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A REVIEW ON- PREPARATION OF BIO PLASTICS FROM AGRI-WASTE

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ABSTRACT

The whole earth is now submerged with plastics, a non-biodegradable substance. It is one of the major environmental hazards now-a-days. Today the entire world is in search of new product development from waste agri-products. In this article an attempt has been made to determine the different optimized method parameters for the preparation of bioplastics from waste agri products. Bioplastics can be fabricated from different food waste like pumpkin skin, cucumber skin, banana peel, apple peel, pomegranate and brinjal peel etc. Bioplastics are biodegradable polymer that can be utilized by microbes as waste treatment technique may be a solution to the problem of plastic pollution in near future around the world. These bioplastics can be utilized in biomedical industry as capsule film; can be a substitute of plastic bags, cosmetic applications, storage utensils, bio-based cutlery and table ware. Non-toxic biodegradable plastics can be used as sutures in heart operations etc.

INTRODUCTION

Bioplastics represent a category of biodegradable polymers that can be effectively broken down by microorganisms. They offer a promising solution to the escalating problem of plastic pollution worldwide. These bioplastics have versatile applications across multiple industries. Nearly half of plastic waste consists of single-use plastics, commonly used for packaging and disposable items (Giacovelli *et al*., 2018). The preferable alternative is transitioning to biodegradable materials instead of synthetic polymers (Moura *et al*., 2017). Biodegradable materials can be broken down by microorganisms, significantly reducing their negative environmental impact.

India generates 62 million tons of waste each year. About 43 million tons (70%) are collected, of which about 12 million tons are treated, and 31 million tons are dumped in landfill sites. In the UK, approximately 15 million tons of foods go to waste annually (Salemdeeb *et al*., 2017). In Malaysia, it is estimated that 6.7 million tonnes of food waste are generated each year (Bong *et al*., 2017). Meanwhile, the USA produces an astonishing amount of food waste, accounting for up to 40% of all the food it produces (US EPA, n.d.).

Rather than resorting to landfill and incineration methods to dispose of food waste, there is a promising and sustainable option known as bio-valorization. This approach involves utilizing food waste as a valuable resource for the development of microorganisms. Additionally, food waste can serve as a cost-effective, nutrient-rich medium that promotes the growth of microalgae, leading to the production of valuable substances like carbohydrates, lipids, and proteins that can be extracted for the production of bioplastics (Tsang *et al*., 2019).

Instead of relying on landfill and incineration practices for the disposal of food waste, there exists a promising and sustainable alternative known as bio-valorization. This method entails the use of food waste as a valuable resource for cultivating microorganisms. Furthermore, food waste can function as an economical and nutrient-rich substrate that fosters the growth of microalgae, ultimately resulting in the generation of valuable substances such as carbohydrates, lipids, and proteins that can be extracted for the production of bioplastics (Tsang *et al*., 2019).

Earlier research on the anaerobic decomposition of paper food waste collection bags has shown encouraging outcomes when conducted in both mesophilic and thermophilic conditions (Dolci *et al*., 2022).

The objective of this research is to explore the potential of using food waste as a bioplastic material for eco-friendly packaging, reducing pollution associated with traditional plastic use. This study aims to lower the cost of bioplastic production and enhance biodegradability. Ultimately, it seeks to investigate the feasibility of utilizing food waste as an environmentally preferable alternative for packaging materials.

BIOPLASTIC PRODUCTION

The most widely employed bio-based plastics are derived from sources such as corn starch, sugar cane pulp, and polylactic acid (PLA). PLA production involves a combination of fermenting bio-based sugars, lactic acid precursors, and chemical polymerization (Battista *et al.*, 2021). Starch-based plastics can be produced through physico-chemical processes, such as partial acid hydrolysis, the chemical conversion of dextrose from maize or other carbohydrate sources, or the creation of synthetic thermoplastic starch by incorporating plasticizers into starch. These thermoplastic materials can be combined with various hydrophobic polymers or suitable nanofillers to enhance their mechanical strength or modify their surface properties (Tommonaro *et al.,* 2016; Tang and Alavi, 2011). Chemically modified cellulose is a linear polymer composed of repeating units of anhydroglucopyranose, which contains three hydroxyl groups. Research efforts have been directed towards chemically altering the surface of cellulose to improve adhesion between the polar hydroxyl groups on cellulose fibers and non-polar polymer matrices. Technical advancements have been made in the field of modifying cellulosic bioplastics (Sandhya *et al.*, 2013; HPS *et al.*, 2016).

