Preparation and Characterization of Starch Based Bioplastic Film from Non-recyclable Food Waste

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Abstract

Bioplastics are an increasingly well known starch based plastics. Firstly, starch was extracted from corn by cold extraction method. The qualitative test of extracted corn starch was performed by various methods such as iodine test, alcohol test, Fehling's test and Molisch's test. Bioplastic film was successfully prepared by combination of two biopolymer, corn starch and potato peel in the presence of glycerol. The water soluble capacity of prepared bioplastic film was also measured. The prepared bioplastic film was easily soluble in water. Biodegradability of prepare bioplastic film was determined by soil burial test. The physicomechanical properties such as thickness, tensile strength, % elongation at break and tear strength of prepared bioplastic were investigated. The prepared bioplastic film was characterized by using Fourier Transform Infrared Spectroscopy (FT IR) and Thermogrivimetry-Differential Thermal Analysis (TG-DTA).The morphology of prepare bioplastic film was characterized by Scanning Electron Microscope (SEM) technique. The decomposition temperatures of bioplastic film obtained from Thermogravimetric analysis was found to be 471.10 °C.

Keywords: Bioplastic, physicochemical properties, Biodegradability, morphology, decomposition temperature

1. Introduction

Today, bioplastics are considered as a promising alternative to plastics [1] since they may diminish the dependency on fossil fuels and the certain environmental problems. 'Bioplastics' are defined as plastics made from renewable resources such as potato, sugar, corn etc. [2, 3] and produced by a range of microorganisms [4]. Photodegradable, compostable, bio-based and biodegradable bioplastics are types of bioplastics. Photodegradable bioplastics are light sensitive group due to the additives, and UV can disintegrate their polymeric structure. However, they cannot be disintegrated where there is lack of sunlight [5]. Bio-based bioplastics are derived from renewable resources containing starch, protein, and cellulose [6]. The most known bio-based plastic is Polylactic Acid (PLA). Compostablebioplastics are defined as biologically decomposed during a composting process [9] and according to American Society for Testing and Materials (ASTM) D6400 standard, the plant should not be damaged after the composting process. Biodegradable bioplastics are completely biologically degraded by microorganisms [5].Bioplastics are polymers that are capable of undergoing decomposition into CO_2, H_2O and inorganic compounds or biomass through predominantly the enzymatic action of microorganisms. The market for these environmentally friendly materials is expandingrapidly with a growth rate of 10-20 % per year. The global market for biodegradable polymers is expected to rise at an average annual growth rate of 12.6 % to 206 million pounds by 2020.Starch is an abundant naturally occurring material composed of two types of glucose polymers, amylose and amylopectin. The respective ratio of amylose and amylopectin, significantly affects the physicochemical properties of starch which, in turn, influences its functionality and eventual applications. Higher amylose content contributes to film strength. However, branched structure of amylopectin generally leads to film with low mechanical properties which can be improved by using plasticizers such as sorbitol and glycerol. [7]

In this study, the overall purpose was to investigate the utilization of the non-recyclable food wastes in order for the bioplastic film production. To achieve this objective, the production of bioplastic film from potato peel was investigated. In addition, some properties of the produced bioplastic film such as water absorption capacity and biodegradability were analyzed.

2. Materials and Method

2.1. Sample Collection

The corn and potato were collected from Pyin Oo Lwin Township, Mandalay Region, Mandalay. The analar grade commercial reagents and solvents were used throughout the experiment.

2.2. Extraction of Corn Starch

100g of corn sample and 200 mL of distilled water were blended to get homogenous slurry. Then the mixture was filtered and the filtrate was allowed to stand for 1 hour. The residual containing starch was washed with water and allowed to stand for 1hour. Finally, the starch was dried at room temperature.

Figure 1. Corn and corn starch

2.3. Qualitative Tests for Corn Starch

The qualitative determination of corn starch was performed. [8, 9]

2.4. Preparation of Iodine Solution

Potassium iodide 10 g was dissolved in about 30 mL of distilled water. Iodine 5 g was added and heated gently with constant mixing until iodine was dissolved. It was diluted to 100 mL with distilled water.

