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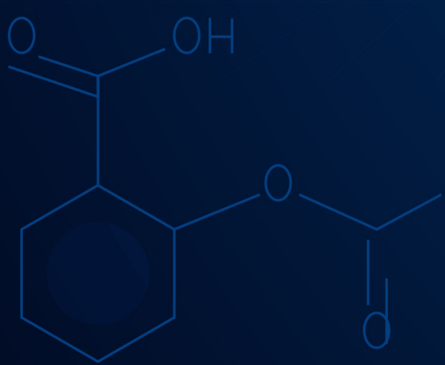

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A Study on Synthesis and Characterization of Bio-Plastic Obtained from Potato

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ABSTRACT

The synthesis of bioplastic is a growing interest among researchers in today's world. Starch extracted from potatoes was utilized to synthesize bioplastic. From raw potatoes starch was extracted after it was peeled, diced, crushed, blended, slurred, sedimented, filtered and oven-dried. The starch was made soluble in water with the help of acetic acid and was gelatinized by glycerol. Constant heat was supplied with regular stirring until homogenous gelatinous mixture was ready. The mixture was molded and dried to obtain bioplastic film. Physical and chemical properties were characterized. The film had average thickness of 3.45 ± 0.26 mm. The average density was 1.20 ± 0.04 g/cm^3. The bioplastic revealed a biodegradability weight loss of 69.28 ± 1.52 % in 14 days. The water absorption of bioplastic was 81.08 ± 1.28 % in 2 hours. The opacity was measured 0.42 AUmm-1. Furthermore, Phenol, concentrated sulphuric acid, and concentrated hydrochloric acid made the bioplastic soluble whereas insoluble in water and wide range of organic solvents. The film had smooth and slightly sticky surface° with slight vinegar smell. The study has shown that starch from potatoes can be utilized to create bioplastic film as replacement for petroleum-based bioplastic.

INTRODUCTION

The application of plastic is ubiquitous in today's world. Most of today's plastics are fossils based, have slow degradability, and cause environmental harm (Wallis, 2019). Traditional petroleum-based plastics are resistant to microbial breakdown and build up in ecosystems and food systems (Boey *et al.*, 2021). Additionally, the process of burning petroleum-based plastic trash to produce energy results in the emission of greenhouse gases and hazardous substances, specifically dioxin, furans, and the polychlorinated biphenyls (Giacovelli, 2018). The release of greenhouse gases, including methane, nitric oxide, and carbon dioxide, contributes to the intensification of global warming (Gironi & Piemonte, 2011). Additionally, it is worth noting that 99% of the plastic originated from non-renewable fossil fuel sources, specifically petroleum and natural gas (Bioplastics, 2020). Various biodegradable polymers, such as polylactide (PLA), polyhydroxyalkanoate (PHA), Poly hydroxybutyrates (PHB), starch, and cellulose are currently under investigation for diverse uses (Venkatachalam & Palaniswamy, 2020).

Bioplastics are plastic products that are made from renewable biomass feedstocks like starch, cellulose or polylactic acid and are therefore, being studied as a potential to reduce the problems associated with conventional plastics (Thompson *et al.*, 2005). Bioplastics have gained significant interest in recent years due to their environmental benefits (Rujnić-Sokele & Pilipović, 2017). Bioplastics has the characteristic of being either biodegradable, bio based, or exhibiting both properties (Tonuk, 2016). Under the right conditions and over a certain amount of time, all materials are degradable (Metro, 2021). We typically consider a material "biodegradable" if it degrades within a relatively short period of time, less than a year (Metro, 2021). They have to change significantly in their structure which leads to the loss of properties (Gilbert, 2015). Biodegradation depends on the chemical structure of material and doesn't rely on the source of polymer therefore, a bio-based plastic is not necessary a degradable plastic (Kershaw & Gilbert, 2015). The degradation of biodegradable plastics give rise to carbon dioxide, methane, water, biomass, humic matter and various other natural substance which can be readily eliminated (Azois, 2007). These bioplastics have the advantage of not causing any environmental pollution, not depleting fossil fuel resources, and ultimately not posing any danger to humans (Paul *et al.*, 2021). Biodegradable plastics are an important invention that can make a big contribution to the development of the bio economy and reduce our dependence on traditional fossil fuel-based resources in favor of bio-based products (Nanda *et al.*, 2022). Biodegradable plastics are a suitable alternative to conventional plastics because they can be used in similar ways (Cinar *et al.*, 2020).

