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Potato peels: Synthesis of Starch-based Bioplastic

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Abstract

Environmental, economic, and waste management concerns are growing as a result of the proliferation of plastics in the environment. As a potential solution to the problem of plastic pollution, glycerol plasticized starch-based bioplastics were investigated for their biodegradability. There are numerous uses of starch, a biopolymer derived from organic waste, due to its unique characteristics, such as its flexibility, degradable nature, and low cost. In the present work, starch was extracted from Solanum tuberosum (potato) peels, and starch-based bioplastics with different concentrations, i.e., 2.4 %, 24.3 %, 36.5 %, 48.6 %, and 97.2 % of glycerol plasticizer were prepared by following the casting method. Starch and bioplastics were analyzed using Fourier Transform Infrared (FTIR) spectroscopy, and their physicochemical properties were evaluated. The water absorption test revealed that the bioplastic with high glycerol concentration, i.e., 97.2%, had a more significant percentage of water absorption, i.e., 79 percentage, compared to 37 % for bioplastic with low, i.e., 2.4% glycerol concentration.

Keywords: Potato peels; Bioplastic; FTIR; Plasticizer.

1. Introduction

Different studies have suggested that around one-third of the food produced for human consumption is lost globally[1]. Food waste sources include household, commercial, industrial, and agricultural residues[2], while the compositional matrix of food wastes varies broadly based on source and type[3]. Even though numerous nations have established rules for minimizing food waste, they have not been able to implement them due to numerous technical obstacles. For instance, European Union guidelines for handling food waste specify that it should be delivered preferentially to animals, but this practice was made illegal due to fears of disease transmission to animals[4]. Therefore, it is essential to utilize the food waste by transforming it into various products with added value, such as fertilizers, bio-gas, and pesticides[5].

Now, food waste can be converted into bioplastics as an alternative to commodity plastics, which are an environmental burden due to their lengthy degradation time. Due to their durability, low cost, and adaptability, commodity plastics are widely used in our daily lives[6]. However, the manufacture of current commodity plastics utilizes non-renewable petrochemical compounds. In contrast, biodegradable polymers may be produced from various renewable sources[7–9], and they can be decomposed by heat, chemicals, microorganisms, and enzymes; this is why bioplastics have attracted much interest in recent years[7]. In addition, the polymer degradation process also alters the physicochemical features such as tensile strength, water absorption capacity, shape, molecular weight, and color.

Similarly, several different bioplastics may be made from agricultural waste, such as cellulose and protein[9], as well as starch[10] by extracting them from the aforementioned agricultural waste. Because of its intrinsic biodegradability, overwhelming availability[11], and annual renewability[12], starch-based bioplastics have been widely used in food packaging[13], agriculture[14], pharmaceutical sectors, etc., as a replacement for existing plastics. Many renewable resources, such as cassava, jute[15], corn[16], potato peels[17], pineapple peels[18], mango seed[19], litchi seeds[20], banana peels[21] etc., can be used to extract this chemical compound. Potato peel is one of the essential bio-waste materials for bioplastic manufacturing as around 70-140 thousand tons of potato

peels are produced each year throughout the world[22]. Bioplastics can be synthesized from potato peels because of their high concentration of starch-containing polymer chains such as amylose and amylopectin[23]. Although starch is not a thermoplastic material, the starch granules melt and flow at moderate temperatures (90-180°C) to produce thermoplastic starch[24]. Because starch-based bioplastics prepared without plasticizers are rigid and brittle, a water-soluble plasticizer is added to the mix when the bioplastics are being made.

Another advantage of using plasticizers in polymer manufacturing is that they are a valuable class of low molecular weight, comparatively non-volatile organic compounds[9]. Using plasticizers is projected to reduce modulus, tensile strength, hardness and density, and the glass transition temperature while simultaneously enhancing flexibility, elongations at the break, and toughness[25]. Research on a variety of plasticizers, such as polyvinyl alcohol (PVA), glycerol, ethylene glycol(EG), propylene glycol(PG), Tri-ethylene glycol(TEG), and diethylene glycol(DEG), as well as other biodegradable polymers, has been conducted using biodegradable polymer. Thermoplastic starch (TPS) degradation was shown to be reduced by the addition of glycerol, a biodegradable polymer[25,26]. As part of this work, we investigated the effect of glycerol concentration on the physicochemical properties of starch-based bioplastics by varying the concentration of glycerol plasticizers.

