials is that they do not readily breakdown in the environment. Bio-plastics consist of either biodegradable plastics (i.e., plastics produced from fossil materials) or bio-based plastics (i.e., plastics synthesized from biomass or renewable resources). Therefore, production of bio-plastics with high degree of degradability has become the best solution for the environment. Bio-plastics can be made from many different sources

* Lecturer, Dr, Department of Industrial Chemistry, Yadanabon University.

and materials such as plant oil, cellulose, cassavastarch, cornstarch, potatostarch, sugarcane, weeds, etc (Kyrikou J., 2007).

There are a lot of advantages that biodegradable plastics can cause such as increased soil fertility, low accumulation of bulky plastic materials in the environment (which invariably will minimize injuries to wild animals), and reduction in the cost of handling, e.g. bending or stretching.

In this research, biodegradable plastic was made from cornstarch. Plastic made with cornstarch will breakdown and not take up space in landfills. The objectives of this study are to produce a biodegradable plastic film from corn starch, to reduce the soil pollution problems, to optimize the process condition of the starch plasticized with glycerol, and to evaluate its degradation through microbial activity in soil.

Materials and Methods

Raw Materials

The raw materials for preparation of biodegradable plastics include corn starch, glycerine, white vinegar, water and color. Corn starch and white vinegar were purchased from ATLAS Chemical Centre situated in Pabedan Township, Yangon Region. Glycerine and color (Apple Green color and Tartrazine color) were purchased from]]Empire Chemical Shop" located in Pabedan Township, Yangon Region.

Preparation of Biodegradable Plastic from Corn Starch

1.5g corn starch, 0.25g glycerine, 1ml white vinegar and 6ml distilled water were mixed in a beaker and stirred continuously until the mixture became a milky white color and quite watery. The beaker was put on the stove and heat was set. While heating, the mixture was stirred continuously and it became more translucent and began to thicken. The clear and thicken mixture was removed from the stove at the temperature of 85˚C for 3 min. At this stage, two drops of food coloring were added as if necessary. Then the heated mixture was spread on the aluminium foil or on the tray. The sample was dried undisturbed at room temperature for three days.

Effect of the Amount of Glycerine on the Characteristics of Biodegradable Plastic

The plastic samples were prepared by varying the amount of glycerine (i.e., 0.25g, 0.5g, 0.75g, and 1.0g) using the same procedure mentioned above and the results are shown in Table 1.

Effect of Water Content on the Characteristics of Biodegradable Plastic

The plastic samples were prepared by varying water content (i.e., 6ml, 7ml, 8ml, 9ml and 10ml) using the same method as in the above section and the results are shown in Table 2.

Characteristics of Biodegradable Plastic

Biodegradability Test

Soil Burial Method

Different weights of plastic samples (2g and 3.5g) were wrapped separately in synthetic net and buried in the soil at different depth levels (i.e., 6in, 1ft) for one month. The samples were removed from the soil every two-week interval and the biodegradation level was observed as shown in Figure 1.

Soaking in Water

The weight of plastic sample was measured and dried in a desiccator until the weight became constant. Then the sample was soaked in water for three weeks at room temperature and the biodegradation level was illustrated in Figure 2.

Biodegradation by Monitoring Carbon Dioxide Evolution Test

Approximately 200 g of soil was sieved to obtain the soil having a particle size of at least 2mm. Then, 25g of prepared soil sample was added into the glass jar. The soil sample was adjusted to pH (between 6 and 8) and the moisture content (50 to 70 percent). Plastic sample (1g) and 20 ml of 0.5N KOH were also added to the glass jar. Then, the glass jar was covered with the lid, sealed tightly and placed in the dark cabinet.

For the investigation of aerobic biodegradation of organic chemical in natural soil, carbon dioxide evolution was determined according to the following procedure. The carbon dioxide evolved was trapped by means of 0.5N KOH solution contained in the beaker. The KOH solution was then titrated with 0.5N hydrochloric acid once a week for five consecutive weeks and the results are recorded in Table 3. From the titration, the amount of CO_2 evolved and % mineralization were determined by the following equation:

Amount of CO_2 evolved = 0.5 N of HCl solution × volume of HCl titrated × 44 g/mol of CO_2

% mineralization = g of C evolved/g of C in the sample × 100

Water Absorption Test

The weight of each plastic film was measured and soaked in water at room temperature. After 60 minutes, the sample was taken out, dried and weighed. The water absorption capacity was calculated from the final weight of the film relative to that of the original film sample. The results are tabulated in Table 4.

