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Research Article

ENHANCING FUNCTIONAL PROPERTIES OF BIOPLASTIC FILMS: SOLUBILITY, DEGRADABILITY AND ANTIMICROBIAL EFFICACY

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ABSTRACT

The ever-increasing demand of plastics in the world and their consequent disastrous effects on environment, a suitable environmental-friendly substitute like bioplastics/biodegradable plastics is the need time. Biobased plastics or bioplastics are made from renewable resources, such as corn, potatoes, soy, sugarcane, yam, wheat, and vegetable oil. With the price of oil rising and scarce resources of petroleum, tremendous efforts are being put by researchers to explore a proper and proven alternative to petroleum-based plastics (bio-waste, starch, cellulose, etc). Bio-based, biodegradable and recycled plastic are referred to as the sustainable plastic. Demands of such category have its root the recent changes and the wave of sustainability in the society.

INTRODUCTION

Plastics have become an essential part of modern society. Many of the products we use in our daily lives are made of plastics. Plastics are crucial in various industries like transportation, food, healthcare, and energy.

However, population growth and increasing demand for goods have led to a substantial increase in plastic production, leading to the generation of massive quantities of plastic waste and environmental concerns, including the emission of greenhouse gases (GHGs). Only around 9% of the plastic waste produced is recycled, causing the remaining untreated plastic waste to accumulate in our lands and oceans. This accumulation is causing severe harm to the environment, plants, and animals, as well as posing risks to human health.

In order to address these challenges, it is necessary to explore and implement alternative, sustainable methods where non-renewable resource use is minimized and materials are reused and recycled. One promising approach involves using biomass as renewable raw materials. This type of plastic is known as bioplastic. (Sanju Tamang, 2023)

The global environmental crisis driven by plastic pollution has intensified the search for sustainable alternatives to conventional petroleum-based plastics. Bioplastics, derived from renewable biological sources, present a promising solution due to their potential for biodegradability and reduced ecological footprint. However, for bioplastics to be viable replacements, they must meet specific functional requirements, including solubility control, degradability, and antimicrobial efficacy, particularly for applications such as food packaging.

Degradability is a critical aspect of bioplastics, as it ensures that these materials can break down in natural environments, thereby mitigating long-term pollution issues. Studies have demonstrated that bioplastics can be engineered to degrade under specific conditions, utilizing microbial activity in soil or compost environments. The addition of natural fillers and nanocomposites not only improves mechanical properties but also accelerates the biodegradation process by enhancing microbial interactions (Jessica R et al;2023)

This paper aims to explore the development of antimicrobial plastics by examining various methods of incorporating antimicrobial agents into polymer matrices and evaluating their effectiveness. We will focus on the synthesis, characterization, and performance testing of these materials to determine their potential applications in reducing microbial contamination and enhancing public health safety. By advancing the understanding and capabilities of antimicrobial plastics, this research contributes to addressing both environmental sustainability and health concerns associated with traditional plastic use.

Bioplastics are typically made from natural polymers such as starch, cellulose, polylactic acid (PLA), and polyhydroxyalkanoates (PHA). These materials exhibit unique solubility characteristics based on their molecular structure and the nature of their functional groups. The solubility behaviour

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of bioplastics in organic solvents is not only essential for their processing but also for their end-use performance in applications such as packaging, coatings, and biomedical devices.(Miksch *et al*;2022)

Solubility testing involves exposing bioplastic samples to various organic solvents to observe their dissolution behaviour. Common solvents used in these tests include ethanol, acetone, chloroform, and toluene, among others. The solubility data can provide insights into the interaction between the bioplastic polymers and solvents, which is influenced by factors such as polarity, hydrogen bonding capability, and molecular weight of the polymers.

For instance, PLA, a widely studied bioplastic, exhibits good solubility in solvents like chloroform and dichloromethane due to its polar ester groups, which interact favourably with these solvents. Conversely, PLA shows limited solubility in non-polar solvents like hexane and toluene. Similarly, bioplastics based on starch are more soluble in polar solvents due to the hydroxyl groups present in their structure, which form hydrogen bonds with the solvents (Ikramullah *et a*l., 2022)

This paper aims to investigate the solubility of various bioplastic formulations in different organic solvents. By systematically testing and analysing the dissolution behaviour, we seek to understand the factors influencing solubility and identify suitable solvent systems for bioplastic processing and applications. The findings from this study will contribute to optimizing bioplastic production techniques and expanding their practical applications while ensuring environmental sustainability.

MATERIALS AND METHOD

Materials

1. Banana peels and corn starch powder (rich sources of starch)
2. Glycerol
3. ZnO (zinc oxide) as a antimicrobial agent
4. Citric acid / acetic acid (to impart strength)
5. Water

Method

A. Banana Peel starch

A.1. ***Extraction of starch from Banana Peel***

- Rinse the banana peel under running water to remove any dirt or residue.
- Cut the peel into small pieces to increase the surface area for extraction.
- Blend the pieces of banana peel with water to form a slurry.
- Pour the slurry through a filter paper to separate the liquid from the solid pulp.
- Allow the liquid to settle in a container for some time. Starch will settle at the bottom while other. Let it dry.
- Once dried, grind the starch into a fine powder using a mortar and pestle or a food processor

A.2. ***Addition of materials and production of bioplastics***

- In 25 gram of banana peels paste add 3ml of glycerol and stir it evenly. Then add 2ml of citric acid with constant stirring.
- Then pour it on fibre plate and spread in thin film of the paste
- Let it dry in a direct sunlight for 24-30 hours or dry it in hot air oven for 160°C.
- Then after complete drying of sample a plastic film is formed and is scraped off from the plates.