2. Materials and Methods

2.1 Materials

Potatoes, Glycerol (99%), sodium metabisulphite ($Na_2S_2O_5$), hydrochloric acid(HCl), and sodium hydroxide (NaOH).

2.2 Method

i) Extraction of Starch from Potato Peels

The potato peels were washed with distilled water, sliced into small pieces, soaked for 30 minutes in a beaker containing 1% sodium metabisulphite solution, and then ground into a paste using a blender with minor adjustment[27]. The ground paste was filtered after being rinsed with distilled water. The filtrate was collected in a beaker and left for one hour to allow sedimentation and decantation of brownish-white particles with a muddy appearance. The remaining bottom particles were washed four times with distilled water[28]. The obtained starch powder was dried in an oven at 50 °C for two hours.

ii) Preparation of starch-based bioplastics

2.5 grams of extracted starch was dissolved in 25 milliliters of deionized water with continuous stirring. After adding 3 mL of 0.5 N HCl and 2 mL of glycerol as a plasticizer, 0.5 N NaOH was added to neutralize the acidic solution. The neutralized solution was heated for 15 minutes before being placed onto Petri dishes. The prepared sample was heated at 80 °C for five hours before being air-dried for three days. The same procedure was followed to prepare starch-based bioplastics by altering the glycerol concentration[20,24].

2.3 Characterization Technique

The Fourier Transform Infrared spectroscopy (FTIR) analysis was carried out using the IR Prestige-21 model, SHIMADZU, Japan. The FTIR spectrum of the sample was obtained at the wavenumber in the range of 4000-400 cm^{-1}.

2.4 Water absorption Analysis

The bioplastics were cut in size approximately 30×10 mm and dried in an oven at about 50 °C. Then the dried bioplastics were weighed before being kept in water at room temperature. The weight of the bioplastic was recorded every two hours at intervals in day time while deep in water to till 50 hours. The amount of water absorption was calculated according to the equation[29,30].

$$\text{water uptake} = \frac{W_w - W_d}{W_w} \text{..... (i)}$$

where, W_w = wet weight (after absorption), W_d = dry weight (before absorption)

2.4Soil Burial Test

The soil burial test experiment was performed in the laboratory by taking the moist soil in a 250 mL beaker. The bioplastic was cut in 30×30 mm size and weighted, and then the bioplastic was buried in the soil at about 4 cm in depth. The degradation of bioplastic was inspected at every five days intervals for 64 days and was calculated by using equation[30,31].

$$\text{weight loss}(\%) = \frac{W_i - W_d}{W_i} \text{.....(ii)}$$

Where W_d= dry weight of film after being washed with distilled water

W_i= initial dry weight of specimen.

3. Result and Discussion

3.1 FTIR Spectroscopy Analysis of Bioplastics in Different Concentrations of Glycerol Plasticizer

The FTIR spectra of the synthesized bioplastics with different concentrations of plasticizers are shown in Figure 1.

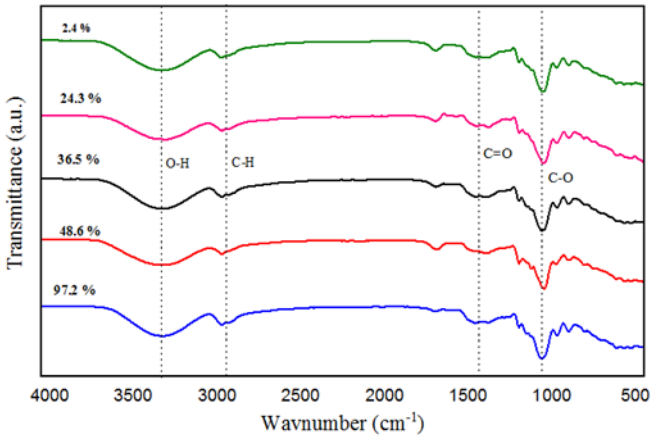

Figure 1: FTIR spectra of starch-based bioplastic using various concentrations of glycerol

