PREPARATION OF CELLULOSE-BASED DEGRADABLE BIOPOLYMER USING PINEAPPLE WASTE

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Abstract

The growing environmental challenges posed by plastic waste has prompted the search for sustainable alternatives that can reduce ecological impact. The present study explores the development of a biodegradable plastic from pineapple peel, an agricultural waste product that is often discarded. By utilizing the natural polysaccharides present in the peel, a strong and completely degradable biopolymer is created, offering a sustainable alternative to conventional plastics. The procedure incorporates glycerol as a plasticizer, enhancing the material's flexibility and durability. This approach not only addresses plastic pollution but also contributes to waste valorization, turning pineapple peel into a high-value product. The use of agricultural byproducts for bioplastic production offers a promising solution for environmental applications, mitigating plastic pollution and promoting sustainable materials for a healthier planet.

Keywords: *Bioplastic Polymer, Glycerol, Degradation, Environment, Waste Management*

Introduction

Plastics have become an integral part of modern life. They are widely used in daily activities, including packaging, cosmetics, pharmaceuticals, food, and brewing industries. The term plastic is derived from the word 'pliable,' meaning 'easily shaped.' Plastics can be reshaped based on their intended function. They are also referred to as polymers, which consist of long chains of monomers that bond together to form a polymer (Evode Niyitanga, et al., 2021). Due to their exceptional physical and chemical properties, plastics have become a widely used commodity globally, serving various industrial and commercial purposes. This growing demand has contributed to an increase in large-scale plastic production worldwide (Frienkel, Susan, 2020).

Despite their utility, plastics pose significant environmental challenges due to improper waste management and their production process. Studies indicate that approximately 60-99 million metric tonnes of plastic waste are mismanaged (Lebreton, L. et al., 2019), with only 9% of this waste being recycled. Around 80% of generated plastic waste accumulates in landfills or the natural environment (Asgher, et al., 2015). The non-biodegradable nature of plastics leads to environmental hazards, such as clogged drainage systems in urban areas and broader ecological concerns (Evode Niyitanga, et al., 2021).

As plastics continue to be extensively used, there is an urgent need for effective plastic waste disposal methods. The demand for biodegradable plastics and environmentally friendly plastic degradation techniques has significantly increased in recent years (S Bonhomme et al., 2003).

A viable solution to this issue is the adoption of sustainable alternative technologies that help mitigate environmental damage while enhancing the economic value of discarded waste materials (Yaradoddi, Jayachandra, et al., 2016). Bioplastics are a potential alternative with reduced environmental impact. One promising biopolymer for bioplastic production is cellulose, which is abundant and can be extracted from fruit waste. An example of such waste is pineapple (Ananas comosus), a highly valuable tropical fruit. During pineapple processing, waste materials such as peels and stems are discarded, accounting for nearly 50% of the total fruit weight. Additionally, pineapple peels contain about 25% cellulose (Dai, H. et al., 2018). This study focuses on producing bioplastics from pineapple peels by utilizing their natural components and converting them into a valuable product. This approach offers an eco-friendly solution to address the long-term problems associated with plastic pollution.

Materials and Methods

The process of developing biodegradable plastics from pineapple peel involves multiple stages, from biopolymer preparation to assessing its biodegradability.

Collection and Processing of Pineapple Peel Waste

Initially, peels were sourced from various local fruit vendors. The collected peels were weighed, and 100 grams were blended mechanically to break down the complex structure, aiding in polymer extraction. The resulting paste was then heated at 60°C for 40 minutes in a hot air oven to reduce moisture content.

Production of Bioplastic Film

A mixture of 12 ml of 0.24 M HCl and 8 ml of glycerol was added to the processed material and stirred using a glass rod. This blend was poured onto a mold, ensuring a uniform thickness of 0.5 mm. The sheets were then placed in a hot air oven at 70°C for 24 hours to solidify (Jayachandra S. Yaradoddi et al., 2022).

To enhance the flexibility and durability of the biopolymer, additional plant waste materials such as rice bran and sugarcane bagasse were incorporated.

Pineapple Peel and Rice Bran

Pineapple peels were blended with 5 grams of rice bran powder and processed into a paste following the same methodology as mentioned earlier.