Starch, which is the most common carbohydrate in human diet, can be utilized to fabricate compostable plastic (Garcia *et al.*, 2015). It is also abundant, biodegradable, and renewable, and its possibility of blending with conventional polymers has garnered wide interest in the bioplastic market (Prabhu & Prasantha, 2016).Starch can be obtained from various sources, including tubers like tapioca and potato, as well as cereals like rice, wheat and corn. Additionally, cashew nuts can also serve as a source of starch (Kharb & Saharan, 2022). Potato, corn, wheat, and tapioca are the primary botanical source of starch (Ali *et al.*, 2017). Starch consists of two kinds of

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glucose units connected by 1, 4-α connections. One type is amylose, which is a linear component, and the other type is amylopectin, which is a branching component (García *et al.*, 2015). The fundamental starch structure is amorphous, consisting of amylose and an inter-crystalline zone of dense cross-branched amylopectin and such morphology is responsible for the thermal, plasticization, and rheological properties of the starch (Ochoa *et al.*, 2016). In native starch, amylopectin chain length and chain ramification determine the granule crystallinity (Ochoa *et al.*, 2016). The native structure of starch is not suitable for industrial applications, because of its brittle nature and poor mechanical and rheological properties (Sung *et al.*, 2013). Plasticizers are substrates with low molecular weight which when introduced into the starch matrices, can enhance the flexibility and processability of polymeric compounds by decreasing the hydrogen bonding of the starch-starch molecules (Liu *et al.*, 2004). Plasticizers on the other hand can influence the physical properties of the processed starch by controlling its collapsing rate and depolymerization (Ochoa *et al.*, 2016). The amount of amylopectin and amylose has a major impact on the distinctive features of starch (Prabhu & Prashantha, 2018). The potato starch contains 80% amylopectin and 20% amylose (Tarte & Rodrigo, 2009). Most commonly known starch-sugar based bioplastics are polylactic acid (PLA) and poly-hydroxyalkanoates (PHA) (Barker & Stafford, 2009; Momani 2009). Starch is widely utilized as a biopolymer due to its ample availability, ability to naturally break down, and cost-effectiveness (Kharb & Saharan, 2022). Currently, starch and thermoplastic starches are utilized in diverse industries like medicines, packing food, horticultural and agricultural technology, textiles, paint, building, paper and cardboard industries, and automotive industries (Liew & Khor, 2015). Starch-based biodegradable polymers have been widely utilized in the manufacturing of films, grocery bags, food storage containers (such as cups, plates, and trays), overwraps, and sanitary goods (Kharb & Saharan, 2022). Starch-based biopolymers have been acquired as packaging materials for food goods (Ferreira *et al.*, 2016). Starch and polymer mixes have been effectively employed in the medical field to create films for drug release, bone cement, and other applications (Çalgeris *et al.*, 2012).

MATERIALS AND METHODS

The local potatoes (Solanum tuberossum) were bought from a local market from Butwal. The chemical used for this study are Hydrochloric acid, Vinegar, Glycerol, Sodium hydroxide, Sulphuric acid, Phenol, Acetone, Diethyl ether, Nitrobenzene, Chloroform, Ethanol, Picric avid, Bromine water, Aniline and Benzene.

Starch Extraction from Potato

600 grams of potato bought from Golpark, Butwal was weighted, washed, peeled, diced, blended, slurred, filtered and dried in oven at 45°C for 2 hours to obtain 40-gram powdered starch.

Figure 1: Steps of starch extraction from potato

Synthesis of Bioplastic

15-gram dry potato starch (monomer molecule) added in 60 mL of distilled water (solvent) in a beaker. 20 mL acetic acid (react with amylopectin of starch), was added. Then 15 mL glycerol (as plasticizer for elasticity) was added to mixture with constant stirring. The solution was kept undisturbed at 27°C for 25 minutes. The solution was heated over flame below 60°C with gentle stirring with glass rod, preventing the bubble formation. White insoluble starch starts to get dissolved and water evaporates to form thick gelatinous dense liquid. The hot thick transparent gelatinous dense liquid is spread over mold made from aluminum foil. It was dried in hot air oven at temperature of 120°C for 1 hour. Lower the temperature to 45°C and store inside oven for 3 days.