BIOPLASTIC FORMATION FROM JACK FRUIT (JF) PEEL

The process began by cutting the jackfruit peels into small pieces and exposing them to sunlight for two to three days to facilitate drying. The resulting bleached fiber was then boiled for 45 minutes at 100°C in a solution containing 90 mL of 80% acetic acid and 10 mL of 45% nitric acid. Following this, the cellulose residue underwent another round of boiling, this time for 30 minutes at temperatures ranging from 80 to 90°C, with continuous stirring. The boiling solution included 75 mL of 20% acetic acid, 5 mL of sulfuric acid, and 2.0 g of A.R. NaCl. Subsequently, the pure cellulose solution was mechanically agitated for 6 hours, followed by 10 minutes of homogenization at 7400 rpm. The resulting nanocellulose (NC) suspension was stored at 4°C as a stock solution (Reshmy *et al.*, 2020 and Tomkinson, 2005). To create thin films, NC was used as the matrix, a plasticizer was added, and B S served as the filler. The solvent evaporation technique was employed for film preparation, with research conducted to optimize various plasticizers to enhance the filler's effects. A control film was also produced using a homogenization method (Reshmy et al., 2020). The process involved making a suspension of NC, filler, and plasticizer, with careful optimization of the plasticizer composition. The filler was obtained from BS through an ethyl acetate extraction process using a Soxhlet extractor (Reshmy *et al.*, 2021).

The surface morphology analysis was performed using the VEGA3 TESCAN instrument at an operating voltage of 15 kV. Various properties, including water holding capacity, WENSAR PGB moisture content, thickness, ASTM D2765-95C swelling ratios, and soil degradability (ASTM D 2216), were also examined (Machado et al., 2015 and Rosentrater and Otieno, 2006). Atomic Gravimetric analysis was conducted using the TGA Q50 V6.7 build 203 instrument.In comparison to synthetic plastic, bioplastic made from biomass rich in carbohydrates can be more environmentally friendly. Three distinct blend systems from their study and dis-covered that plastic made from jackfruit starch has both tensile and thermal stability quali-ties (Kahar *et al.*, 2019). Other researchers who used standard plasticizers to plasticize jack-fruit starch, also described it. Early testing revealed that among the plasticizers that per-formed adequately were water, glycerol, sodium bicarbonate, and citric acid (Lubis *et al.*., 2018; Nguyen *et al.*, 2022).

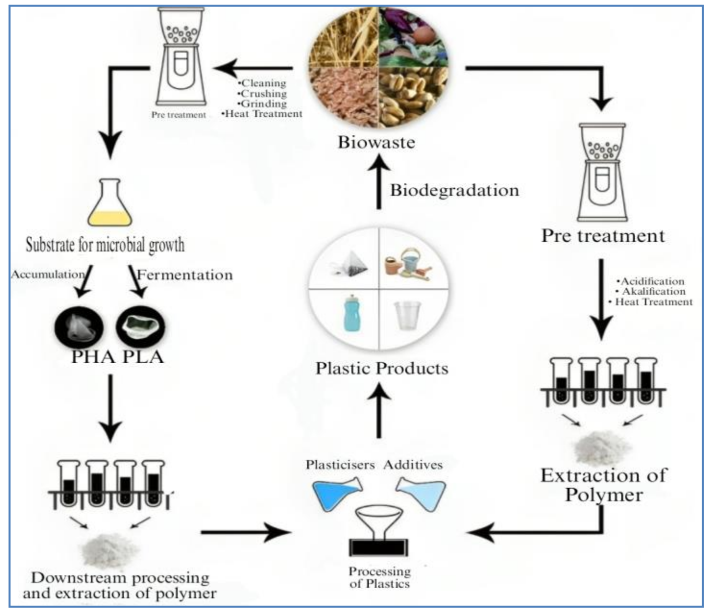

Fig 1: Preparation of bioplastics from agri-waste

(B) BIOPLASTIC FORMATION FROM BANANA PEES(BPP)

The procedure commenced with a thorough cleaning of the peels, followed by cutting them into smaller pieces using scissors. These pieces were then boiled for duration of 30 minutes. After boiling, the peels were left to dry, and the used water was discarded. Subsequently, the dried peels were processed into a paste. The key ingredients involved in this process included plasticizers, water, and a 5% aqueous acetic acid solution. To create a variety of distinct samples, a total of 12 samples were generated, labeled as BPP1 to BPP12. These variations encompassed changes in the plasticizer content (glycerol, sorbitol, and a 1:1 mixture of both) and adjustments in the filler content within the potato peel powder (ranging from 0:100, 5:95, to 10:90% w/v) (Shafqat *et al.*, 2021).

Within the range of bioplastic samples, those containing glycerol demonstrated the highest moisture content, whereas those comprising glycerol-sorbitol had lower levels of moisture, and those with sorbitol alone exhibited the lowest moisture content. This variation can be attributed to glycerol's strong affinity for water molecules, as previously noted in studies (Sanyang *et al.*, 2016; Cerqueira *et al.*, 2012).