Pineapple Peel and Sugarcane Bagasse

Equal portions of pineapple peel and sugarcane bagasse were blended into a paste. A mixture of 12 ml of 0.24 M HCl and 8 ml of glycerol was added as a plasticizer and stirred thoroughly. The mixture was poured onto a mold with uniform thickness and then placed in a hot air oven at 70°C for 24 hours to set.

Biodegradability Test

A biodegradability assessment was conducted by using conventional PVC plastic of 0.2 mm thickness (Fig 2b) as a control, while the bioplastic derived from pineapple peel (Fig 2a) was used as the test sample. Both control and bioplastic samples were cut into equal sizes, and their initial weights were recorded before being buried (Fig 2c). The weight loss was monitored and recorded on days 1, 5, and 8 (Table 1).

Results and Discussions

The present study assessed various plant based materials, namely, pineapple peel, rice bran, and sugarcane bagasse, as biopolymers for production of eco-friendly plastic. The present study also assessed the properties of the biopolymer based on the plasticizer concentration, durability and flexibility when integrated with other bio-wastes, and its biodegradability in soil with respect to conventional synthetic polymer.

Glycerol is an efficient and commonly used plasticizer with non-toxic properties. Concentration of glycerol (plasticizer) affects biopolymer texture and its production time.

Optimal concentration of glycerol needs to be standardized as increasing glycerol concentration beyond a certain volume does not necessarily improve the mechanical properties of the bioplastic. Two distinct glycerol concentrations were analysed, upon mixing with 100 grams of pineapple peel each. The formulations included 8 ml and 100g; 16 ml and 100g. The outcomes displayed a remarkable variation in texture as well as mechanical properties (Graph 1). Visual examination revealed that the sample with 8 ml of glycerol had better texture as well as mechanical properties when compared to the sample with 16 ml of glycerol. It was observed that concentration of glycerol affected the time taken for plasticization. In the formulation of 8 ml per 100 grams, the bioplastic was obtained within 24 hours, while the 16ml per 100 grams took over 70 hours to plasticize (Graph 1).

Comparative analysis of best biopolymer combination

The composition consisting purely of pineapple peel with 8 ml glycerol displayed better durability than all the other combinations (Fig 1a). The composition with a ratio of 6:4 pineapple peel with sugarcane bagasse formulated displayed durability but very few signs of flexibility (Fig 1b). The composition formulated for pineapple peel and rice bran displayed no flexibility and durability (Fig 1c).

Evaluation of Biodegradability

The biodegradability of the sample composed of only pineapple peel (Fig 2a) is shown in Table 1. Percentage of degradation was calculated after Day 1 and Day 5 by the using following formula:

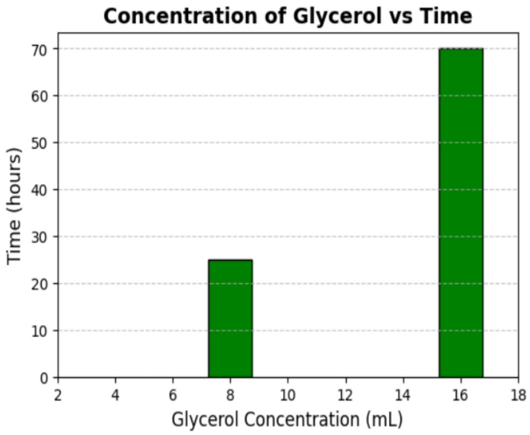
Biodegradability (%) = (initial weight - final weight) / initial weight X 100

The data was obtained by using the above formula, and the graphs were plotted to visualize the degradation trend.

Table 1: Biodegradability percentage of pineapple bioplastic and PVC control

Days	Plastic (control) (grams)	Biodegradability percentage (%)	Bioplastic (grams)	Biodegradability percentage (%)
Day 1	0.03	0	0.1	0
Day 5	0.03	0	0.08	20
Day 8	0.03	0	0.05	50

A steady degradation rate was observed until day 5 after which the degradation accelerated. The plotted graphs (Graph 2 and 3) therefore follow a non-linear trend and suggest breakdown of material at faster rate beyond day 5.