Figure 2: The synthesized bioplastic film

Biodegradability Test

The level of biodegradability of bioplastic films is indicated by weight loss (Hermaen *et al.*, 2016). Samples were dried at 45°C for 24 hours, it was weighted and buried in soil for 14 days. Finally, the final weight of sample was recorded. The biodegradability was measured from the following formula (Tan *et al.*, 2016).

Weight loss (%)= $(W_0 - W/W) * 100$

Where;
W_0 = Weight of sample before Test
W = Weight of sample after Test

Opacity Measurement
An UV- Visible spectrophotometer with wavelength 600 nm is often the chosen choice to measure absorbance (Balasubramanian *et al.*, 2019; Du *et al.*, 2020; Sirvio *et al.*, 2020; Tedeschi *et al.*, 2020). UV-VIS Spectrophotometer at 600 nm was used to determine the opacity of bioplastic films (4 × 1 cm) (Tunc & Duman, 2010). The blank cell was used as reference opacity (Priyadarshi *et al.*, 2018).
Opacity= Absorbance/Thickness

Water Absorption Test
The samples of varying weight were taken and put in a beaker with 100 mL water, kept there at 27 degrees centigrade for 1 hours and again weighted to record final weight.
Water Uptake= $(W_2 - W_1/W_1)$ * 100%
Where;
W_1 = Initial Weight of Sample
W_2 = Final Weight of Sample

Density Measurement
Few pieces of bioplastic samples were weighted. Water was poured into measuring cylinder and initial level of water was recorded. Pieces of bioplastic samples tied in fine thread was gently lowered into measuring cylinder, until it is completely immersed into water. Final volume of water in measuring cylinder was recorded. Density was measured at room temperature i.e. 27°C.
Volume of sample = Water level after immersion of sample – Water level before immersion of sample
Density= Mass/Volume

Thickness
Using screw gauge thickness was checked at different random points of bioplastic film. Linear scale, circular scale and error of circular scale was determined and thickness of sample was calculated using formula:
Thickness of Sample point= a + (b+c) * 0.001
Where;
a = Linear Scale of screw gauge (mm)
b = Circular Scale of screw Gauge (mm)
c = Error in Circular Scale (mm)
Average thickness= Sum of Mesured Value/Number of reading

Solubility Test
At 27°C small pieces of bioplastic was immersed into various organic and inorganic solvents taken in test-tube and slowly stirred with glass rod to check its solubility.

RESULTS AND DISCUSSIONS

Table 1: Physical properties of bioplastic obtained through manual sensory evaluation

Strength	Medium flexible
Color	Slightly white
Odor	Vinegar smell
Surface	Smooth and slightly sticky

Table 2: Solubility test of bioplastic samples in different organic and inorganic reagents

S. N	Solvent	Solubility
1	Diethyl ether	-
2	Nitrobenzene	-
3	Phenol	+
4	Acetaldehyde	-
5	Benzene	-
6	Chloroform	-
7	Ethanol	-
8	Acetone	-
9	Picric acid	-
10	Aniline	-
11	Bromine water	-
12	Conc. HCl	+
13	Conc. H_2SO_4	+
14	NaOH	-
15	Water	-

+ = *Soluble* - = *Insoluble*

The bioplastic was insoluble in water which is green signal for its utility in real world as a plastic material. Moreover, it was not able to solvate in wide variety of organic compound which also supports for its application in organic products. However, in extreme high concentrations it corroded and ultimately dissolved in sulphuric acid and hydrochloric acids indicating it is limited for use with mild and soft reagents.

Figure 3: Demonstration of Solubility Test

Table 3: Calculation of weight loss percentage per two weeks to find out degradability rate of synthesized bioplastic samples

Sample	**Weight loss percentage**
A	68.47
B	68.53
C	68.23
D	71.91
Average	69.28
Standard deviation	1.52
Total	**69.28 ± 1.52**

In our research, the biodegradability weight loss percentage was found to be 69.28±1.52 % per 14 days which is 49.48% weight loss per 10 days which was in good agreement with Nigam *et al.* (2021) who performed research on Synthesis, characterization and biodegradation of bioplastic films produced from Parthenium hysterophorus by incorporating a plasticizer (PEG 600).

