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SYNTHESIS AND CHARACTERIZATION OF BIODEGRADABLE PLASTIC FROM POTATO STARCH AND GELATIN

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Abstract

There is a large demand for various materials for a variety of uses due to the expansion in global population and the resulting rise in material supply. An important material that has become indispensable use is plastic. The most widely used plastics cannot be easily decomposed in soil, and ultimately result in environmental hazards and pollution. Finding alternatives to plastic packaging is crucial. Bio-plastics help reduce the dependence of petroleum-based polymers and serve as an excellent service in controlling CO_2 emissions into the atmosphere. Using Gelatin and potato starch, the biodegradable and compostable films were created in this research. This Technology uses solely renewable raw resources to create bioplastics from gelatin and starch combinations. These materials might take the place of single-use plastic and non-biodegradable film because of their quick rates of disintegration. Bioplastics were acquired by casting method and classified based on colour, solubility, Bio degradability test, water uptake test. The resulting films are further chemical characterization acquired by Fourier Transform Infrared spectroscopy (FTIR). FTIR is revealed the best compatibility between starch, glycerol and Gelatin. The result of synthesis of bioplastic film from the potato starch and gelatin was white and light yellow in colour. The biodegradable qualities of these polymers have a good effect on society and raise awareness. This biodegradable plastic mainly produced because of biodegradation time is very less compare to the plastic and other materials.

Key words: Bio plastic, potato starch, Gelatin, biodegradable.

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INTRODUCTION

A class of synthetic or organic natural materials called plastics can be moulded and hardened. Nowadays, plastics are widely employed to address fundamental needs in multiples of contexts, including packaging for food, luggage, cell phones, electronics, the pharmaceutical, and automotive industries [1]. The plastics industry is one of the newest and most rapidly growing industries in the world. It started when nitrocellulose and camphor mixture were introduced in the middle of the nineteenth century. Excellent low-temperature resistance, exceptional power insulation, fantastic chemical resistance, wonderful radiation resistance, and decent pressure resistance are all properties of polyethylene. Because it simply contains carbon and hydrogen and lacks any polar elements, polyethylene has good water resistance [2]. When plastics are produced, carbon and numerous other hazardous gases are released, posing environmental and health risks. The environment may need many hundreds of years for the plastic to decompose. In an attempt to advance bioplastic initiatives are used more rarely in synthetic polymer production. [3]. Plastics made from naturally occurring, primarily organic resources, such as corn, potatoes, cassava starch, banana peels, and other cellulose-based materials, are known as biodegradable plastics. An alternative to polymers made from petroleum is biodegradable plastic. It contributes to a greener environment and a decrease in oil usage. Starch-based plastics account for about 50% of the market for bio-plastic. Plastic pollution can negatively impact lands, streams, and oceans since it takes a long time for plastic to disintegrate. Living things, especially marine ones, can also be harmed by entanglement, direct ingestion of plastic trash, interaction with toxins found in plastics, and disruptions of their biochemical processes. Interstellar polymers display different properties from those of their terrestrial counterparts, and these bio-polymers demonstrate the distinctive characteristics of highly functionalized spherical nature [4]. There are two different kinds of these: plastic materials that decompose naturally in aerobic environments and anaerobic environments. When soil microbial consortia start consuming these polymers, degradation starts to take place, and There is little doubt that the eventual release of polymers into the natural environment has fewer hazardous impacts on the ecosystem. These polymers are either made of petroleum-based plastics, bio-plastics (PHA or PHB), plastics produced from sustainable raw materials, additive-containing plastics, or plastics with a petroleum base. These days, corn starch, potatoes or banana starch, cassava starch, cellulose, etc. are used to make bioplastics. In the soil, fungi and bacteria start to work on disassembling PLA into its constituent elements. PLA will compost if given the right aerobic conditions, including heat and moisture [5]. Starch is a soluble carbohydrate that occurs naturally and can be derived from a a number of sources, including corn, potatoes, yams, banana peels, and sweet potatoes. When exposed to hydrolysis, starch exhibits several characteristics of polymers. Starches are commonly utilised during the making of bio-plastic due to their widespread accessibility, low cost, sustainability and biodegradability. the use of a plasticizer, the application of heat, and mechanical processing, starch can behave like a thermoplastic. In order to modify and improve the properties of Other natural biopolymers are frequently used as fillers in starch based film, which are typically limited to high water attraction and brittleness. [6]. Traditional polymers based on petroleum are being replaced with PLA, a plastic substitute manufactured from fermented plant starch commonly from corn or sugarcane [7]. As solar-powered bio-factories with the potential to produce renewable, sustainable, and natural polymers like starch and cellulose, plants are seen as a lucrative option for the manufacturing of bio-plastic. The total biodegradability, low cost, and renewability of starch make it an attractive contender among those naturally occurring plant polymers for creating sustainable materials. However, there are several downsides to starch-based materials, such as long-term stability due to water absorption, ageing due to retrogradation, and low mechanical qualities. Glycerin, a plasticizer, has been added to the product to increase its flexibility and shelf life in order to get around these restrictions [8]. Gelatine may be recovered from collagen-rich waste (skin, bone), and it be using as the foundation for an unique line of bioplastics. Due to the downsides of porcine and bovine gelatine, which are linked to ailments including Bovine spongiform encephalopathy and disease of the foot and mouth, porcine gelatine has gained interest (BSE). Gelatine, a functional protein with film-forming abilities, is produced when collagen becomes hydrolyzed partially. In the bioplastics sector, mixtures of Gelatin and starch are utilised to create films with better polymeric matrices [9]. The study of starch-based films from various sources has continued, and it has been discovered that a single starch cannot contribute enough physicochemical and mechanical characteristics on its own. Instead, it must combine with other ingredients to achieve the desired results, such as improved product texture and resistance to a variety of physical changes. In addition, since the launch of the potatoes food staple strategy, potato planting areas have increased by a total of 6.7 million hectares, making potatoes the largest non-cereal food crop globally (2020). The production of potato starch, a promising natural carbohydrate for food packaging material, went up to 96 million tonnes (2016). Granules of potato starch range in size from 25 to 100 micrometres(μm). Additionally, potato starch would develop thermoplastic properties when exposed to plasticizers, high temperatures, and shearing conditions [10].

