Preparation of Bioplastic Films from Pineapple Stem Starch Reinforced with Natural Plasticizer

Manjudevi Mariappan, Vishnupriya Benaltraja*
Department of Biotechnology, Kongunadu Arts and Science College, G.N. Mills, Coimbatore, 641029, Tamil Nadu, India.
E-mail address: bvishnupriyabiotech@gmail.com

Abstract
Bioplastics have gained importance among petroleum-based polymers due to their non-hazardous properties. This study replaced biodegradable starch films manufactured from pineapple stem waste for non-sustainable petroleum-based films for recyclable applications with moderately high strength requirements. Starch was extracted from pineapple stem an agricultural waste. Solvent casting was used to generate starch-based bioplastic films with varying concentrations of beeswax as a plasticizer.

Keywords: *Stem, Starch, Biofilm, Plasticizer, Beeswax*

1. Introduction
Plastics are an essential part of modern life because of their unique qualities. These polymers are diverse and adaptable, which allows for the production of many products that improve human existence (Patti and Acierno. 2022). As a result, plastic production has increased dramatically in recent years. The most recent data from associations of plastic manufacturers was issued in 2019, and it revealed a 368-million-ton rise in plastic production globally (Prata *et al*., 2022). Fortunately, they tend to be detrimental to our ecology and the soul of our living soil due to their long-term survival on Earth and incapacity to biodegrade. (Chathalingath *et al*., 2023).

Conventional plastics are man-made materials composed of petroleum-derived polymers that are strong and eventually break down, depleting resources and contributing significantly to the accumulation of waste (Sohn *et al*., 2020). Moreover, burning plastic waste releases a lot of dangerous chemicals, including carbon dioxide, into the atmosphere, contributing to global warming. Entanglement, direct absorption of plastic waste, contact with toxins present in plastics, and disturbances of their biochemical processes can also cause harm to living organisms, particularly marine ones (Tuuri and Leterme., 2023). Over the years, efforts have been made to tackle these environmental issues on two different fronts: recycling currently available plastic items and finding new, ecologically favorable resources to replace conventional plastics. Khalid *et al*., 2022). Monomers like ethylene, propylene, and styrene, or non-renewable resources like petroleum-based raw materials, are used to make synthetic plastics. (Atiwesh *et al*., 2021).

Due to their inability to biodegrade or difficulty to dissolve, synthetic materials are used, which greatly adds to environmental contamination. (Shogren *et al*., 2019). Plastic-derived pollutants and microparticles are ubiquitous in our surroundings, posing a threat to human health and animal welfare (Ziani *et al*., 2023). Entanglement, direct absorption of plastic waste, contact with toxins present in plastics, and disturbances of their biochemical processes can also cause harm to living organisms, particularly marine ones (Ghaffar *et al*., 2022). Bioplastics have arisen as a potential replacement for conventional polymers and their applications. (Moshood *et al*., 2022).

One way that people are trying to counteract pollution of the environment caused by plastic waste is by producing bioplastics. Furthermore, adopting bioplastic can lessen greenhouse gas emissions indirectly. (Moshood *et al*., 2022). Bioplastics are a kind of plastic that can be either 1) biodegradable or 2) non-biodegradable yet derived from renewable or biological resources (Mangal *et al*., 2023). On the other hand, materials that are "biodegradable" are those that decompose quickly, may be composted, and can turn almost completely into harmless trash in a few months. The kind of raw materials used, how concentrated they are, and the burial environment all affect how rapidly bioplastic breaks down (Zoungranan *et al*., 2020).

Further investigators are using bioplastic for preparation-related studies. When disposed of in a recyclable manner, bioplastics—which are made entirely of renewable resources—are quickly absorbed by the environment as carbon dioxide, water, and biomass. While biodegradability is frequently associated with materials derived from biological sources, the polymer's chemical makeup is the only factor that influences it (Tyagi *et al*., 2022). The necessity for food products with controlled quality and prolonged shelf life from retailers and consumers has led to the development of active and intelligent food packaging films in recent years. The corn plant is the world's main supplier of commercial starches, accounting for about 85% of all starches (Vilpoux and Junior., 2023). Other plants, like potatoes, rice, and wheat, are also significant producers of native starch, albeit their share of the world's total starch output is relatively small (Junejo *et al*., 2022).

