JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# Invention of biodegradable plastics from potato peel starch with diverse plasticizer and their characterization

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**Abstract**

Conventional plastics derived from precious petrochemicals. But they use fossils fuels and provides environmental problem. Also over the time, fossil fuel get depletes. Researchers are busy to find out the solution of these problems and solution had come known 'Bio-degradable Plastic'. This study explores the synthesis of biodegradable plastics using potato peel starch, a renewable agro-waste, combined with glycerol & sorbitol as plasticizers. The bio-plastics were characterized for their mechanical properties, and biodegradability. The results indicates that the choice of plasticizers significantly influence the properties of the resulting bi-oplastics, highlighting their potential as sustainable alternatives to conventional plastics.

**Key words:** Potato peel, biodegradable plastic, plasticizer, glycerol, sorbitol

## 1. INTRODUCTION

Our whole world is wrapped in Plastic. Due to the major uses of plastics, it became significant thing in our day to day life. Plastics are so vital to our lives and so versatile in their usage that their use cannot be completely stopped.[1]

Due to its properties such as versatility, Lightweight, durability, Cost-Effect, Energy Efficiency etc. Plastics are used in packaging, Medical and Healthcare, Construction, Automotive industries.

With these advantages plastics have much more disadvantages. Few are listed below:

1. Environmental Pollution
2. Threat to Marine and Wildlife
3. Human Health Risks
4. Economic Costs
5. Low Recycling Rates and Waste Management Challenges

Conventional plastics derived from precious petrochemicals. But they use fossils fuels and provides environmental problem. Also over the time, fossil fuel get depletes. Researchers are busy to find out the solution of these problems and solution had come known 'Bio-degradable Plastic'. To solve this problem, biodegradable plastics are being explored as a better alternative. Due to the action of living organisms such as fungi, bacteria or other microorganisms, the degradation of bio-plastics take place easily and it can convert into organic substances like carbon-dioxide and water[2-3].

Starch is a renewable resource of plant that is bio-degradable.[4] Starch can be processed directly into biodegradable plastic on adding plasticizer (like sorbitol, glycerol etc). Plasticizer is used to impart flexibility and mould ability to the plastics and thus produce a range of different characteristics. Starch is an excellent material for creating biodegradable plastic. It completely breaks down, is affordable, and comes from renewable plant sources.

In the present research work we synthesized bio-plastics from potato peel with glycerol and sorbitol as plasticizer and their different characterization were studied.

## 2. MATERIALS AND METHODS

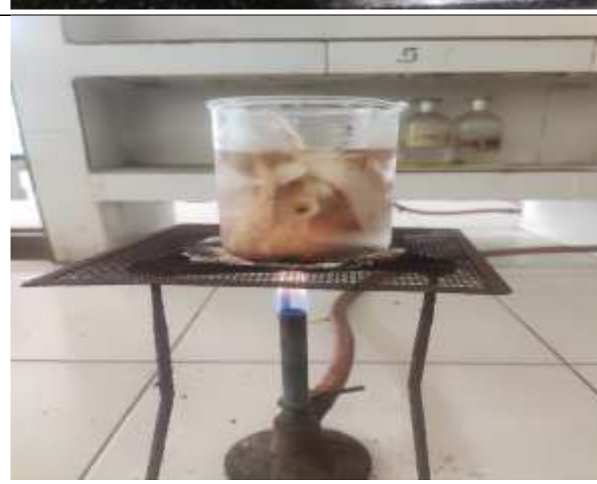
**1) Sample collection:** Potato were purchased from local market at Latur, Maharashtra, India.

### 2.1 Synthesis of bio-plastic from potato peel:

**a) Preparation of potato starch from potato peel:**

Potato peels obtained from 5-6 potato were dipped in sodium metabisulphite (0.2M) solution for 45 minutes to increases the biodegradation period of plastic. Then these peels were boiled in water for about 30 minutes. Water was removed from the beaker and the peels were left to dry. When peels were completely dried, grinded using grinder until uniform powder was obtained[5].