MATERIALS AND METHODS

1.Preparation of Potato Starch

Before the potato's starch could be extracted, a few steps had to be taken. They are :1. Weighing, 2. Cleaning, 3.Peeling, 4.Dicing.

First, the chosen sample was weighed. This stage was carried out to get the tuber's initial bulk. A total of one kilogram's worth of potato tubers were used in the extraction. In order to get rid of impurities like dirt, soil, tiny roots, and other undesired plant elements, the chosen sample was first washed with water. To determine the difference between the weight before and after washing, the sample was weighed once more. After that, a knife was used to manually peel the sample. The potato was meticulously hand chopped into thin, uniform cubes after being gently skinned. A blender was used to mix and slur the sample while it was being dissolved in double-distilled water. A 500ml ratio of tuber to water (double distilled water) was introduced to slur the sample of diced potato in water. By running the resulting slurry through two layers of cheesecloth, the filtration process was completed.

Figure 1. Potato starch

To separate the starch extract from the potato sample's leftovers, filtering was used. In order to remove the starch from the residue, double-distilled water from a wash bottle was added to the filtrate. In order to obtain pure starch, the starch sediment was washed twice. After the washing process, the sample should be allowed to air dry or in the sun for about 2 days. After the entire drying process, collect the starch power in a container.

2.Preparation of Bio Plastic

Mroczkowska et al. (2019) [11] and Eyre et al. (2019) [12] presented the previous research that generated the variables discussed in this study. In an beaker, 20g of gelatine is hydrated in 140 mL of tap water. The gelatine was dissolved by continuously rotating the beaker at 60 ^{0}C. The dissolved gelatin solution was placed in a different beaker together with 10g of potato starch, 15 mL of glycerol, and 60 mL of tap water. The mixture was agitated until a uniform mixture was obtained and all the components had dissolved after being heated to between 75 and 80 degrees Celsius. A silicon tray measuring 210 mm by 115 mm was used to pour the bioplastics solution onto, and it was left to air dry for 48 hours in a well-ventilated area. The bio plastic was then taken out of the dish and was prepared for use in further investigation.

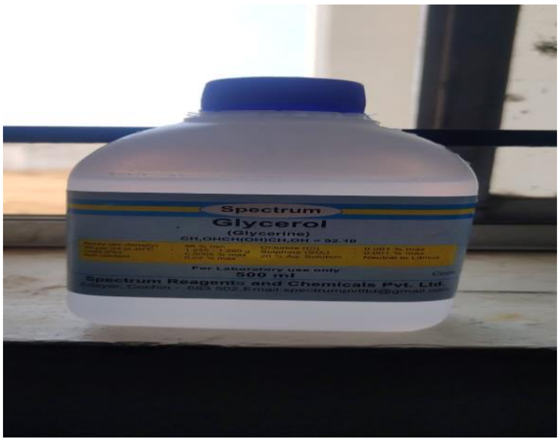


Figure 2. Glycerol

Figure 3. Gelatin

A) FTIR Spectroscopy

FTIR (Fourier Transform Infrared) Spectroscopy is an technique used to evaluate the vibrational modes of molecules in the infrared (IR) region of the electromagnetic spectrum.In this technique, a beam of IR radiation is directed through a sample, and the molecules in the sample absorb some of the radiation. The remaining radiation is then passed through an interferometer, which splits it into two beams of light that travel different paths. The two beams are then recombined and detected by a detector, which produces a spectrum of the intensity of the radiation as a function of the frequency or wavelength.