Table 1 displays the FTIR spectra of starch-based bioplastics with varying concentrations of glycerol, where the peaks at 3278 cm^{-1} corresponding to the stretching vibration band of the free O-H group, and 2924 cm^{-1} represents the stretching of the C-H bond which indicating the interaction between glycerol and starch. Similarly, the 1643 cm^{-1} and 995 cm^{-1} FTIR spectra were caused by C=O stretching and C-O stretching, respectively. The parallel readings were consistent with the research conducted on corn starch[34–38]. The band between 704 and 1014 cm^{-1} reflected the stretching of the C-O band, while the peak at 3270 cm^{-1} represented the stretching of the -OH groups. Table 1 summarizes the principal absorption peaks obtained from FTIR spectra for starch-based bioplastics with varying glycerol contents.

In addition, similar peak intensities were discussed in the literature[28,29] for the characterization of starch-based bioplastic using glycerol as a plasticizer. Thus the FTIR spectra of each bioplastics confirmed the formation of good linkage between the glycerol and starch.

3.2 Water Absorption

The bioplastic mostly used as the commodity for daily use, its life span in water is also important part to know the water uptake properties. The water uptake properties was investigated by the water absorption test. The water absorption of glycerol plasticized bioplastic is shown in Figure 2.

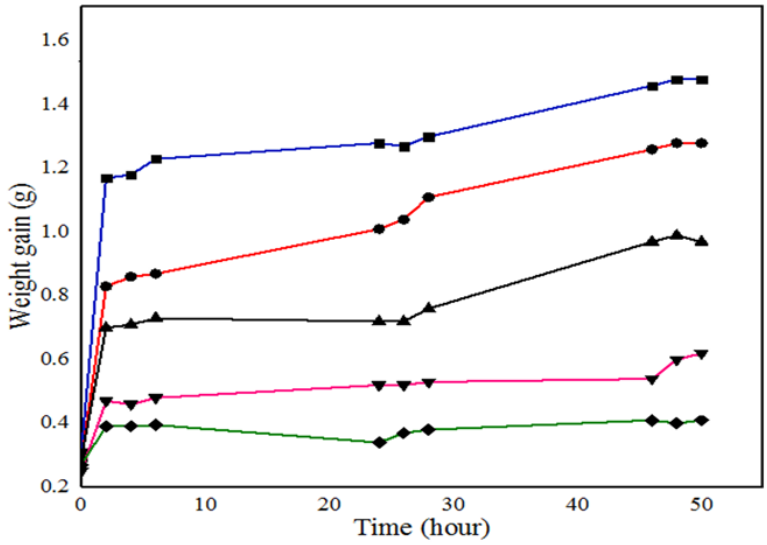

Figure 2: Water absorbability of different concentrations of glycerol plasticized film

The plot of weight gain v/s time revealed weight gain of glycerol-plasticized film at various concentrations. In 6, 28, and 50 hours, the weight of pure glycerol-plasticized bioplastic reached 1.23 g, 1.33 g, and 1.48 g, respectively. After 6 hours of exposure to moisture, the weight of glycerol-plasticized bioplastics at concentrations of 97.2, 48.6, 36.5, 24.3, and 2.4 percentage w/w increased by 74%, 67%, 60%, 48%, and 30%, respectively; after 50 hours of exposure, their weight reached to 79%, 78%, 70%, 59%, and 37% respectively. The plot of the water absorption test revealed that the 97.2% glycerol plasticized bioplastic absorbed more water than the 2.4% glycerol plasticized bioplastic. Since the hydroxyl group of glycerol has a great affinity with water molecules to form hydrogen bonds[39,40], glycerol-plasticized starch-based bioplastics become more hydrophilic as glycerol concentration increases[32].