Biodegradable plastics are made from biopolymers, such as proteins, cellulose, and starch, that are extracted from biomass directly or by modification. Biodegradable polymers are created using protein, chitosan, cellulose, and starch obtained from sustainable biomass (Marichelvam *et al*., 2019). The usage of starch-based biodegradable polymers is limited by their water sensitivity, high moisture permeability, and production of films with mechanical characteristics that are unsuitable for many applications. This underscores the need for modifications to enhance these attributes (Zhang *et al*., 2022). In the bioplastic market, starch-based polymers make up almost half of the products. Plastic takes a long time to break down, therefore pollution from plastic can have a detrimental effect on lands, streams, and oceans.

One of Thailand's most significant industrial fruit crops, pineapple yields about 1.67 million tons of fruit annually. Increased pineapple production thus results in a consistent annual waste output. After they are collected, pineapple stems and leaves are regarded as agricultural waste (Sarangi *et al*., 2023). Most of this trash has no obvious use and might be disposed of improperly, which poses serious risks to the environment. Making use of agricultural waste from pineapple stems is essential for improving sustainability, economics, and maybe raising the value of items used in the production of food and medicine (Gupta., 2022).

Pineapple stem starch is a unique alternative for making films that are water-resistant because of its properties. These coatings can be used to extend the shelf life and postpone ripening of fruits and vegetables. A good source of resistant and thermoplastic starch for both culinary and non-food uses is pineapple stem starch (Namphonsane *et al*., 2023). Pineapple plant stems contain a high concentration of starch, which may be processed to produce items of additional value, such as amino acids. The food, pharmaceutical, paper, cosmetic, and other industries can all benefit from the use of native starches (Chu *et al*., 2021). The cellulose envelope, soluble fractions, protein, starch, and other plant components like lignocellulosic material, which is present in the stem or basal stem of pineapple plants are separated by the starch industry. The industrial tools are typically devoted to a particular raw material, and the manufacturing processes are unique to each factory. Typically, starch is utilized in its original state, having been purified through extraction from raw materials. But through physical, chemical, enzymatic, or genetic modifications, changes to the natural starch referred to as modified starch can be made to achieve specific qualities or improved starch attributes (Olawoye *et al*., 2023). Nevertheless, no research on the creation of bioplastic film using beeswax as a plasticizer has been published. In this study, biodegradable film was produced using pineapple stem starch and beeswax as a natural plasticizer.

2. Methodology

2.1 Starch extraction

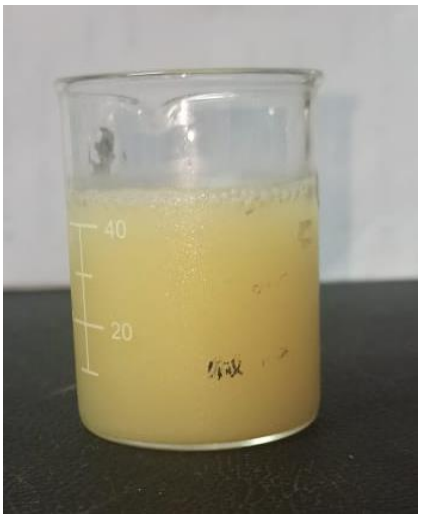
Pineapple stem starch was obtained from Attapadi, Mannarkad, Kerala. The starch was extracted using a modified Schoch and Maywald (1968) method. The pineapple stem was surface sterilized with tween 20 and washed thoroughly with distilled water and cut into small pieces. In a mechanical blender, pineapple stems were ground until very fine in a sodium bisulfite solution. The crushed bulk was filtered using cotton cloth. The starch suspension was decanted at room temperature for 30 minutes before being washed several times with sodium bisulfite solution and centrifuged at 5000 rpm for 5 minutes at 25 °C. The pellet obtained was kept at 50^{o} C for 24 hrs. The dried Pineapple stem starch was stored at room temperature for further studies.

2.2 Bioplastic film formation

Bioplastic film was prepared with starch powder, beeswax as plasticizer and distilled water by solvent casting method. 1g of starch powder, (0.5-2g) of various concentration of beeswax and 20 mL of distilled water were added into the beaker and heated with constantly stirring using magnetic stirrer until the mixture to gelatinize at approximately 70ºC. The solution was poured into a Petri plate and dried at 50^{0}C.