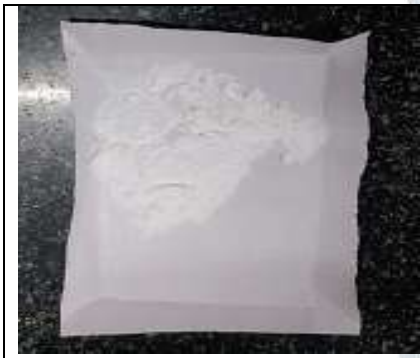
**2.2 Production of bio-plastic:**

**A) By using glycerol as plasticizer:**

5gm of potato powder was taken in a clean beaker. In this beaker, 30ml of (0.5 N) HCl was added and stirred by glass rod. 2ml Plasticizer (Glycerol) was added and stirred. Then according to pH desired, 0.5 N NaOH was added to maintain neutral pH. The mixture was spread on a ceramic tile and this was put in the oven at 120°C and was baked. The tile was allowed to cool and the film was scraped off the surface.[6]

**B) By using sorbitol as plasticizer:**

5gm of potato powder was taken in a clean beaker and 3ml of (0.5 N) HCl was added to it and stirred well. 2ml Plasticizer (sorbitol 1M) was added and stirred. Then according to pH desired, 0.5 N NaOH was added to maintain neutral pH. The mixture was spread on a ceramic tile and this was put in the oven 120°C and was baked. The tile was cooled down and the film was scraped off the tile surface.[7]

| | | |
|---|---|---|
|  |  |  |
| **Fig- 2.1 Preparation of potato starch from potato peels** | **Fig- 2.2 A Production of bio-plastic using glycerol as plasticizer** | **Fig- 2.2 B Production of bio-plastic using sorbitol as plasticizer** |

**Mechanism:**

- The hydrochloric acid is used in the hydrolysis of amylopectin (present in starch), in order to help the process of film formation due to the H-bonding amongst the chains of glucose in starch, since amylopectin blocks the film evolution.
- To neutralize the pH of the medium, sodium hydroxide is used
- Glycerol& sorbitol, act as plasticizers increases the flexibility of a material.
- Sodium metabisulfite ($Na_2S_2O_5$) act as an antioxidant to stop the microbial growth in peels

**3. CHARACTERIZATION OF BIOPLASTICS:**

**1) Moisture content:**

Bio-plastic samples of size 1.5 $cm^2$ were weighed to measure the initial weight ($W_1$). In oven, sample (1.5 $cm^2$ each) was kept for 24 h at 85°C for drying. The samples were weighed once more to measure the final weight ($W_2$). The moisture content was then determined using the following formula[8]:

$$\text{Moisture content (\%)} = \frac{W1-W2}{W1} \times 100$$

**2) Absorption of water:**

In oven, sample (1.5 $cm^2$ each) were kept for 24 h at 85°C for drying and then its weight ($W_1$) was measured. For 24 h, kept this sample in a beaker containing 50 ml distilled water and after that filtered out the bio-plastic and measure its final weight ($W_2$). By using the following formula, absorption of water was found[8]:

$$\text{Absorption of water (\%)} = \frac{W2-W1}{W1} \times 100$$

**3) Swelling Test:**

The swelling test is carried out to evaluate their water absorption capacity and hydrophilicity. 1g piece of samples were taken in the test tube containing various solvents such as water, chloroform and methanol and kept in the medium for about 2 hours and the results were recorded accordingly[9].

**4) Solubility:**

a) **Solubility in water**: At 85°C bio-plastic samples, each 1.5 cm², were dried in an oven and its dry weight ($W_1$) was measured. At room temperature this bio-plastic was placed in a beaker containing 50 ml of distilled water for 24 h. Filtered out the bio-plastic residue, kept it again in an oven at 85°C for 24 hours, and measure its

final weight ($W_2$). The solubility of the bio-plastic in water was calculated using a specific formula given below[10]:

$$\text{Solubility in water (\%)} = \frac{W1-W2}{W1} \times 100$$

b) **Solubility in alcohol**: Synthesized bio-plastic samples, each 1.5 cm², were dried in an oven at 85°C for 24 hours and then its weight ($W_1$) was measured. Kept this weighted bio-plastic in test tubes with caps containing 10 ml ethanol for 24 hrs. at room temperature. After 24 hrs. the bio-plastic residue was obtained by filtering the water and again dried in an oven at 85°C for 24 hrs. After 24 hrs. the weight of dried sample was taken as final weight($W_2$).The solubility in alcohol was calculated using a specific formula given below[10]:

