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Study of Microbial Degradation of Bioplastic Sheets Prepared by Using Natural Polymer-Corn Starch

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ABSTRACT

Interest in creating eco-friendly substitutes like bioplastics has increased as a result of growing environmental concerns about non-biodegradable plastics. The microbial breakdown of bioplastic sheets made with natural polymers, such as corn starch, is investigated in the present research work. Bioplastic sheets made from corn starch, a renewable and biodegradable material, were examined under controlled microbiological experiments for their physical characteristics, biodegradability, and structural integrity. The corn starch bioplastic can be added with functional ingredients, for instance, antimicrobial and antioxidant agents, or color and flavor ingredients.

The use of glycerol as a plasticizer gives flexibility to sheets and modifies the physical characteristics of starch-based sheets and coatings. Sheets prepared with starch are colorless and odorless, and the diameter of the sheets is 7.5 cm. Prepared sheets without homogenizer (white vinegar) are uneven and those with homogenizer (white vinegar) are even. Also performed SEM (scanning electron microscopy) to check the surface of bioplastic sheets.

Microorganisms degrade natural polymers and synthetic polymers through a process called biodegradation. The study investigates the microbial degradation of bioplastic sheets made from natural polymers like corn starch. For this study, soil samples were selected as a source of potential microbes having degradation ability naturally. After the biodegradation study, bioplastic sheets were tested for structural integrity and physical properties under controlled experimental conditions. Results showed significant microbial degradation of bioplastic sheets and their potential as sustainable substitutes for traditional plastics. The significance of bioplastics derived from natural polymers in combating plastic pollution and advancing a circular bioeconomy is highlighted by the current research study.

INTRODUCTION

Plastics are widely used in various industries, including packaging, toy making, supermarket bags, cutlery, straws, and 3D-printed rocket nozzles (Gilbert, 2016). Naphtha is a critical component for producing monomers like ethylene, propylene, and styrene, which are then used to make plastics. Plastics are formed by polyaddition and/or polycondensation of monomers using particular catalysts (Armand, 1994). However, this conversion emits pollutants and greenhouse gases, including CO2, which contribute to environmental pollution and global warming. Furthermore, some petroleum-based plastics are not biodegradable, causing them to remain in landfills and harm the environment (Tokiwa et al., 2009). The environmental issues caused by discarded synthetic plastics have led to the search for bioplastics, which are functionally similar to synthetic plastics and environmentally sustainable. Studies suggest bioplastics as an environmentally sustainable alternative to conventional petroleum-based plastics (Atiwesh et al., 2021). Bioplastics are produced from biological materials or renewable feedstock and have degradability times ranging from several days to several years, making their development a promising new material (Bhandari & Gupta, 2018) (Brookfield, 1984; Iwata, 2015).

Bioplastics, often pushed as eco-friendly alternatives to conventional plastics, have been a subject of controversy due to their environmental impact. Biodegradable bioplastics made from natural polymers can decompose into natural materials through microbial mechanisms, blending harmlessly into soil (Licciardello & Piergiovanni, 2020). However, some low-degradable or nondegradable bioplastics only break down at high temperatures or in specific landfill sites, producing methane gas, a potent greenhouse gas. Producing bioplastics from plants like corn and maize has eco-friendly characteristics, such as saving energy and emitting 70% less greenhouse gases when degraded in landfills. This suggests that future production of new bioplastics can be achieved using renewable energy while significantly reducing greenhouse gas emissions (Atiwesh et al., 2021), (Ruggero et al., 2019).