Moisture Absorption Test

The samples were dried in a desiccator until their weights became constant W_1. These samples were then placed in normal atmosphere for 24 hours. After that, the samples were weighed (W_2) and the percentage of moisture absorption (% M) can be calculated from the following equation: The results are shown in Table 4.

$$\% M = (W_2 - W_1)/W_1 \times 100$$

Solubility Test

The plastic sheet samples were cut into small pieces of 0.1g. These samples were put into10 ml test tubes containing 3 ml of a solvent (i.e., ethanol, methanol, petroleum ether, 10% NaOH, water). The solubility of the samples was observed at both room and elevated temperatures (60˚C). The results of solubility test are shown in Table 5 and Table 6.

Results and Discussion

In this work, biodegradable plastics were made from corn starch by varying the proportions of the ingredients such as glycerine (0.25g, 0.5g, 0.75g, 1g) and water (6ml, 7ml, 8ml, 9ml). It was found that the viscosity of the prepared plastic is directly proportional to the glycerine extent. The more the extent of the glycerine, the more viscous the plastic is. Drying time is also varied with the amount of glycerine. The drying time is longer when more glycerine is used. Also, the thickness of the plastic depends on the variation of glycerine since more glycerine gave thicker layer and less glycerine made thinner layer. If more water was used, the more translucent and more bubbles would be formed in plastics.

Among the prepared plastic samples, optimum product was obtained by using corn starch 1.5g, vinegar 1ml, glycerine 0.5g and distilled water 7ml because it has less drying time, no bubbles and good tensile strength. The drying temperature must not exceed 80˚C because the boiling point of the product was 85˚C. If the temperature was elevated to 100˚C, the plastic would become brittle.

The prepared plastics were dried in three days under room temperature with normal humidity (28 grams of water per cubic meter of air). Under more humid environment, the plastic would absorb more moisture. Since the plastics had tendency to absorb more moisture, it would be better to store the dried plastics in air-sealed bags.

Figure 1 shows a significant reduction in the sizes of the plastic samples when buried in the soil for two weeks and for one month. For the soil burial test, it was found that half of the plastics degraded after two weeks and all parts of the plastic completely degraded after one month. From the results of the burial test, it could be assumed that the prepared plastic samples could be used without any negative impact on the environment. If the plastic was placed in water, it slowly absorbed water, swelled up and broke apart into small fragments that were readily digestible by bacteria after three weeks. The steps of biodegradability of the plastic film in the water are illustrated in Figure 2.

In carbon dioxide evolution test, it could be assumed that there was the biodegradation of the plastic samples due to the evolution of carbon dioxide in this test. Moreover, it has been observed that about nearly 50 percent carbon content was transformed into carbon dioxide.

The prepared plastic sample (0.5 gram of glycerine and 7 ml of water) exhibited much lower water absorption which indicates higher moisture resistance. Hence it is the most suited plastic for packaging material application.

Solubility test showed that the solubility of prepared plastic samples was found to be varied with the temperature and the type of the solvent used in this test. At room temperature, the prepared plastic samples were not soluble in ethanol, methanol, petroleum ether but they can swell in 10% NaOH solution and water. At the elevated temperature, they could swell in the ethanol and methanol solution but swelling activity was higher in 10% NaOH solution and water. The plastic samples were insoluble in the petroleum ether solution both at room temperature and at elevated temperature.

Table (1) Effect of Glycerine Content on Preparation of Biodegradable Plastic

Corn starch = 1.5 g Water = 7 ml
Vinegar = 1ml Color = 2 drops

Sr. No	Amount of Glycerine (g)	Remarks
1	0.25	soft, thin and translucent
2	0.5*	good tensile strength, little viscous, no bubbles, thin and translucent
3	0.75	good tensile strength, more viscous, thick, fairly little bubbles and translucent
4	1	low tensile strength, most viscous, more bubbles, translucent and more thick

*the most suitable condition

The experiments were carried out at the Department of Industrial Chemistry, University of Yangon.

Table (2) Effect of Water Content on Preparation of Biodegradable Plastic

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Corn starch = 1.5 g   Glycerine = 0.5 g
Vinegar = 1ml   Color = 2 drops

Sr. No	Volume of Water(ml)	Remarks
1	6	more viscous, thick and translucent
2	7*	viscous, no bubbles and translucent
3	8	less viscous, contains fair amount of air bubbles and translucent
4	9	soft, contains more amount of air bubbles and translucent

*the most suitable condition

The experiments were carried out at the Department of Industrial Chemistry, University of Yangon.