B. Corn starch

B.1. ***Extraction of corn starch from corn***

- Soak the corn kernels in water for several hours or overnight. This helps to soften the kernels and loosen the starch. Grind the soaked corn kernels into a fine paste.
- Pour the mixture through a fine mesh sieve or cheesecloth to separate the suspended starch from the liquid and solid particles. The starch to settle at the bottom of the container.

B.2. ***Addition of materials and production of bioplastics***

- Extract corn starch from corn.
- In 25 gram of corn starch add 10ml of water, 3ml of glycerol and 2ml of citric acid.
- Then heat it to form a semi-solid structure.
- Pour it and make a thin layer of the paste by spreading it, let it dry in direct sunlight for 15 to 20 hours. (M. K. Marichelvam 2019), (Rizwana Beevi. K 2020]

Solubility Test

A solubility test was also seldom used for the estimation of the soluble fraction of the bioplastic. We have used organic solvents such as Ethyl Alcohol, Acetone, Acetic Acid and mineral acid that is Sulphuric Acid.

Banana peel Bioplastic Sample Corn Starch Bioplastic

An estimated amount of corn starch was heated with 100ml of water in a beaker for 20mins.In this, 3 grams of rice husk and lotus leaf powder was added. These served as ller in plastic. Along with this, 0.1N HCl, 3ml of glycerol and 2ml of vinegar was added and mixed thoroughly. Then the concentrate was spreaded over the silver foil and kept in hot air oven for 1hr at 150°C After drying in oven, the plastic sheets were cooled at room temperature for 30 minute

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RESULT

- Insoluble - ethyl alcohol, acetic acid, acetone {banana peel& corn starch bioplastic}
- Soluble - sulphuric acid {banana peel & corn starch bioplastic.

Degradability Test

An estimated amount of corn starch was heated with 100ml of water in a beaker for 20mins.In this, 3 grams of rice husk and lotus leaf powder was added. These served as 洰ller in plastic. Along with this, 0.1N HCl, 3ml of glycerol and 2ml of vinegar was added and mixed thoroughly. Then the concentrate was spreaded over the silver foil and kept in hot air oven for 1hr at 150^{o}C After drying in oven, the plastic sheets were cooled at room temperature for 30 minute.

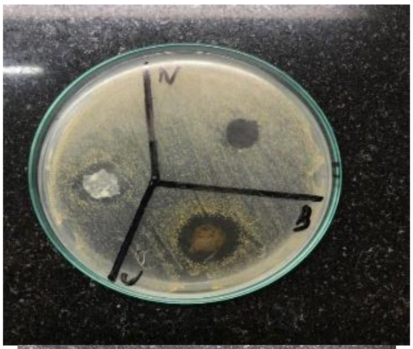
Degradability testing plays a crucial role in improving, and ensuring the environmental sustainability of starch-based bioplastics throughout their lifecycle, from production to disposal.[Pooja, N., Chakraborty, I., Rahman, M.H. et al. **13**, 220 (2023).]

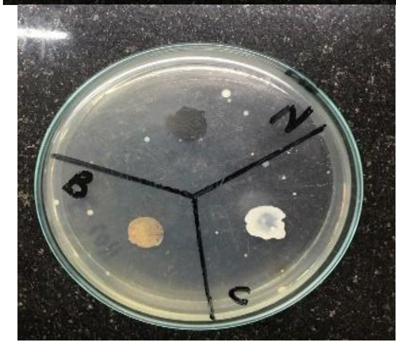
Antimicrobial test

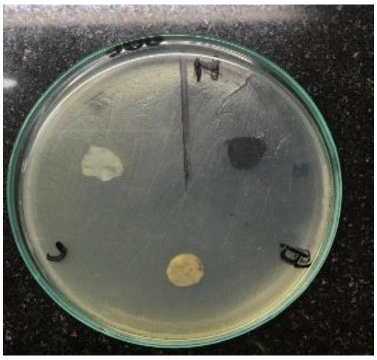
Antimicrobial test is essential to ensure the safety and quality of bioplastics. As the food packaging and other application raises concerns about the potential for microbial contamination.

Optimization

Based on the results of the study, the production process will be optimized to improve the antimicrobial properties of the bioplastics. This may involve adjusting the composition of the bioplastics, change the production process, or using additives to enhance the antimicrobial properties. (Lisman *et al*; 2021)







CONCLUSION

The biodegradability makes the bioplastic more environmentally friendly option compared to conventional plastics which contributes to plastic pollution and environmental issues.

The Solubility Test can indicate the biodegradability of bioplastics, as some polymers dissolve in specific environment. understanding how bioplastics with different solvents contributing to its applications versatility, such as coating, packing or medical devices.

The Antimicrobial Test indicates that the bioplastic is resistant to the above organisms thus ensures the safety and quality of bioplastic.

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