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Preparation and Characterization of Starch Based Bioplastic Film from Potatoes

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Abstract

The aim of this study is to develop a bioactive biodegradable film based on starch and glycerol. Starch was extracted from potato. Two films were developed with different concentrations of glycerol (20 and 30%). humidity level, infrared spectroscopy analysis with Fourier transform (FTIR), thermogravimetric analysis and biodegradability test of these films were evaluated. Infrared spectral analysis showed that the 30% and 20% glycerol films have the same chemical structure and no functional group changes occurred. Thermogravimetric analysis showed that a 30% glycerol film has higher thermal stability than a 20% glycerol film. Biodegradability test showed that the lower the percentage of glycerol, the more easily the biofilm degrades.

Keywords: *Biodegradable Film, Glycerol, Potato starch, thermal stability.*

I. Introduction

In recent years, thermoplastic packaging has grown considerably. They rank first among packaging materials (58%). These materials have the advantage of being inexpensive (raw material), lighter, impact resistant and easy to process (processing temperatures below 300°C) [1].

Around 348 million tons of plastics were produced in 2018 worldwide, and their production and consumption continue to increase. The waste from these plastics causes serious environmental pollution. One of the strategies to solve this pollution problem is the complete recycling of waste. However, the recycling of these materials is limited and consumes a considerable amount of energy [2]. This issue has raised awareness about the need to put in place plastic materials that are more respectful of the environment, made up of renewable and short-lived raw materials known as biodegradable polymers [3].

Starch occurs in the form of semi-crystalline granules composed of two polysaccharides, amylose and amylopectin, which are responsible for the particular physicochemical, functional, and edible properties of starch. Amylopectin is the ramified component formed of glucose units linked by alpha (1–4) bonds in the linear sections and of alpha (1–6) bonds in the ramifications. Amylose is the linear component involved in starch gelatinization and retro gradation (hardness of starch-based products). Granules also contain a small amount of protein, fatty acids, and minerals that influence some physicochemical properties of this polymer [4, 5]. Many studies have been applied to produce starch-based polymer for conserving the petrochemical resources and reducing environmental impact. However, starch based bioplastic film have some drawbacks including poor mechanical properties and long term stability caused by water absorption and retrogradation. To overcome these limitations, plasticizer such as glycerol has been added to improve shelf-life and elasticity of the product [6].

In this research, starch is prepared from potato and edible film is made from prepared starch plasticized with glycerol

II. Materials and Methods

II.1. Materials

In this research, the plant material selected as valuable raw material in the preparation of bioplastic film was the white potatoes (Solanum tuberosum L.) which were purchased from Bejaia local market. Glycerol (MW=92.09) was used as a plasticizer in the filmogenic solution to increase the flexibility and plasticity of the film. Hydrochloric acid (MW=36.46) promotes the destruction of the starch grain by a controlled hydrolysis phenomenon that separates amyloses/amylopectin so that the amylose goes into solution. Distilled water was used to make the solution of starch.

II.2. Methods

Starch extraction was carried out according to the protocol described by Hirpara et al [7]. Figure 1 summarizes the main extraction steps.

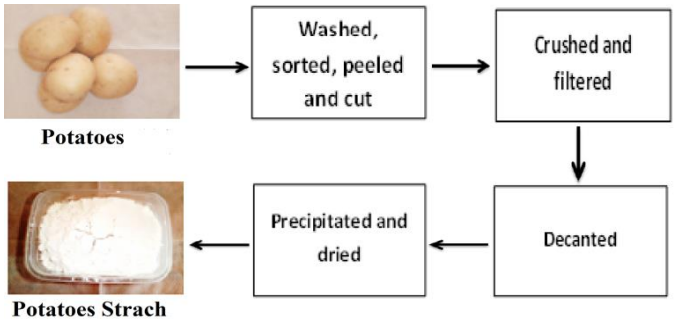

Figure 1: Main stages of starch extraction from potatoes

The films were prepared by casting technique using a film-forming solution containing potato starch 5g and Glycerol Concentration (20 and 30 %) was taken as variable parameter. 100 ml distilled water was added to it. The mixture of dry starch, water and glycerol was taken in a flask. Then 3 ml of Hydrochloric acid (0.1N) was added to the solution. The mixture was mixed with the help of glass rod on heating with stirring on magnetic stirrer at 40˚C for 5 minutes. Now the mixture was kept in water bath at 85˚C temperature for 15 minutes and continuously agitated by glass road. Now a cast was prepared and the entire solution was poured on the cast and was left for drying at room temp for 24 hrs. After drying the films were peeled off and were kept in polythene bags away from moisture.