Our research diverges from those of, Ismail *et al.* (2016) who reported higher degree of biodegradation which. This indicates population of microorganism and soil conditions can vary the rate of degradation of bioplastic. As the starch content consumed by soil microorganisms will fracture the polymer chain thus cause the biodegradation (Khoramnejadian *et al.*, 2013).

Figure 4: Demonstration of biodegradability test

Table 4: Calculation table to calculate water absorption capacity of synthesized bioplastic per hour at 27°C

Sample	**Water uptake percentage**
A	79.16
B	81.81
C	82.6
D	80.77
Average	81.08
Standard deviation	1.28
Total	**81.08 ± 1.28**

The data revealed that the bioplastic have high water absorption property of 81.08 ± 1.28% per hour when completely immersed inside water which further justified that starch molecules are hydrophobic in nature. Thus, starch-based bioplastics can be applied for the purpose of moisture absorption from variety of matters and materials.

Figure 5: Demonstration of water absorption capacity test

Table 5: Calculation table to measure density at 27°C

Sample	**Mass (g)**	**Volume (mL)**	**Density**
A	0.37	0.3	1.23
B	0.25	0.2	1.25
C	0.48	0.4	1.2
D	0.46	0.4	1.15
Average			1.2075
Standard deviation			0.04
Total			**1.20 ± 0.04**

In our research the density of starch derived bioplastic was 1.20 ± 0.04 g/cc which has similar agreement with the (Abdullah *et al.*, 2019) where they have characterized Poly Lactic Acid Starch based bioplastic composites finding the density to be 1.3 g/cc. This indicate that bioplastic is denser than water and explains its property of sinking completely in water.

Figure 6: Demonstration of density measurement

Table 6: Calculation of thickness of synthesized bioplastic in (mm) using screw gauge

Sample	Linear scale	Circular scale	Thickness
A	3	73	3.78
B	3	39	3.44
C	3	9	3.14
D	2	79	2.84
Average			3.45
Standard deviation			0.26
Total			**3.45 ± 0.26**

In our experiment the average thickness of bioplastic was measured 3.45 ± 0.2614 mm.

Figure 7: Demonstration of density measurement

Table 7: Opacity measurement of bioplastic using UV-visible spectrophotometer at 600 nm wavelength

Sample	Absorbance at 600 nm (Au)
A	1.46
B	1.45
C	1.46
Average	1.45
Standard deviation	0.004
Total	**1.45 ± 0.004**

Opacity = Absorbance/thickness
=1.45/3.45
=0.42 AUmm-1
The sample has low opacity of 0.42 Aumm-1. A high value of opacity indicates that the specimen has low transparency (Hermawan *et al.*, 2019). In this research we observed bioplastic's transparent property is dominant and it is in good agreement with the fact that our starch based bioplastic film can be used for food packaging. The ideal food packaging should be inexpensive, easy to process, with good barrier properties to prevent water loss and to protect food from O_2 and moisture, mechanically resistant, transparent, fabricated with renewable sources, recyclable after use, and biodegradable (Yadav & Chiu, 2019).

Figure 8: Measurement of absorbance using UV visible spectroscopy

CONCLUSION

This research aims not only to synthesize bioplastic from starch molecule but also to characterize its basic properties. The main finding of this study shows the bioplastic is more dense than water and it easily sink into it so it do not disturb water animals in their movement It's products will not accumulate waste on water surface. Similarly, it's high degradability rate helps it to completely eliminate from environment. It can be beneficial in making coverings that absorb moisture and prevent damage of food and materials from wet atmospheric air. Moreover, it's insoluble property in wide variety of organic compounds including water, less opacity makes it appropriate to make food packaging material. It can be introduced as alternative solution of petroleum-based plastics.

Recommendation

By continuous research and experiments, further efforts should be made to discover variety renewable organic molecules in order to produce better bioplastics which are widely applicable as well as economical in day-to-day life.

Author Contributions

Krishna G. and Arjun B. were Conceptualization, methodology writing, original draft preparation, project administration. Prakash G. was investigation, validation, review and editing. Finally all authors were review and manuscript finalized.

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