3.3 Soil burial test

The biodegradability of starch-based bioplastic as measured by its weight loss in grams after 64 days of soil burial was depicted in Figure 3. The plot of weight loss vs time indicated that the weight of all bioplastics raised for the first four days before beginning a slow decline after eight days. The increase in weight over the first four days is due to the bioplastic's ability to absorb water.

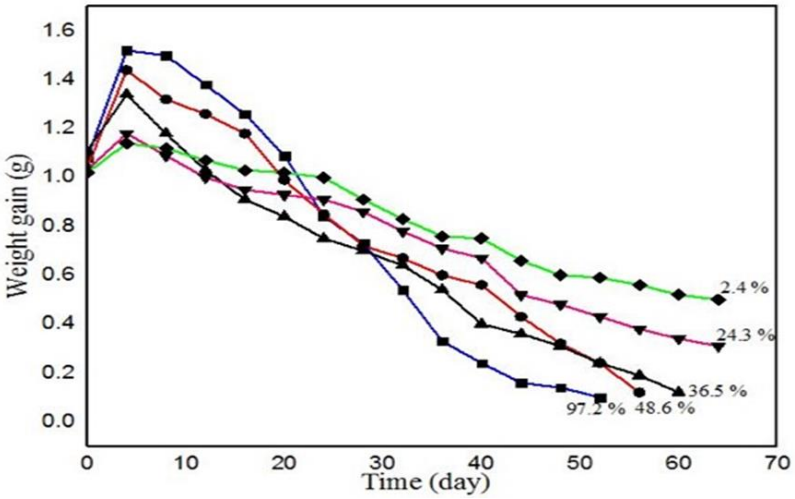

Figure 3: Soil burial test of different concentration of glycerol-plasticized bioplastic

Due to the change in the amount of glycerol contained in the plasticized bioplastic, there is a considerable difference in the weight increase percentage of the material at different glycerol concentrations. Different quantities of glycerol in bioplastic decomposed at different times, but all followed a similar degradation pattern. Bioplastics with a high concentration of glycerol, such as 97.2 % w/w, 48.6 % w/w, and 36.5 % w/w, deteriorated in 52 and 56 days, whereas bioplastics with a lower concentration of glycerol, such as 24.3 % w/w and 2.4 % w/w, took over 64 days to breakdown entirely. The deterioration of bioplastics may be caused by the attack of numerous bacteria, germs, fungus, etc. present in the soil and water[31], which initiated the hydrolysis reaction that caused potato starch to break down into microscopic fragments. Whereas the difference in breakdown rate is primarily attributable to the ability of different bioplastics to absorb water. The pace of bioplastic degradation will increase as the amount of water absorbed by the material increases the microbial process[41]. Due to the hydrolysis of the polymer chain of starch-containing hydroxyl (-OH), carbonyl (C=O), and ester (-COOR), biodegradation occurred[42]

4. Conclusion

The starch was successfully extracted from potato peels for the fabrication of bioplastics by using different concentrations of glycerol as a plasticizer and the synthesized starch-based bioplastic was characterized by using FTIR spectroscopic technique. The formation of starch-based bioplastics was confirmed by the presence of amylopectin, amylose and axial or equatorial C-H bonds to the ring in pyranose sugar. Further, the plasticizer i.e., glycerol showed the good interaction with the starch in the bioplastics. The physicochemical properties *i.e.*, water absorption, soil burial test, and acid-base resistance of glycerol-plasticized starch-based bioplastics were investigated in different concentration (% w/w) of glycerol. The bioplastic plasticized using pure glycerol (97.2 %) absorbed a higher amount of water (*i.e.,* 79%) and gradually decreased the amount of water absorbed in each concentration of glycerol-plasticized bioplastics in water absorption test. Similarly, higher concentration of glycerol (97.2%) plasticized bioplastic was degraded earlier at about 52 days and other concentration (48.6%-2.4%) of glycerol-plasticized bioplastics gradually extended the day of decomposition upto 64 days in soil burial test. Further, the concentration (97.2%) of glycerol-plasticized bioplastics showed higher resistance to both acid and base in acid-base resistance test.

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