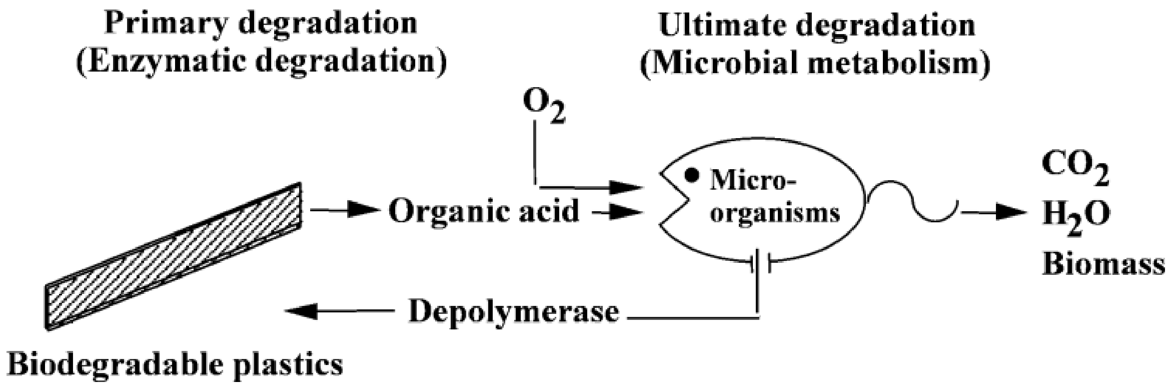


Figure 1: Biodegradation routes of bioplastics (Source : (Iwata, 2015)**)**

Bioplastics are gaining interest as an alternative to fossil-based plastics. In addition, biodegradable bioplastics may yield biogas after their use, giving an additional benefit (Shrestha et al., 2020), (Adhikari et al., 2016), (Trivedi et al., 2016). Microorganisms can consume natural polymers such as starch, cellulose, and starch-based polymers through enzymatic processes in extracellular environments (outside the cells) (Figure 1). Enzymes split polymer chains, and tiny parts are absorbed by cells. Hydrolysis can enhance the biodegradation rate of polymers by causing random chain scission, resulting in fast molecular weight reduction. Smaller molecules are more sensitive to enzyme attack, leading to quicker polymer degradation (Kale et al., 2007). The current study has focused on the microbial breakdown of bioplastic sheets composed of natural polymers, such as maize starch, following the scenario mentioned above. Because of its abundance, affordability, and environmental friendliness, this naturally occurring polymer generated from plants can be used to create biodegradable polymers (Wahyuningtyas & Suryanto, 2017), (Amin et al., 2019).

Corn is a tropical grain plant that was first domesticated approximately 8,000 years ago. Recently, demand for maize has soared dramatically for use in the creation of various foods and edible oils, as well as the manufacture of bio compounds and biopolymers.

Corn is a rich source of starch, a biodegradable polymer widely used in industries such as food, pharmaceuticals, textiles, biomass energy, and chemicals. The starch is biodegradable in various conditions and can enable the production of completely biodegradable products based on specific market requirements.

This paper focuses on maize plants as a source of biodegradable polymers and fiber-based biochemicals, along with their potential applications (Sapuan & Sulaiman, 2020).

Material and methods

2.1 Preparation of corn starch based on a bioplastic sheet:

Bioplastic sheets are prepared through the following steps: In the initial stage, corn starch is weighed, and corn starch mixed with hot water for homogenization is put into a magnetic stirrer. Then, glycerol is added as a plasticizer, and vinegar is added. The whole solution is at 60° C for 10 to 15 min. The slurry is then put into the plate, and the plate is incubated in a hot air oven for 30 min. The plate is then removed, and it is dried. The sheets were prepared into uniform sizes (5 cm x 5 cm) for testing (REF).

2.2 Biodegradation studies

2.2.1 Collection of soil sample:

The soil samples were collected from the rhizospheric area of the plants, from the garden of YCIS Satara.

2.2.2 Preparation of minimal medium:

A minimal medium is made by carefully measuring and combining certain ingredients to produce a nutrient-limited environment that is favorable to microbial growth. The minimum medium is composed of 0.1 g of ammonium sulfate, 0.05 g of sodium citrate, 0.01 g of $MgSO_4$, 0.7 g of K_2HPO_4, and 0.2 g of KH_2PO_4 the medium's pH is adjusted to 7.2 ± 2 (Article & Access, 2023). Distilled water makes up the entire volume, which is 100 ml. After preparation, the medium is sterilized.