Graph 1: Effect of Varying Glycerol Concentrations on Production Time of Bioplastic

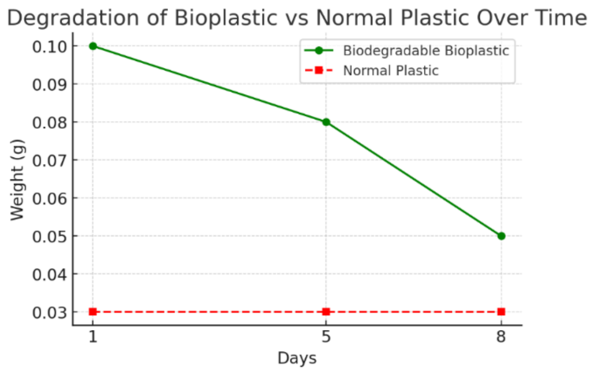
(a) (b) (c)

Figure 1: Bioplastics (a) Pineapple Peel (b) Pineapple Peel and Sugarcane Bagasse (c) Pineapple Peel and Rice Barn

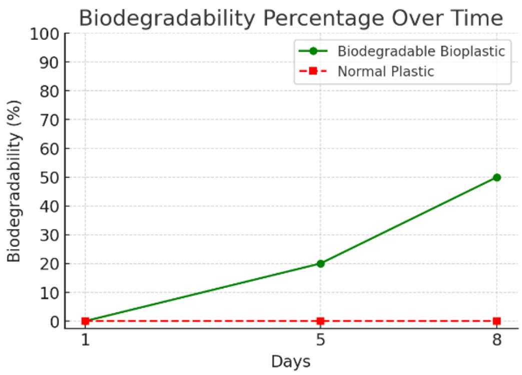
Comparing Bioplastic Texture as an Indicator of Durability and Flexibility

(a) (b) (c)

Figure 2: (a) Bioplastic, (b) Synthetic polymer, (c) Biodegradability test



Graph 2: Average Weight of Bioplastic and Control in Soil over Time



Graph 3: Biodegradability of Bioplastic and Control in Soil over Time

Conclusion

A bioplastic with high mechanical strength is a suitable alternative that is not just eco-friendly, but also an efficient waste management option. There is a need to produce and optimize biopolymers from plant waste to promote sustainability. It was observed that 8ml of glycerol for 100g of pure pineapple peel produces an effective bioplastic with good texture and biodegradability. Making bioplastics an alternative for traditional plastics can serve as a suitable option to curb plastic pollution and create a cleaner environment.

References

1. Asgher, M., Arshad, S., Qamar, S. A., & Khalid, N. (2015). Global plastic production rises, recycling lags. *Vital Signs, 22*(1), 91-95.
2. Bonhomme, S., Cuer, A., Delort, A.-M., Lemaire, J., Sancelme, M., & Scott, G. (2003). Environmental biodegradation of polyethylene. *Polymer Degradation and Stability, 81*(3), 389-393. https://doi.org/10.1016/S0141-3910(03)00129-0
3. Dai, H., Ou, S., Huang, Y., & et al. (2018). Utilization of pineapple peel for production of nanocellulose and film application. *Cellulose, 25*, 1743–1756.
4. Fienkel, S. (2020). *Plastics: A toxic love story.* Henry Holt.
5. Gourmelon, G. (2015). Global plastic production rises, recycling lags. *Vital Signs, 22*, 91-95.
6. Lebreton, L., & Andrady, A. (2019). Future scenarios of global plastic waste generation and disposal. *Palgrave Communications, 5*(1), 6.
7. Niyitanga, E., Qamar, S. A., Bilal, M., Barceló, D., & Iqbal, H. M. N. (2021). Plastic waste and its management strategies for environmental sustainability. *Case Studies in Chemical and Environmental Engineering, 4*, 100142.
8. Yaradoddi, J., Patil, V., Ganachari, S., Banapurmath, N., Hunashyal, A., & Shettar, A. (2016). Biodegradable plastic production from fruit waste material and its sustainable use for green applications. *International Journal of Pharmaceutical Research and Allied Sciences, 5*(4), 72-81.