Figure (1) Soil Burial Test for Biodegradable Plastic Film
(a) Plastic Film before Soil Burial Test
(b) Plastic Film after Two Weeks
(c) Plastic Film after Four Weeks

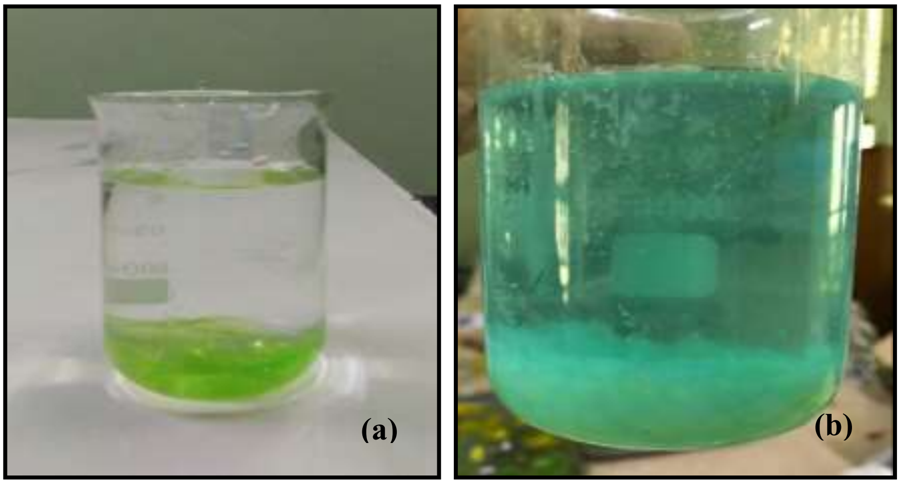

Figure (2) Biodegradation of Plastic Film by Soaking in Water
(a) Before Soaking
(b) After Three Weeks

Table (3) Biodegradability Test for Corn Starch Plastic Film

Sir. No.	HCL (ml)	CO_2 (g)	% Mineralization
1	5	0.0968	45.45
2	3	0.1408	45.44
3	2.8	0.1452	45.46
4	2.3	0.1562	45.46
5	2.2	0.1584	45.47

The experiments were carried out at the Department of Industrial Chemistry, University of Yangon.