2.2.3 Design of the bioplastic degradation experiment:

The purpose of the experiment was to assess how bioplastic sheets degraded under various circumstances. The following three experimental configurations were made:

A minimal medium containing soil suspension and bioplastic sheets was contained in Flask 1. The bioplastic sheets and synthetic plastic sheets were suspended in flask two containing soil suspension in a minimal medium, while flask three contained synthetic plastic sheets suspended minimal medium containing soil suspension. Using bioplastic sheets as the only carbon source, a minimum media was created to evaluate biodegradation. A sample of soil was used to inoculate this medium, acting as a natural supply of potential microorganisms that could break down bioplastics. To assess weight loss and structural alterations in the bioplastic sheets, which suggest microbial deterioration, observations were made at 24 and 48 hours (Amin et al., 2019).

Result and discussion

Preparation of corn starch based on a bioplastic sheets:

In order to evaluate microbial deterioration over time, a biodegradation study using bioplastic sheets based on corn starch was carried out under various conditions. Using vinegar as an adjuvant and glycerol as a plasticizer, the corn starch-based bioplastic sheets were effectively made. The sheets were dried and trimmed into uniform sizes (5 cm × 5 cm) for additional testing after being homogenized and incubated.

3.2 Biodegradation studies

Potential microbial degraders were found in the rhizospheric soil that was taken from the YCIS Satara garden. In order to make a regulated, nutrient-limited environment, the minimal medium was effectively made with the required composition. To facilitate microbial activity, the medium was sterilized and kept at a pH of 7.2 ± 2. Experiment on bioplastic degradation over the course of 24 and 48 hours, the weight loss and structural alterations in bioplastic sheets were noted.

Significant weight loss and surface deterioration were noted in Flask 1 (Bioplastic + Soil Suspension), suggesting microbial activity on the bioplastic sheets. Bioplastic sheets showed a relatively reduced rate of breakdown in Flask 2 (Bioplastic + Synthetic Plastic + Soil Suspension), possibly as a result of competition or interference from synthetic plastic sheets. Flask 3 (Synthetic Plastic + Soil Suspension), the synthetic plastic sheets showed no discernible alterations, indicating that they are resistant to microbial deterioration. Degradation indicators such as surface roughness, thinning, and weight loss over time were evident in the bioplastic sheets. In Flask 1, where bioplastic was the only carbon source, the degradation process was more noticeable, indicating efficient microbial utilization. Flask 2's synthetic plastic content might have impacted microbial efficiency, resulting in less breakdown. Flask 3's synthetic plastic did not change, indicating that it is not biodegradable. These findings suggest that bioplastics derived from corn starch can be broken down by soil bacteria, making them a sustainable substitute for synthetic plastics (Figure 2 & 3).