3. Result and Discussion

Starch was extracted from Pineapple stem with the common extraction technique (Fig 1). The stem starch has unique and distinct properties. Pineapple stem starch has unique and distinct properties when compared to the commercial starches. Under normal cooking condition, it has the lowest paste viscosity. These potentially beneficial characteristics make pineapple stem starch a good source of resistant and thermoplastic starch for food and non-food applications.



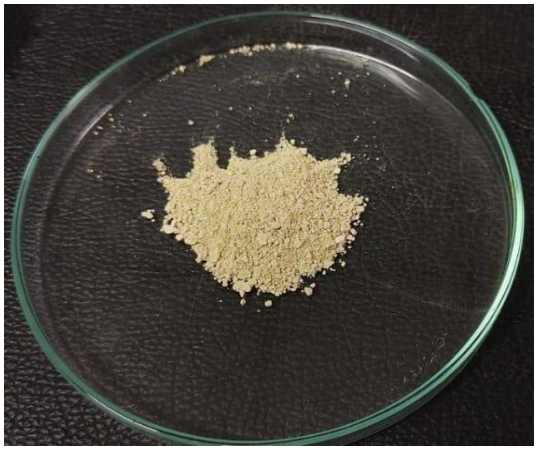


Fig 1: a) Pineapple stem b) Pineapple stem extract c) Pineapple stem starch powder

Beeswax was used as a natural plasticizer to successfully generate the bioplastic film. The elasticity of the bioplastic sheet increases with a rise in plasticizer concentration. It seemed appropriate for using a higher concentration of plasticizer.