The resulting spectrum provides information about the functional groups present in the sample, as different functional groups have characteristic vibrational frequencies. In analysing the spectrum of unknown sample those of well-known compounds can be compared to identify the components of sample. It is a powerful tool for identifying and characterizing the composition of samples, as well as studying the interactions between molecules.

B) Solubility Test

The waterless film mass was precisely weighed and documented after the film sample was divided into six 2.0 cm squares. The samples were submerged in the solutions and water in the beaker for six hours. The remedies are: 1) conc. HCL); 2) conc. H2SO4; 3) chloroform; 4) methanol; 5) acetone; 6) ethanol; and 7) water.

After six hours, the film's remaining sections were filtered, and after drying in a hot air oven at 1100C, a final fixed weight was determined. A suitable water solubility range for glycerol is between 18% and 25%. Calculations were made to determine the amount of total soluble materials (%) as:

$$\mathbf{WS(\%) = [(W_i - W_f)/W_i] * 100}$$

WS= solubility in water

W_i = initial weight

W_f= final weight

C) Biodegradability Test

The specimen was divided into 4.0 cm sections. A small amount of moisture that was discovered around the roots of wealthy plants was collected and kept in a beaker. Two samples-one at a depth of 3 cm and the other at a depth of 4 cm—were buried in the ground for 2 weeks. The specimen's weight was recorded both before and after the test. Equation used to measure the results of the biodegradability test was:

Weight Loss (%) = $[(W_i - W)/W_i)] * 100$

W_i = weight of an sample (before the test)

W = weight of an sample (after the test)

D) Water Absorption Test

Two samples of varying weights were collected for the water uptake test. The samples' original weight was noted. The samples were then put into a beaker with 60 ml of water and kept there at a room temperature for 24 hours. After that, the sample were removed from the water and cleaned. The following formula was used to determine the amount of water taken in:

Water uptake = $[W_w - W_d / W_w] \times 100$

W_w = Wet weight

W_d = Dry weight

RESULTS AND DISCUSSIONS

CHARACTERIZATION

Fourier Transform Infrared Spectroscopy (FTIR)

The objective of the FTIR study was to identify and assess the numerous linkages created in the gelatine and potato starch bioplastic mixes. Figure 5 displays the ranges of the potato starch and gelatin mix of bioplastics produced during the research. The bioplastic spectra obtained for this study showed the existence of six significant absorption peaks. A C-O-H stretch was seen at 990 cm^{-1}, an O-H stretch at 3500–3000 cm^{-1}, a C-H stretch at 2910 cm^{-1}, a C=O stretch at 1600 cm^{-1}.

Table 1. FTIR

Functional Group	Wave number [cm^{-1}]
O-H	3297.49
C-H	2929.99
C=O	1651.99
C=O	1411.84
C-O-H	1018.22
C-O-H	924.96

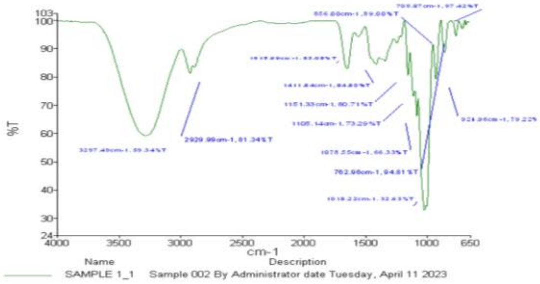
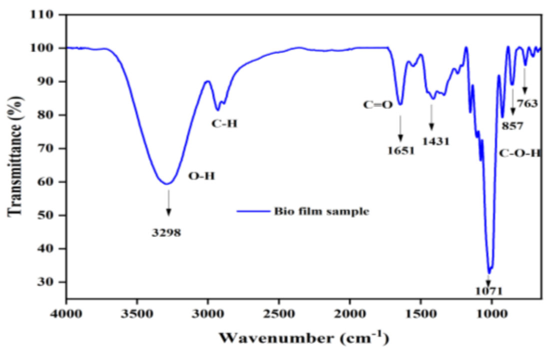


Figure 5. Fourier Transform Infrared Spectroscopy



APPLICATION STUDIES

SOLUBILITY TEST

Table 2. Solubility Test

solvents	Initial weight (W_i)	Final weight (W_f)	Solubility (%)
Acetone	0.05	0.05	0
Ethanol	0.06	0.06	0
Methanol	0.07	0.07	0
Chloroform	0.07	0.04	43
Water	0.08	0.08	0
Hydrochloric Acid (conc.)	0.08	0.00	100
Sulfuric Acid(conc.)	0.08	0.00	100

On the synthesised bioplastic, a solubility test was performed to assess the impact of various solvents. The starch-based bioplastic's solubility test findings showed that it is not soluble in water, which increases its suitability as a bioplastic. In order to improve product integrity and water resistance, potential applications require water insolubility. Additionally, it was insoluble in polar solvents like acetone, methanol, and ethanol. but it was entirely soluble in concentrated sulfuric (HCL) and hydrochloric acids(H_2SO_4) (100%) and partially 43% in chloroform acids.