Both the BPP and COM (control) bioplastics exhibited the highest rates of water absorption. This heightened absorption can be explained by the process of gelatinization, which involves the breakdown of starch granules, allowing for greater water penetration. Additionally, the presence of hydroxyl groups in the bioplastics attracts water molecules. The incorporation of a plasticizer reduced water absorption, while the inclusion of glycerol had the opposite effect, increasing water absorption. Furthermore, it was observed that glucose exhibited a stronger attraction to water molecules in comparison to glycerol-sorbitol, as supported by previous studies (Sujuthi and Liew, 2016; Aranda Garcia *et al.*, 2015).

DISCUSSION:

The production and marketing of bioplastics pose challenges beyond just industrial and economic viability. The presence of impurities and their potential to contaminate food waste impose significant limitations on the "second life" of food waste. In this context, environmental friendly technologies, such as subcritical water extraction, offer an alternative to the traditional citric acid method for extracting pectin from jackfruit peel. However, it's worth noting that subcritical water extraction may modify the physicochemical properties of pectin (Li *et al.*, 2019).

The introduction of four different plasticizers and the use of BS(Biocellulose) as a filler have been shown to enhance the characteristics of bioplastics, with PVA being identified as the most suitable choice for producing (Nanocellulose) NC thin films Biocellulose is produced by certain types of bacteria, like *Acetobacter xylinum*. Unlike plant-derived cellulose, which is a major component of cell walls in plants, biocellulose is produced through microbial fermentation. The resulting material has unique properties that make it valuable for various applications. Nanocellulose is a type of cellulose material that has been processed into nanoscale dimensions. It is derived from natural cellulose sources, such as wood pulp, plants, or bacteria. The unique properties of nanocellulose, including its high surface area, mechanical strength, and biocompatibility, make it a versatile material with a wide range of potential applications. There are three main types of nanocellulose: cellulose nanocrystals (CNC), cellulose nanofibrils (CNF), and bacterial nanocellulose (BNC). CNCs are rod-like nanoparticles with dimensions in the range of a few nanometers in width and several tens of nanometers in length. CNFs are flexible, thread-like structures with diameters in the nanometer range and lengths extending to micrometers. BNC is produced by certain bacteria, such as Acetobacter xylinum, during fermentation (Reshmy *et al.*, 2021).

The absorption of water varies depending on the type of bioplastics utilized and the quantity of BPP (Bioplastic from banana peel starch) and COM (Cornstarch and rice starch) filler incorporated. Research by Darni *et al*. demonstrated that bioplastics without any filler had the lowest water absorption capacity, while those containing filler exhibited a consistent increase in water absorption (Darni *et al.*, 2017).

The biodegradability of BPP bioplastics is influenced by various physical characteristics, which encompass chemical structure, molecular weight, water affinity, and surface area. Among the samples, the control sample displayed the lowest level of biodegradation. However, the introduction of plasticizers and fillers led to an improvement in biodegradation capacity. Notably, as both plasticizers have an affinity for water, increasing the filler concentration from 5% w/v to 10% w/v can enhance both biodegradation and water absorption capacity. The most significant level of biodegradation was observed in samples containing both glycerol and sorbitol, followed by samples with a plasticizer. Further increasing the filler concentration to 10% w/v contributed to enhanced biodegradation, as supported by prior research (Tokiwa *et al.*, 2009).

The tensile strength and Young's Modulus of various bioplastics were evaluated using Universal testing machines, and the findings revealed that plasticizers had a consistent impact on both types of bioplastics, namely BPP and COM. Specifically, glycerol resulted in lower tensile strength values and higher Young's Modulus values, whereas samples containing sorbitol-sorbitol as a plasticizer exhibited results that fell in between these extremes. The lower molar mass of glycerol was identified as the primary factor responsible for its more pronounced plasticizing effect. However, when both plasticizers were combined, they influenced both the tensile strength and Young's Modulus of the bioplastics. (Spiridon *et al.*, 2013; Ooi *et al.*, 2012).

CONCLUSION:

Bio-based, biodegradable, and compostable plastics offer promising alternatives to oil-based single-use plastics (SUPs), necessitating a fresh approach to their design. The field of bioplastics has evolved into a dynamic area of research for scholars worldwide, driven by the growing demand for eco-friendly alternatives. This remarkable progress is a response to the imperative need for environmentally friendly options.