$$\text{Solubility in Alcohol (\%)} = \frac{W1-W2}{W1} \times 100$$

**5) Bio-degradability Test:**

Bio-plastic samples of size 1.5 $cm^2$ were weighed to measure the initial weight ($W_1$). These weighted samples were placed under 2 cm of wet garden soil. They were kept in Styrofoam cups. Foe five days, they were kept in styrofoam by maintaining the condition of soil to be moist. After 5 days, the bio-plastic residue was collected from the soil, cleaned with water and dried in an oven at 85°C for 24 hours. After 24 h the weight of dried sample was taken as final weight ($W_2$). Biodegradability was calculated using a specific formula given below[11]:

$$\text{Bio-degradability (\%)} = \frac{W1-W2}{W1} \times 100$$

**6) Thickness measurement:**

The thickness of samples were measured by tool like screw gauge . Samples were placed between the two part of screw gauge and measurement were taken at different spots of sample. Then average thickness was calculated[12].

7) **Chemical resistance:** To check chemical resistance of bio-plastic in acid and alkali, 0.1N NaOH and 0.1N HCl solution were samples were immersed for 24 h. 0.1 N NaOH was prepared by mixing 0.4g NaOH with 100ml distilled water whereas 0.1N HCl was prepared by mixing 0.83ml of HCl acid with 100ml of distilled water. The effects of strong acid and base on the samples were ascertained by measuring change in appearance[13].

8) **Flame test:** Bio-plastics were weighed in order to obtain initial weight and then they were subjected to high flame for 30 seconds and was observed for any poisonous gases[14].

**9) Creep measurements:**

To measure the creep behavior of bio-plastics, we need to assess how the material deforms over time under a constant load and temperature. Synthesized bio-plastic samples with consistent dimensions were used. The thickness of each sample at multiple points using a screw gauge was measured and the average thickness was calculated.

Equipment calibrated to maintain constant 1.0 MPa stress and 25°C temperature and ensuring proper alignment to avoid inaccurate readings. Bio-plastic samples were secured in the grips of the testing machine and strain at regular intervals was recorded.

**10) Fourier Transform Infrared Spectroscopy (FTIR)**

Aligent Cary 630 FTIR spectrometer was used to investigate the interaction and chemical composition changes in synthesized bio-plastics. Spectra of bio-plastics synthesized from banana peels were recorded.

## 4. RESULT AND DISCUSSION

In the present study bio-plastics were prepared from potato peel using plasticizers as glycerol and sorbitol etc. Also prepared bio-plastics were characterized by moisture content, absorption of water, swelling test, solubility, bio-degradability, thickness measurement, chemical resistance, flame test, Creep measurements and Fourier Transform Infrared Spectroscopy (FTIR). The result of moisture content and absorption of water test is depicted in Table-1

**Table-1 Moisture content and Absorption of water test**

| Sr. No. | Sample No. | Moisture content (%) | Water Absorption (%) |
|---|---|---|---|
| 1 | 1 | 32.35 | 39.98 |
| 2 | 2 | 10.11 | 31.02 |
| 3 | **Control-1** | 4.35 | 57.92 |

From the observed data, sample with glycerol has the highest moisture content and control-1 has the lowest. Sample with sorbitol has lower value in comparison with sample with glycerol because glycerol contains hydroxyl group which has an attraction for water molecules that grant them to make hydrogen bonds and contain water in the structure[15] while sorbitol forms substantial hydrogen bonds with the starch molecules, thus reducing the affinity for water molecules.

In the test of water absorption, control -1 had the highest water absorption. This is because the hydroxyl group in starch attracts water molecules and gelatinization breaks starch granules, allowing water to diffuse. Previous studies show water absorption increases with more starch. Thus, adding plasticizer reduces water absorption.[16]. With glycerol had the highest absorption of water, followed sorbitol. Glycerol attracts water molecules more strongly than sorbitol. The result of swelling test is depicted in Table-2.