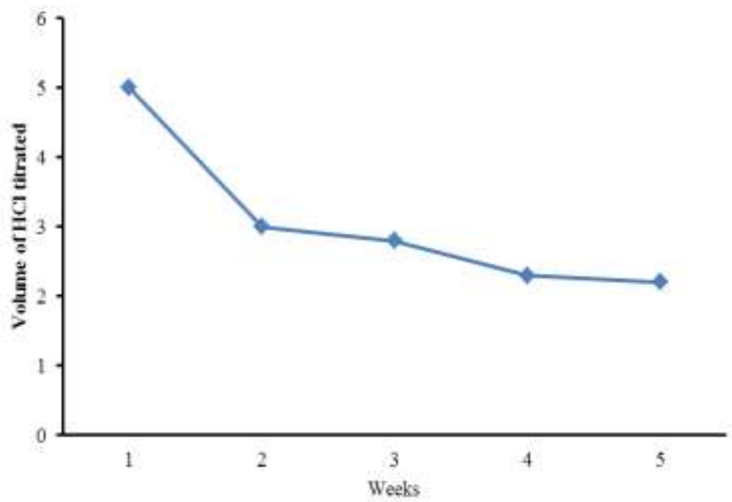

Figure (3) Volume of HCl Needed to Titrate CO_2 Evolved from the Plastic Film

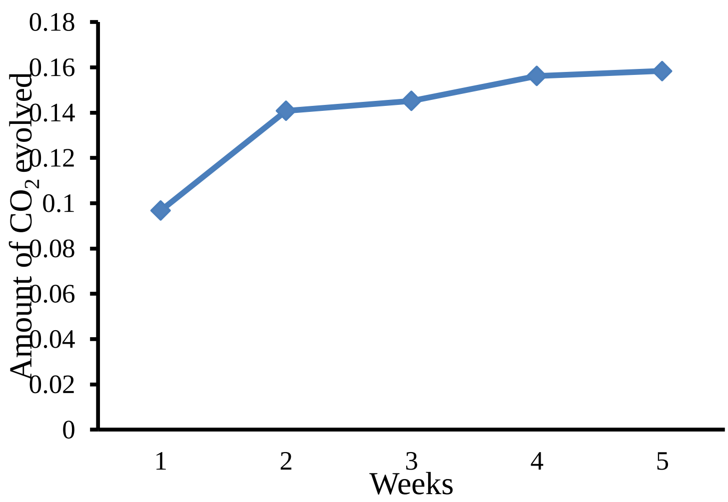

Figure (4) Amount of CO_2 Evolved from the Plastic Film Every Week

Table (4) Characteristics of Biodegradable Plastic Film

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Sr. No.	Test	Biodegradable Plastic Film							
		G1	G2	G3	G4	W1	W2	W3	W4
1	Water Absorbance g(water uptake)/g(film)	3.05	3.03	3.68	3.81	3.9	3.85	3.12	3.5
2	Moisture Absorption (%)	2.1	1.96	2.9	2.62	3.5	3.3	2.4	2.75

experiments were carried out at the Department of Industrial Chemistry, University of Yangon.

G1 = Biodegradable corn starch plastic by using 7ml water and 0.25g glycerine
G2 = Biodegradable corn starch plastic by using 7ml water and 0.5g glycerine
G3 = Biodegradable corn starch plastic by using 7ml water and 0.75g glycerine
G4 = Biodegradable corn starch plastic by using 7ml water and 1.0g glycerine
W1 = Biodegradable corn starch plastic by using 6ml water and 0.5g glycerine
W2 = Biodegradable corn starch plastic by using 7ml water and 0.5g glycerine
W3 = Biodegradable corn starch plastic by using 8ml water and 0.5g glycerine
W4 = Biodegradable corn starch plastic by using 9ml water and 0.5g glycerine

Table (5) Solubility Test for Biodegradable Plastic Film with Glycerine Variation

Solvent	Biodegradable Plastic Film							
	G1		G2		G3		G4	
	Tr	Te	Tr	Te	Tr	Te	Tr	Te
Ethanol	x	s	x	s	x	s	x	s
Methanol	x	s	x	s	x	s	x	s
Petroleum Ether	x	x	x	x	x	x	x	x
10% NaOH	s	ss	s	ss	s	ss	s	ss
Water	s	ss	s	ss	s	ss	s	ss

The experiments were carried out at the Department of Industrial Chemistry, University of Yangon.

Tr = room temperature x = insoluble s = swell
Te = elevated temperature (60˚C for 1 hour soluble) ss = more swollen

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Table (6) Solubility Test for Biodegradable Plastic Film with Water Variation

Solvent	Biodegradable Plastic Film							
	W1		W2		W3		W4	
	Tr	Te	Tr	Te	Tr	Te	Tr	Te
Ethanol	x	s	x	s	x	s	x	s
Methanol	x	s	x	s	x	s	x	s
Petroleum Ether	x	x	x	x	x	x	x	x
10% NaOH	s	ss	s	ss	s	ss	s	ss
Water	s	ss	s	ss	s	ss	s	ss

The experiments were carried out at the Department of Industrial Chemistry, University of Yangon.
Tr = room temperature x = insoluble s = swell
Te = elevated temperature (60˚C for 1 hour soluble) ss = more swollen

Conclusion

Biodegradable plastics are one of the most innovative materials being developed in the packaging industry. Companies cannot work fast enough to produce this highly valuable technology. How widespread the use of biodegradable plastics will depend on how strongly society embraces and believes in environmental preservation. There certainly are an abundant amount of materials and resources to create and find more uses for biodegradable plastics. In this research, biodegradable plastic was made by varying the amount of ingredients such as water (6ml, 7ml, 8ml, 9ml) and glycerine (0.25g, 0.5g, 0.75g, 1 g). Corn starch 1.5g, vinegar 1ml, glycerine 0.5g and distilled water 7ml were the most suitable conditions for the preparation of biodegradable plastic.

Large quantities of plastics are disposed in the landfills every year. It can be presumed that the consumption of these bags will increase and the amount of plastic waste will increase proportionally. It is necessary to address this issue furthermore and search for the most suitable manner in which to treat this kind of waste. The same types of bags shall be subjected to further testing, namely the process of composting in both laboratory conditions and real conditions.

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