a

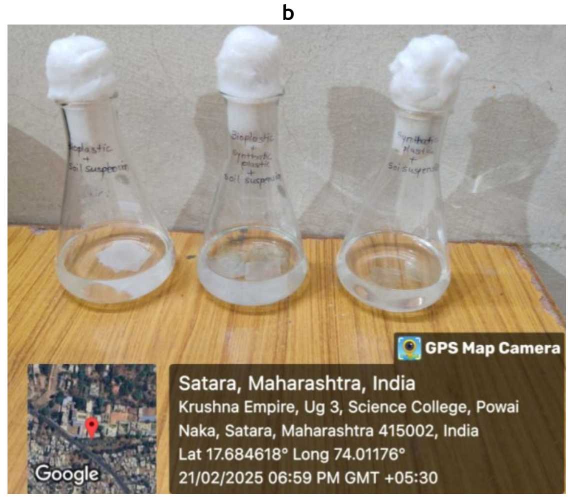
b

Figure 2: Results of After 24 hrs

a

b

c



d

Figure 3: Results After 48 hrs

DISCUSSION

The current study assessed the biodegradation capacity of maize starch-based bioplastic sheets under a variety of circumstances. The findings show that soil microorganisms play a substantial role in bioplastic degradation, as shown by the weight loss and structural changes observed in Flasks 1 and 2. The bioplastic sheets in Flask 1 (bioplastic + soil suspension) showed evident weight loss and surface degradation, demonstrating that the native soil bacteria could break down the bioplastic material. The addition of starch-based components likely increased the bioplastics' susceptibility to microbial enzymatic activity. In Flask 2 (bioplastic + synthetic plastic + soil suspension), bioplastic degradation was slower than in Flask 1. This shows that the presence of synthetic plastic may have had an impact on microbial activity, either by changing microbial colonization or nutritional availability. The rivalry between microorganisms that use bioplastics and those that use synthetic plastics may have resulted in decreased effectiveness in bioplastic degradation. The synthetic plastic in Flask 3 remained unaltered, with no substantial weight loss or structural alterations. This confirms its resistance to microbial deterioration within the specified duration. Unlike bioplastics, conventional plastics lack easily hydrolyzable linkages, making them extremely persistent in the environment. The observed weight loss and surface modifications in bioplastic sheets indicated the existence of microbial activity in the rhizosphere. Microbial enzymes that break down starch-based polymers, such as amylases and esterases, are most likely to facilitate the breakdown. The degree of breakdown indicates that maize starch-based bioplastics are biodegradable under natural settings, offering them a potentially eco-friendly alternative to traditional plastics. The study's findings show the promise of maize starch-based bioplastics as a sustainable alternative to standard plastics. Because of their capacity to decompose in natural soil conditions, they could help minimise plastic pollution if used in place of non-biodegradable plastics. However, environmental circumstances, microbial variety, and the presence of other materials can all have an impact on the pace of breakdown. Bioplastics, often touted as superior alternatives to traditional plastics, are gaining attention for their environmental impact and potential limitations (Atiwesh et al., 2021). The research aims to develop biodegradable thermoplastics from soy protein isolate and maize starch, offering practical applications in environmentally friendly decomposition. By blending biodegradable plastic with polyphosphate fillers, water sensitivity is reduced, enabling new applications in damp and load-bearing settings where unfilled biodegradable plastic is ineffective (Brookfield, 1984). The study compared bioplastic film and polylactic acid coffee capsules, finding bioplastic film produced more biogas but had less than 50% biodegradability, making it unsuitable for current biogas digesters (Shrestha et al., 2020). The study investigates cassava starch's role in bioplastics, highlighting the impact of glycerol on microbial degradation, revealing that high glycerol concentration accelerates degradation, increases moisture, and extends shelf life (Wahyuningtyas & Suryanto, 2017). Bioplastics, made from renewable resources like agricultural waste, offer alternatives to conventional plastics due to their biodegradability, influenced by their structure, environmental conditions, and microbial communities (Emadian et al., 2017). The study investigates the use of starch-based biodegradable materials like cassava, corn, and potato in producing bioplastic sheets, revealing cassava-based sheets as the most water-resistant (Sujuthi & Liew, 2016).

CONCLUSION

This research provides important insights into the microbial degradation of bioplastic sheets manufactured from natural maize starch polymer. The findings show that bioplastics generated from maize starch may be successfully broken down by certain microbial strains, indicating their potential as ecologically friendly alternatives to conventional plastics. The degradation process was impacted by a variety of parameters, including microbe type, ambient conditions (temperature, humidity), and bioplastic composition. The findings imply that, while microbial degradation of maize starch-based bioplastics is promising, there are issues with the rate of degradation, which varies depending on the species utilized. More study is needed to optimize the environment and microbial strains for increased degradation efficiency. Furthermore, future research should look into the environmental impact of bioplastic degradation, such as soil health and potential degradation byproducts. Finally, maize starch-based bioplastics have significant potential as sustainable packaging solutions, providing an environmentally benign alternative to petroleum-based plastics. Microbial breakdown of these bioplastics has the potential to drastically reduce plastic waste and the total environmental footprint, paving the path for the future of biodegradable materials.

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