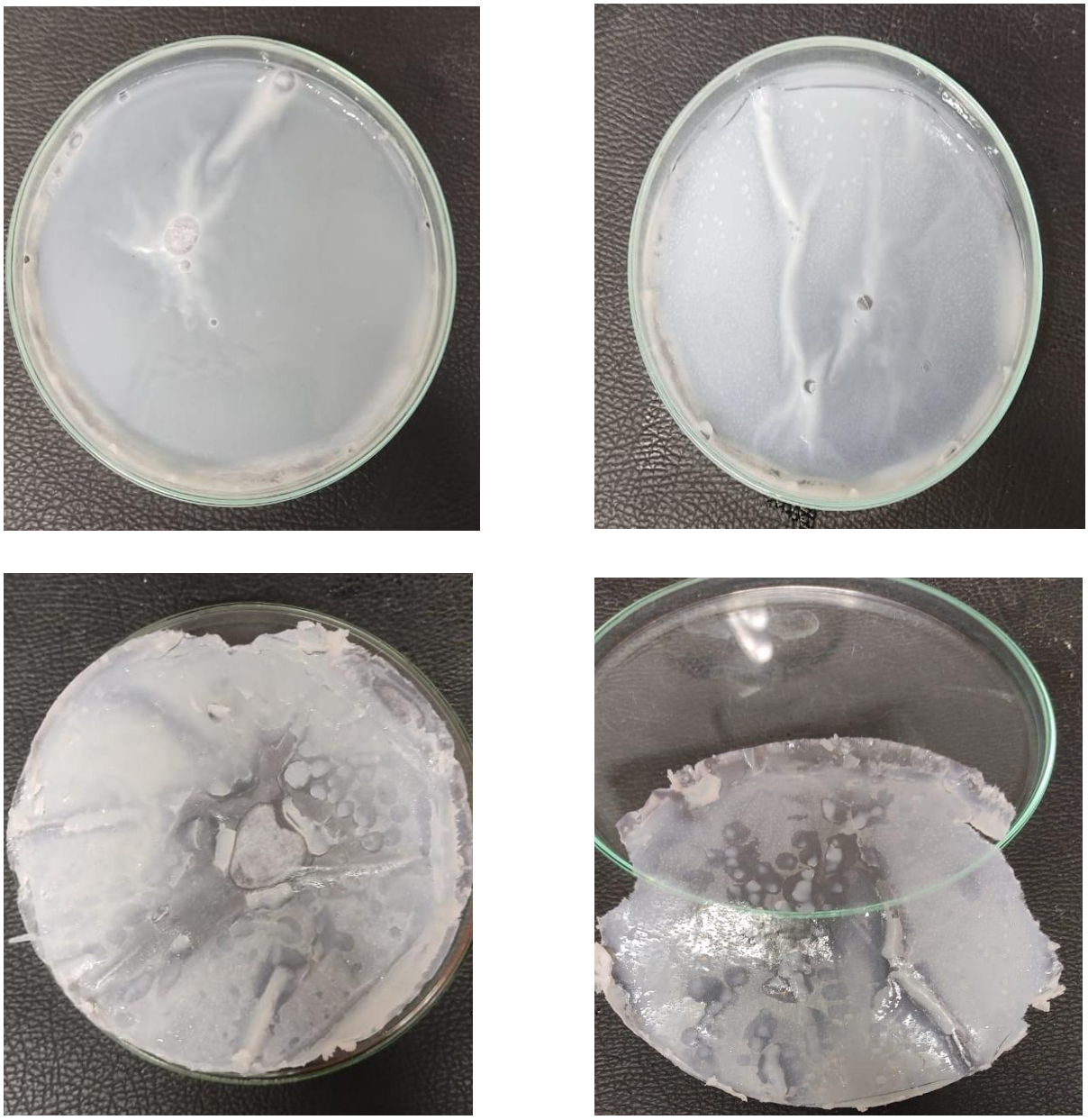


Fig 4: Bioplastic formation with different concentration of plasticizer (0.5,1.0,1.5 and 2.0 µL)

Conclusion

Without using any chemicals or other modifications, water-resistant and biodegradable flexible films were successfully prepared from pineapple stem starch with Beeswax as natural plasticizer. Pineapple stem starch films can be made with the least number of associated materials and energy intensities. The mechanical properties of the film were high, hydrophobicity and good thermal stability. The films can completely dissolve in the natural environment in a couple of weeks and all of the compounds are biobased. This bioplastic film we had produced can be used as an alternative to conventional plastic.

Acknowledgments

All the authors would like to thank PG and Research Department of Biotechnology, Kongunadu Arts and Science College and DST-FIST for supporting all the laboratory facilities.

REFERENCE

1. Atiwesh, G., Parrish, C. C., Banoub, J., & Le, T. A. T. (2022). Lignin degradation by microorganisms: A review. *Biotechnology Progress*, *38*(2), e3226.
2. Chathalingath, N., Kingsly, J. S., & Gunasekar, A. (2023). Biosynthesis and biodegradation of poly (3-hydroxybutyrate) from Priestia flexa; A promising mangrove halophyte towards the development of sustainable eco-friendly bioplastics. *Microbiological Research*, *267*, 127270.
3. Chu, P. H., Jenol, M. A., Phang, L. Y., Ibrahim, M. F., Prasongsuk, S., Bankeeree, W., ... & Abd-Aziz, S. (2021). Starch extracted from pineapple (Ananas comosus) plant stem as a source for amino acids production. *Chemical and Biological Technologies in Agriculture*, *8*(1), 1-15
4. Ghaffar, I., Rashid, M., Akmal, M., & Hussain, A. (2022). Plastics in the environment as potential threat to life: an overview. *Environmental Science and Pollution Research*, *29*(38), 56928-56947.
5. Gupta, M. (2022). Pineapple waste utilization: Wealth from waste. *Pharma Innovat. J*, 1971-1978.
6. Junejo, S. A., Flanagan, B. M., Zhang, B., & Dhital, S. (2022). Starch structure and nutritional functionality–Past revelations and future prospects. *Carbohydrate Polymers*, *277*, 118837.
7. Junejo, S. A., Flanagan, B. M., Zhang, B., & Dhital, S. (2022). Starch structure and nutritional functionality–Past revelations and future prospects. *Carbohydrate Polymers*, *277*, 118837.
8. Khalid, M. Y., Arif, Z. U., Ahmed, W., & Arshad, H. (2022). Recent trends in recycling and reusing techniques of different plastic polymers and their composite materials. *Sustainable Materials and Technologies*, *31*, e00382.
9. Li, D., Jing, M., Dai, X., Chen, Z., Ma, C., & Chen, J. (2022). Current status of pineapple breeding, industrial development, and genetics in China. *Euphytica*, *218*(6), 85.
10. Mangal, M., Rao, C. V., & Banerjee, T. (2023). Bioplastic: an eco-friendly alternative to non-biodegradable plastic. *Polymer International*, *72*(11), 984-996.
11. Marichelvam, M. K., Jawaid, M., & Asim, M. (2019). Corn and rice starch-based bio-plastics as alternative packaging materials. *Fibers*, *7*(4), 32.
12. Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., & AbdulGhani, A. (2022). Sustainability of biodegradable plastics: New problem or solution to solve the global plastic pollution?. *Current Research in Green and Sustainable Chemistry*, *5*, 100273.
13. Namphonsane, A., Suwannachat, P., Chia, C. H., Wongsagonsup, R., Smith, S. M., & Amornsakchai, T. (2023). Toward a Circular Bioeconomy: Exploring Pineapple Stem Starch Film as a Plastic Substitute in Single Use Applications. *Membranes*, *13*(5), 458.
14. Olawoye, B., Jolayemi, O. S., Akinyemi, T. Y., Nwaogu, M., Oluwajuyitan, T. D., Popoola-Akinola, O. O., ... & Akanbi, C. T. (2023). Modification of Starch. In *Starch: Advances in modifications, technologies and applications* (pp. 11-54). Cham: Springer International Publishing.