2.5. Iodine Solution Test

2 mL of starch solution was taken and placed in the test tube. 2-3 drops of iodine solution was added into starch solution. Dark blue color was changed and starch was present.

2.6. Alcohol Test

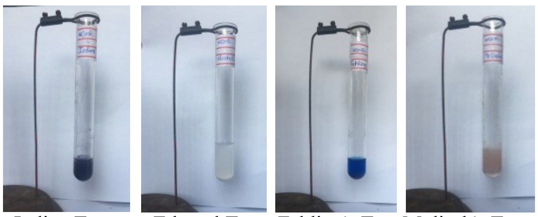
An equal volume of ethanol and starch solution were taken and placed in the test tube. A few-minute later starch was precipitated from solution and starch was present.

2.7. Fehling's Test

Equal amount of Fehling's solutions (A) and (B) were taken in a test tube (1mL each) and mixed well. Then the mixture was added into 1mL of the sample solution and boiled for a few minutes. The formation of blue color was obtained. Therefore, starch was present in this sample.

2.8.Molisch's Test

2 drops of Molisch's reagent was added to 2mL of the test solution. The solution was mixed properly and 1mL of concentrated sulphuric acid was poured along the sides of the test tube. The precipitatd was observed and starch was present in sample.



Iodine Test Ethanol Test Fehling's Test Molisch's Test

Figure 2. Identification of corn starch

2.9. Preparation of Bioplastic Film

The peels of potato were removed from the fresh by using a stainless knife. 100 g of peels were boiled with 250 mL of water in the beaker for 30 mins and it was cold at room temperature for 30 mins. The water was decanted off and the peels were left to dry 30 mins at room temperature. The peels were then placed in a clean beaker. The peels of potato were grinded using the blender. 25 mL of the paste was placed in a 250 mL beaker. 3 mL of 0.5 M HCl was added and the mixture was stirred using a spatula. Then 2 mL of 5% glycerol solution was added and the mixture was stirred. A 3 mL of 10% corn starch was then added as co-biopolymer and the mixture was stirred again. Then, a 3 mL of 0.5 M NaOH was added to the mixture and stirred. The mixture was poured into a mould and dried at room temperature about 3 days. [11]

Figure 3. Bioplastic Films of potato peel

2.10. Solubility Test of Bioplastic Film

A small piece of sample was cut. The initial weight of the sample was recorded. The sample was immersed in 60 mL of distilled water at room temperature for 15 hours. The sample was then out from the water and wiped off. The final weight was recorded. The amount water uptake was calculated by using the following equation. [11]

$W_A (\%) = W_1 - W_0 \times 100/ W_0$

Where W_0 is the weight of dry sample and W_1 is the weight of the sample in distilled water absorption for time intervals 15 hours.

Figure 4. Solubility test of bioplastic

2.11. Biodegradation Test (Soil Burial Test)

Biodegradability test was done based on the soil burial method. Sample 1.85g was taken. Weight of the samples was weighed (W_1). This sample was then buried in soil for 3,5,7,9 and 12 days. After that the sample was collected and weighed (W_2). Percentage weight loss, (%W) can be calculated from the following equation. [11]

Weight loss

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

Where the initial weight of bioplastic film is W_1 and the weight of the sample after being immersed in water is W_2.

Figure 5. Biodegradable test of prepare bioplastic film

2.12. Determination of Physico-mechanical Properties

Physico-mechanical parameters of prepared bioplastic film were determined such as thickness, tensile strength, elongation at break and tear strength were tested at Development Center of Rubber Technology, Yangon.

2.13. Determination of Functional Groups

FT IR spectroscopy was characterized the functional group that present in prepared bioplastic film in this study. FT-IR was determined at Department of Chemistry, University of Monywa.

2.14. Determination of Thermal Stability

Thermal stability of the prepared bioplastic film was studied using thermal analyzer SDT-600 under nitrogen atmosphere rate increase of 20°C/min. Thermogravimetric analysis was determined at Department of Chemistry, University of Mandalay.