**Table-2 Swelling Test**

| Sample No. | Final weight of the sample in water (g) | Difference in weight (g) | Final weight of the sample in Chloroform (g) | Difference in weight (g) | Final weight of the sample in Methanol (g) | Difference in weight (g) |
|---|---|---|---|---|---|---|
| 1 | 1.39 | 0.39 | 1.02 | 0.02 | 1.02 | 0.02 |
| 2 | 1.18 | 0.18 | 1.01 | 0.01 | 1.01 | 0.01 |
| Control-1 | 1.00 | 0.00 | 1.00 | 0.00 | 1.00 | 0.00 |

When the bio-plastic material was soaked in organic solvents like chloroform and methanol, there is no much change in the weight of bio-plastic material. But when it is immersed in water, there is a slight increase in the weight of bio-plastic material. Bio-plastics swell in water because they are hydrophilic in nature and water is polar, hydrogen bonding solvent so strong polymer-water interaction allowed water to enter and expand polymer size. Organic solvents like chloroform (non-polar) and methanol (less-polar) cannot form strong hydrogen bond with polymer.

The result of solubility in water and in alcohol depicted in Table-3

**Table-3 Solubility in water and in alcohol**

| **Sr. No.** | **Sample No.** | **Solubility in water (%)** | **Solubility in alcohol (%)** |
|---|---|---|---|
| 1 | 1 | 62.57 | 56.58 |
| 2 | 2 | 59.60 | 51.35 |
| 3 | **Control-1** | 46.56 | 45.18 |

From the above results we found that adding plasticizers increased the water solubility of all bio-plastics. Starch molecules have a crystalline structure with hydrogen bonds, making starch granules insoluble in cold water[17]. Like water absorption, bio-plastics with glycerol as a plasticizer showed the highest water solubility and lowest in samples with sorbitol. This can be explained with the fact that glycerol has a lower molecular weight and greater attraction to water than sorbitol, allowing water molecules to penetrate easily into polymer chains.[18] From the literature survey, the type of plasticizer affects on solubility of bio-plastic in water.[19]

From the result of above study, adding plasticizers increased the alcohol solubility of all synthesized bio-plastics. In existence of glycerol plasticizer, bio-plastic samples had the elevated solubility in alcohol, and in presence of sorbitol plasticizer had the lesser solubility in alcohol.[20]

The result of bio-degradability and thickness measurement is depicted in Table-4

**Table-4 Bio-degradability and thickness measurement**

| **Sr. No.** | **Sample No.** | **Bio-degradability (%)** | **thickness mm** |
|---|---|---|---|
| 1 | 1 | 68.89 | 0.02 |
| 2 | 2 | 59.62 | 0.03 |
| 3 | **Control-1** | 42.01 | 0.04 |

Physiochemical properties include chemical structure, molecular weight, water affinity, and surface area etc. of the bio-plastics determine their biodegradation ability.[21] Control-1 was observed to have the lowest biodegradation. Including plasticizers increased the biodegradation of bio-plastic samples. Also, biodegradation increased due to better water absorption and water absorption increased due to the water affinity of plasticizers like glycerol and sorbitol towards water. Bio-plastic samples with glycerol showed the highest biodegradation than sample with sorbitol.

Glycerol films are thicker due to higher moisture retention but less dense. Sorbitol films are usually thicker and denser because of their tight and crystalline structure. It makes stronger bio-plastics. The result of Chemical resistance is depicted in Table-5

**Table-5 Chemical resistance measurement**

| Sample | Acid solubility | Base solubility |
|---|---|---|
| 1 | Yes | No |
| 2 | Yes | No |
| Control-1 | Yes | No |

The three samples of bio-plastics were subjected to acid and alkali test to check their resistance. From the observed result, all the samples were insoluble in base but degraded in acid soon.