II.2.1. Moisture rate

Film moisture content was determined by drying small pieces of film in an oven at 105°C for 6 h. Knowing the mass of the film before (m1) and after (m2) stoving, the moisture content can be determined from the relation (1)

$$Moisture\ rate\ (\%) = \frac{m_0 - m_f}{m_0} \times 100 \qquad (1)$$

II.2.2. Spectroscopic characterization (FTIR)

The IRTF spectra of the different samples were recorded in absorbance mode using an infrared spectrometer model SHIMADZU FTIR-8400S, the analysis is carried out on thermoplastic films. The scanning range is between 400 and 4000 cm^{-1} with a number of scans of 32 and a resolution of 4 cm^{-1}.

II.2.3. Thermal characterization

The thermograms of the different samples were recorded using a thermogravimetric device of the type (SETAREM TGA 92), controlled by a microcomputer. A mass of 10 to 20 mg is introduced into an aluminum crucible. The mass loss is measured using a thermo balance under an inert nitrogen atmosphere in a temperature range of 20 to 700°C with a heating rate of 10°C/min.

II.2.4. Biodegradability test

The biodegradation of the samples was evaluated by measuring the mass loss of the composites as a function of time in a compost environment. Samples of size 30mm*30mm were weighed and buried in compost boxes at a depth of 12 to 15 cm. after 2 days. The buried samples were removed, washed with distilled water then dried in an oven at 50℃ for 6 hours. The samples were then weighed before returning them to the compost at 2 day intervals for a 21 day period.

The evaluation of the mass loss was calculated according to the following formula (2):

$$Mass\ loss\ (\%) = \frac{m_i - m_f}{m_i} \times 100 \qquad (2)$$

With:

m_f: the final mass of the sample tested.

m_i: the initial mass of the sample tested.

III. Results and Discussion

III.1. Moisture rate

The result of moisture content of potato starch biofilm are illustrated in Table I .The maximum moisture content was observed for the combination 5 g of starch concentration and 30% glycerol this has been explained in a previous study that glycerol comprises of hydroxyl group which has an affinity for water molecules that allowing them to make hydrogen bonds and contain water in the structure. The result in agreement with the results reported in literature [8, 9].

Table 1: Moisture rate of potatoes starch biofilms

Biofilms	Moisture rate (%)
20% Glycerol	26
30% Glycerol	28

III.2. Spectroscopic FTIR

The FT-IR spectrum curve of prepared bioplastic film was shown in Fig 2. The band at 3247 cm^{-1} was represented the presence of alcohol and phenol group which has –OH stretching vibration [10]. The band at 2923 cm^{-1} was indicated the alkynes group which has C-H stretching vibration [11]. The existence of C=O stretching vibration of carbonyl groups showed up the peak at 1659 cm^{-1}[12]. The frequency at 1342 cm^{-1} was corresponded to the presence of C-O-C stretching vibration of the aldehyde group [13]. The band at 1019 cm^{-1} was also represented the characteristics of C-O stretching vibration of alcohol and phenol group. This analysis showed that the 30% and 20% glycerol films have the same chemical structure and no functional group changes occurred. FT-IR spectra exhibited that the intermolecular interaction in bioplastic occurred through C-O-H, O-H, C-H, C=O, C-O groups, it can be proved that this bioplastic was completely biodegradable [14].