2.15. Determination of Surface Morphology by *Scanning Electron Microsopy*

The morphology of the prepared bioplastic film was examined at University Research Centre, Yangon.

3. Results and Discussion

3.1. Determination of Solubility of Bioplastic Film

Water resistance is an important characteristic in determining a suitable source for bioplastic film. The solubilities of bioplastic film in water were investigated at various time intervals 15hours and results shows in Table 1.

Table 1. Results of solubility of bioplastic film

	Potato film	3 hour	6 hours	9 hours	12 hours	15 hours
Weight of sample (g)	0.09	0.0875	0.0841	0.0789	0.0721	0.0639
Weight loss (g)	0	0.0025	0.0034	0.0052	0.0068	0.0082

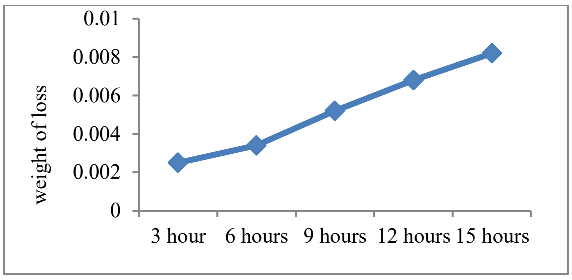


Figure 6. Solubility in water of biodegradable plastic film

The results of the water absorption experiments showed that prepare bioplastic film was absorbed water by 2.78%, 3.89%, 6.18%, 8.61% and 11.37% within three to 15 hours. The water absorption capacity of prepare bioplastic film was depended on the time duration. It was found that more solubility of the film in water and more decreased in weight of the film. The prepare bioplastic film was easily biodegradatable and reduced the effect of environmental pollution.

3.2. Biodegradation of Bioplastic Film

From soil burial test, the weight loss and degradation of bioplastic film were determined. They indicated that the amount of degradation in natural environment by action of microorganisms. The starch content consumed by soil microorganisms, soil fracture the polymer chain thus cause the biodegradation.

Table 2. Results of biodegradation of bioplastic film

	3 Day	5 Days	7 Days	9 Days	12 Days
Potato Film	32.43%	48.00%	72.31%	94.28%	Completely degraded

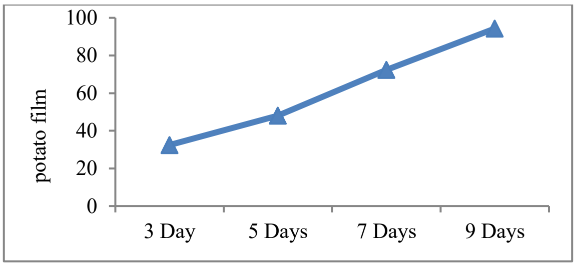


Figure 7. Biodegradation of bioplastic film

The schematic representation of the biodegradation process followed for the days and weight loss of prepare bioplastic film. Biodegradability of 32.43%, 48.00%, 72.31%, 94.28% and completely degraded was achieved in 15 days for the sample placed in the soil.

3.3. Physico-mechanical Properties of Bioplastic Film

The results of physico-mechanical properties of bioplastic film were tabulated in Table 3.

Table 3. Results of physico-mechanical properties

Thickness (mm)	Tensile strength (MPa)	Elongation at break (%)	Tear strength (kN/m)
0.28	5.3	13	11.7

The thickness value of prepare bioplastic films is found to be 0.28 mm. Tensile strength is the amount of maximum strength needed to break the bioplastics film. Tensile modulus is defined as the stress change divided by change in strain within the linear viscoelastic region of the stress/strain curves. Elongation at break is the indication of the amount of the variation of extreme film length while attaining tensile strength until the film breaks, related to the original length. Furthermore, bioplastic film exhibited the highest tensile strength (5.3 MPa) indicated the highest strength and stiffness.

3.4. FT-IR Assignments of Bioplastic Film

The infrared spectrum of bioplastic film was carried out by FT-IR instrument at Department of Chemistry, University of Monywa. FT IR spectra using 4000 to 500cm[1] wave numbers. The result obtained was illustrated in Figure 7.