**Flame Test:** During flame test, samples were burned without releasing any harmful gas so these bio-plastics are environmental eco-friendly and also it burn like a normal paper. The result of creep measurement is depicted in Table-6

**Table-6 Creep Measurement**

| Sr. No. | Time (hours) | Strain (%) | | Creep Rate (%/hrs.) = strain/time | |
|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 1 | Sample 2 |
| 1 | 0 | 0.00 | 0.00 | -- | ---- |
| 2 | 1 | 0.12 | 0.09 | 0.12 | 0.09 |
| 3 | 24 | 0.18 | 0.17 | 0.0075 | 0.0070 |
| 4 | 48 | 0.32 | 0.23 | 0.0066 | 0.0047 |

Glycerol, a hydrophilic plasticizer, reduced intermolecular forces in the starch by forming hydrogen bonds with glucose chain, increasing chain mobility. This enhances flexibility but likely increases creep deformation under constant load, as the loosen structure allows polymer chains to slip more easily over time.

Sorbitol, with its stronger hydrogen bonding and lower hygroscopicity, creates a stiffer, more cohesive matrix. Due to cohesive matrix, chain mobility of polymer got reduces which affects to creep rates lower and finally polymers got better dimensional stability.

**Table-7 IR Measurements**

| Sample No. | O-H stretching | C-H stretching | C=O stretching | C-O stretching | C-H deformation | C-C stretching |
|---|---|---|---|---|---|---|
| 1 | 3276.3 $cm^{-1}$ | 2929.6 $cm^{-1}$ | 1640.0$cm^{-1}$ | 998.9 $cm^{-1}$ | 1390.3$cm^{-1}$ | 857.2$cm^{-1}$ |
| 2 | 3291.2 $cm^{-1}$ | 2933.4$cm^{-1}$ | 1636.3$cm^{-1}$ | 998.7$cm^{-1}$ | 1364.2$cm^{-1}$ | 924.3 $cm^{-1}$ |

The broad peak at 3276.3 $cm^{-1}$ and at 3291.2 $cm^{-1}$ are associated with the hydroxyl groups (-OH) in starch (amylose and amylopectin) and glycerol and the hydroxyl groups (-OH) in starch (amylose and amylopectin) and sorbitol. The presence of glycerol and sorbitol enhances hydrogen bonding between starch molecules and the plasticizer.[23]

Peaks at 2929.6 $cm^{-1}$ and 2933.4$cm^{-1}$ are associated with C-H stretching vibrations from the aliphatic chains in starch, glycerol and sorbitol. This confirms the presence of organic components in the bio-plastics.[24]

Peak at1640.0$cm^{-1}$ and 1636.3$cm^{-1}$ indicates carbonyl groups, often from residual organic acids or ester linkages formed during processing. This can also reflect interactions between starch, glycerol and sorbitol.

Peaks in the range at 998.9 $cm^{-1}$ and 998.7$cm^{-1}$ are associated with C-O stretching in starch, glycerol and sorbitol indicating the polysaccharide backbone and plasticizer integration, confirming C-O stretching in the starch-glycerol and starch-sorbitol matrix.

## 5. CONCLUSION

This research is significant because it uses agro-waste, like potato peel to create valuable materials. This preparation method is very simple, low cost and produces good quality starch. FTIR analysis showed the presence of functional groups, confirming no harmful substances are in the material, making it environmentally safe. The carboxylic acid in the material suggests potential uses in pharmaceuticals. Plasticizers added to the material make it more workable, while pectin and cellulosic fibers provide strength and ensure biodegradability, making it suitable for short-term packaging.

Although promising, the material needs further improvements, especially to make it more water-resistant. Using banana peel as waste to produce bio-plastic is an effective way to address fruit waste disposal and promote sustainable resource use.

**Acknowledgement:**

The author expresses their gratitude towards the host Institution Dayanand science college, Latur and also extend their sincere appreciation to the Rajiv Gandhi Science and Technology Commission, Govt. of Maharashtra, Mumbai and Swami Ramanand Teerth Marathwada University, Nanded for funding this research work under Assistance for Science & Technology applications through University scheme. [File No. APDS/RGSTC/Cycle VII/ASTA-Proposal/2023-24/1609]. Authors are deeply thankful to Dayanand college of Pharmacy, Latur for proving IR Data of synthesized bio-plastics.

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