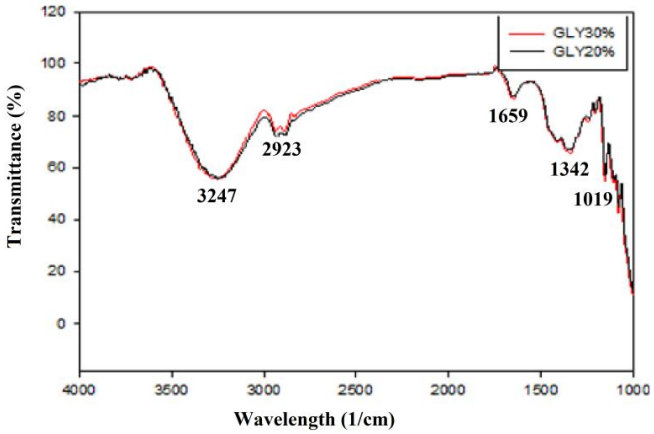

Figure 2: FT-IR Spectrum of Prepared Bioplastic film

III.3. Thermal stability

The thermal decomposition of the two biofilms was carried out by thermogravimetric analysis (TG/DTG). From the TG thermograms of the different materials, it was possible to derive the values of the decomposition temperatures at 10, 50 % (T10% and T50%) of mass loss (Table 2). According to the results illustrated in Table 2, it was found that the film prepared with 30% of the glycerol is the most thermally stable compared to that with 20%. These results were similar to those reported in the literature [15,16]. The thermal stability of the film was increase with increased the glycerol content. This behavior could be explained because increasing the glycerol content promotes the formation of more hydrogen bridges with starch (hydrophilic nature of biopolymers and presence of voids in their structure).

Table 2: Degradation temperature of Potatoes starch biofilms

Temperature (°C)/ Biofilms	20% Glycerol	30% Glycerol
$T_{10\%}$	170	179
$T_{50\%}$	322	340

III.4. Biodegradability test

According to the results of the biodegradable property of prepared biodegradable plastic films are shown in Figure 3, it can be seen that prepared biodegradable plastic film was completely biodegrade after 21 days of exposure to soil. It is suggested that this degradation was due two main stages of degradation: Firstly, the diffusion of the water into the film samples resulted in the swelling of the films then, allowed the growth of microorganism on the film and enzymatic and other secreted degradation caused a weight loss and disruption of the film samples [17-20].

After 21 days, complete biodegradation of the sample (GLY30%) is noticed and pores are more apparent in the sample (GLY20%), indicating a higher level of biodegradation. The rate of weight loss (GLY30%) was significantly accelerated compared to (GLY20%). The weight loss of the samples reached nearly 90% for (GLY20%) and 99% for (GLY30%). The hydroxyl groups of glycerol can form strong hydrogen bonds with the hydroxyl groups on the starch, thus, improving the interactions between the molecules, improving the cohesiveness of biopolymer matrix, and decreasing the lost mass.

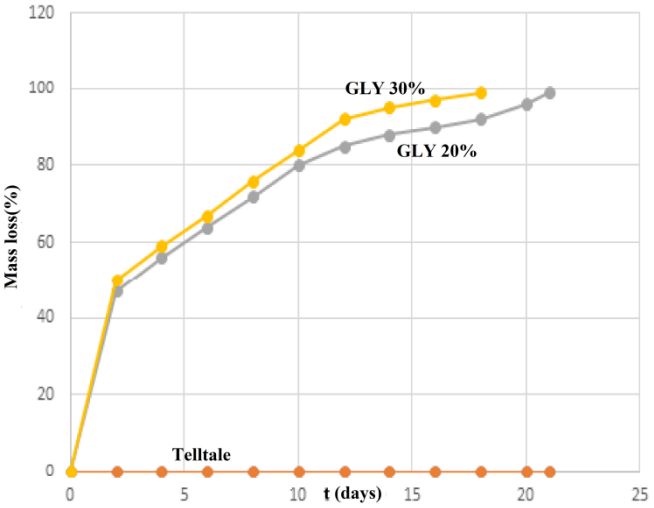

Figure 3: Biofilms mass loss rate

IV. Conclusions

The objective of this work is to develop and characterize biodegradable biofilms based on starch, plasticized by glycerol (20 and 30%). The elaboration of the biofilms was carried out by the casting method under simple conditions. The samples were characterized by infrared spectroscopy analysis with Fourier transform (FTIR), thermogravimetric analysis and biodegradability test. Infrared spectral analysis showed that the 30% and 20% glycerol films have the same chemical structure and no functional group changes occurred. Thermogravimetric analysis showed that a 30% glycerol film has higher thermal stability than a 20% glycerol film. Biodegradability test showed that the lower the percentage of glycerol, the more easily the biofilm degrades.

Disclosure of interest: The authors report no conflict of interest.

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