15. Patti, A., & Acierno, D. (2022). Towards the sustainability of the plastic industry through biopolymers: properties and potential applications to the textiles world. *Polymers*, *14*(4), 692.
16. Prata, J. C., Silva, A. L. P., Duarte, A. C., & Rocha-Santos, T. (2022). The road to sustainable use and waste management of plastics in Portugal. *Frontiers of environmental science & engineering*, *16*, 1-16.
17. Sarangi, P. K., Singh, A. K., Srivastava, R. K., & Gupta, V. K. (2023). Recent Progress and Future Perspectives for Zero Agriculture Waste Technologies: Pineapple Waste as a Case Study. *Sustainability*, *15*(4), 3575.
18. Shogren, R., Wood, D., Orts, W., & Glenn, G. (2019). Plant-based materials and transitioning to a circular economy. *Sustainable Production and Consumption*, *19*, 194-215.
19. Sohn, Y. J., Kim, H. T., Baritugo, K. A., Jo, S. Y., Song, H. M., Park, S. Y., ... & Park, S. J. (2020). Recent advances in sustainable plastic upcycling and biopolymers. *Biotechnology Journal*, *15*(6), 1900489.
20. Tuuri, E. M., & Leterme, S. C. (2023). How plastic debris and associated chemicals impact the marine food web: A review. *Environmental Pollution*, 121156.
21. Tyagi, V. V., Chopra, K., Sharma, R. K., Pandey, A. K., Tyagi, S. K., Ahmad, M. S., ... & Kothari, R. (2022). A comprehensive review on phase change materials for heat storage applications: Development, characterization, thermal and chemical stability. *Solar Energy Materials and Solar Cells*, *234*, 111392.
22. Vilpoux, O. F., & Junior, J. F. S. S. (2023). Global production and use of starch. In *Starchy Crops Morphology, Extraction, Properties and Applications* (pp. 43-66). Academic Press.
23. Zhang, M., Biesold, G. M., Choi, W., Yu, J., Deng, Y., Silvestre, C., & Lin, Z. (2022). Recent advances in polymers and polymer composites for food packaging. *Materials Today*, *53*, 134-161.
24. Ziani, K., Ioniță-Mîndrican, C. B., Mititelu, M., Neacșu, S. M., Negrei, C., Moroșan, E., ... & Preda, O. T. (2023). Microplastics: a real global threat for environment and food safety: a state of the art review. *Nutrients*, *15*(3), 617.
25. Ziani, K., Ioniță-Mîndrican, C. B., Mititelu, M., Neacșu, S. M., Negrei, C., Moroșan, E., ... & Preda, O. T. (2023). Microplastics: a real global threat for environment and food safety: a state of the art review. *Nutrients*, *15*(3), 617.
26. Zoungranan, Y., Lynda, E., Dobi-Brice, K. K., Tchirioua, E., Bakary, C., & Yannick, D. D. (2020). Influence of natural factors on the biodegradation of simple and composite bioplastics based on cassava starch and corn starch. *Journal of Environmental Chemical Engineering*, *8*(5), 104396.