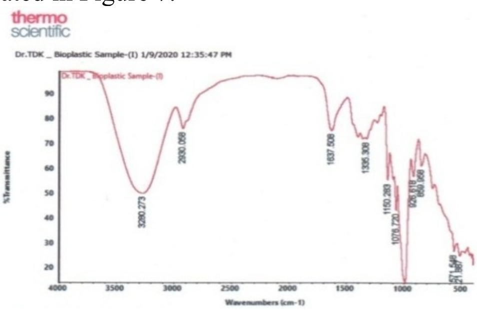


Figure 8.FT-IR spectrum of bioplastic film

The FT-IR spectrum of bioplastic film, it could be seen that the characteristic peaks of bioplastics were O–H stretching peaks at 3280.27 cm^{-1} and C–H stretching peaks at 2930.06 cm^{-1}. The C=C stretching peaks appear at 1637.51 cm^{-1}. The characteristic absorbing band ranging from 1335.30 cm^{-1} to 1150.28 cm^{-1} is attributed to C–O stretching vibration.

3.5. Thermal Analysis Data of Bioplastic Film

Thermal stability of the bioplastic film was studied using thermal analyzer and results data were listed in Table 4.

Table 4. Thermal analysis data of bioplastic film

No.	Temperature range (°C)	Weight loss (%)	Peak nature	Remark
1	40-320	46.373	A small exothermic peak at 317.30 °C	Loss of surface water and lower molecular weight compounds of film
2	320-470	82.642	An exothermic peak at 471.10 °C	Complete degradation of the polymer film

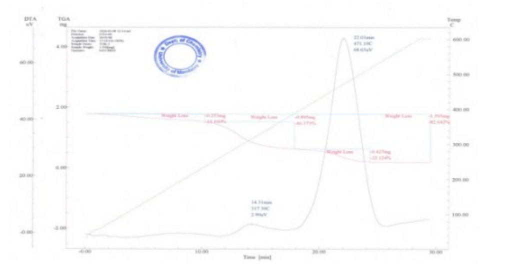


Figure 9. TG-DTA assignment of bioplastic film

The TGA curve indicated two distinct stages of mass loss for prepare bioplastic film. In the first stage, the mass lost 46.373% occurs 317.30 °C and the second stage, mainly arising temperature 471.10 °C, the plastic film decomposed with mass loss of 82.642%.

3.6. Scanning Electron Microscopy (SEM)

Surface morphology of bioplastic film was visualized using scanning electron microscope under normal atmospheric conditions. The sample was analysed in SEM at high vacuum in varying magnifications.

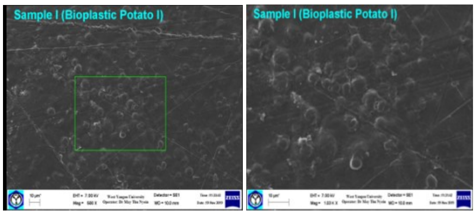


Figure10. SEM image of bioplastic film

SEM examination demonstrated the microbial activity of degradation on the bioplastic samples. The surface structure of the material had lost its evenness, and flaws were evident. The sample exhibited a substantial variation in the structure.

4. Conclusion

This study concluded that food wastes were used for bioplastic film preparation. The bioplastic film was successfully prepared by using corn starch and potato peels with glycerol as plasticizer and water as solvent. The corn starch and potato peels were found to be cheap raw materials, abundant, renewable and readily available ubiquitously. Bioplastic film prepared from corn starch was found to be non– sticky, soft, flexible and opaque. The bioplastic film has high water solubility and more possessed biodegradable properties. The hydrophilic nature caused bioplastic film to be degraded more easily. The bioplastic film produced from corn starch and potato peels was completely biodegraded within 12 days. The maximum tensile strength of the bioplastics film is found to be 5.3 MPa.

The thermal and mechanical properties made them a suitable alternative for the existing conventional plastics. This research can performed for reduce the environmental plastic pollution no longer as severe as today.

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