BIODEGRADABLE TEST

Table 3. Biodegradable test

S NO.	Sample burial depth(cm)	Before weight (W_i)	After weight (W)	Weight loss (%)
1.	3	0.19	0.10	47
2.	4	0.19	0.08	58

The samples were measured in order to calculate the percent weight reduction after a two weeks of soil burial test. Potato starch and gelatin mixture were found to have lost 47% of their weight after being buried under 3 cm for 2 weeks. Additionally, 58% of the second sample that was buried 4 cm deep was found. Over fairly short periods of time, these materials disintegrate and are released into the environment. potato starch and gelatin-based bioplastic showed a greater level of biodegradation based on the amount of weight loss.

WATER UPTAKE TEST

To ascertain the material's water absorptivity, a water absorption test is conducted. Due to its innate hydrophilicity, starch is mostly to blame for the water absorption. For the water uptake test, 2 samples of various weights were collected. The first sample weighs 0.12g dry and 0.33g moist, respectively. A second sample is then taken, this one weighing 0.19g wet and 0.06g dry. The analysis's findings indicate that the starch-based bioplastic absorbs water to a greater extent.

Table 4. Water absorption test

S.NO	Dry weight (W_d) (gm)	Wet weight (W_w) (gm)	Uptake (%)
1.	0.12	0.33	64
2.	0.06	0.19	68

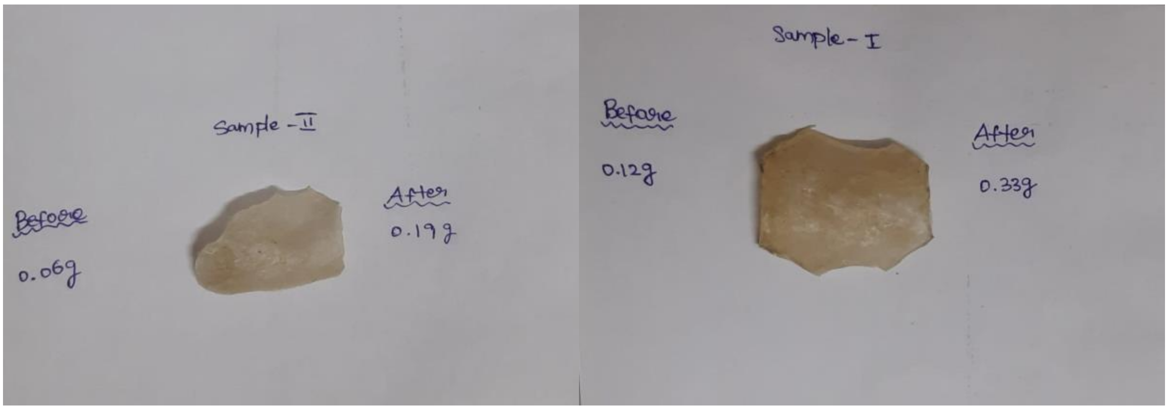


Figure 6. Water absorption Test

Figure 7. Bio Plastic Film

CONCLUSION

With the use of biodegradable components (potato starch, gelatin, and glycerol), a comprehensive performance film was successfully created, and its formulation was improved using FTIR.A detailed multi-index evaluation of responses, including their mechanical, physical, as well as barrier qualities, was performed. The model's accuracy was confirmed by FTIR measurements, and the improved film performed well. The bioplastics made from potato peels in this study were shown to totally biodegrade in just 28 days, and it was recommended that these bioplastics could be employed in the packaging sector. For use in various industrial fields, it is important to investigate how mechanical qualities develop. However, it was found that the commercial bioplastic did not breakdown within the allotted 28 days. The use of bioplastics has expanded recently, both globally. Hence, criteria should be devised to ensure the sustainability of anything referred to as "biodegradable". In conclusion, a fresh manual on the manufacturing, use, and disposal of bioplastics in the world needs to be created as soon as possible. A good alternative to plastics are an effective technique to reduce the issue of plastic emission, all the bio plastics generated were environmentally friendly and biodegradable. Moreover, FTIR examination showed that the optimised films had fine microstructures and homogeneous surfaces, which indicated good compatibility. The biodegradable starch-based film created in this study may end up being utilized for eco-friendly food packaging due to its excellent overall performance.

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