Future Scope

Over the past three decades, the development of bioplastics has accelerated significantly since the introduction of the first modern biodegradable plastics. While the adoption of bioplastics carries both risks and advantages, it is crucial to replace the currently ubiquitous conventional plastics. This is particularly important as food waste can contribute to greenhouse gas emissions and other environmental challenges, posing a substantial hurdle to achieving sustainable development.

Conflict of Interest: There is no conflict of interest between the authors in publication of this paper.

Author's Contribution: Animesh Biswas undertook the entire literature review. Srijani Pal was responsible for creating all the figures and handling the references. Dr. Rupali Dhara Mitra conceptualized the idea and title of this paper and also provided comprehensive editing for the entire manuscript.

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REFERENCES

Aranda Garcia, F.J., Gonzalez Nunez, R., Jasso Gastinel, C.F., Mendizabal, E. 2015. Water absorption and thermomechanical characterization of extruded starch/ poly (lactic acid)/agave bagasse fiber bioplastic composites. Int. J. Polym. Sci. 2015, 343294.

Battista, F., Frison, N., Bolzonella, D. 2021. Can bioplastics be treated in conventional anaerobic digesters for food waste treatment? Environmental Technology and Innovation, 22, 101393.

Bong, C. P. C., Ho, W. S., Hashim, H., Lim, J. S., Ho, C. S., Tan, W. S. P., Lee, C. T. 2017. Review on the renewable energy and solid waste management policies towards biogas development in Malaysia. Renewable and Sustainable Energy Reviews, 70, 988-998.

Cerqueira, M.A., Souza, B.W.S., Teixeira, J.A., Vicente, A.A., 2012. Effect of glycerol And corn oil on

physicochemical properties of polysaccharide films—A Comparative study. Food Hydrocolloids 27 (1), 175–184.
Darni, Y., Dewi, F.Y., Lismeri, L. 2017. Modification of Sorghum Starch-Cellulose Bioplastics with Sorghum Stalks Filler. Jurnal Rekayasa Kimia dan Lingkungan 12 (1), 2
Dolci, G., Venturelli, V., Catenacci, A., Ciapponi, R., Malpei, F., Turri, S. E. R., Grosso, M. 2022. Evaluation of the anaerobic degradation of food waste collection bags made of paper or bioplastic. Journal of environmental management, 305, 114331.
Ebrahimian, F., Denayer, J. F. M., Karimi, K. 2022. Potato peel waste biorefinery for the sustainable production of biofuels, bioplastics, and biosorbents. Bioresource technology, 360, 127609.https://doi.org/10.1016/j.biortech.2022.127609
HPS, A. K., Saurabh, C. K., Adnan, A. S., Fazita, M. N., Syakir, M. I., Davoudpour, Y., Dungani, R. 2016. A review on chitosan-cellulose blends and nanocellulose reinforced chitosan biocomposites: Properties and their applications. Carbohydrate polymers, 150, 216-226.
Kahar, A. W. M., Lingeswarran, M., Amirah Hulwani, M. Z., Ismail, H. 2019. Plasticized jackfruit seed starch: a viable alternative for the partial replacement of petroleum-based polymer blends. Polymer Bulletin, 76, 747-762.
Li, W. J., Fan, Z. G., Wu, Y. Y., Jiang, Z. G., Shi, R. C. 2019. Eco-friendly extraction and physicochemical properties of pectin from jackfruit peel waste with subcritical water. Jounal of the science of food and agriculture, 99(12), 5283–5292.
Lubis, M., Gana, A., Maysarah, S., Ginting, M. H. S., & Harahap, M. B. 2018. Production of bioplastic from jackfruit seed starch (Artocarpus heterophyllus) reinforced with microcrystalline cellulose from cocoa pod husk (Theobroma cacao L.) using glycerol as plasticizer. In IOP Conference Series: Materials Science and Engineering (Vol. 309, p. 012100). IOP Publishing.
Machado, A.V., Araújo, A., Oliveira, M. 2015. Assessment of Polymer-based Nanocomposites Biodegradability, Biodegradable Polymers. Volume 1: Advancement in Biodegradation Study and Applications.
Nguyen, T. K., That, N. T. T., Nguyen, N. T., Nguyen, H. T. 2022. Development of starch-based bioplastic from jackfruit seed. Advances in Polymer Technology, 2022, 1-9.
Ooi, Z.X., Ismail, H., Bakar, A.A., Aziz, N.A.A. 2012. The comparison effect of sorbitol and glycerol as plasticizing agents on the properties of biodegradable polyvinyl alcohol/rambutan skin waste flour blends. Polym.-Plast. Technol. Eng. 51 (4), 432–437.
Ramadhan, M. O., Handayani, M. N. 2020. The potential of food waste as bioplastic material to promote environmental sustainability: A review. In IOP Conference Series: Materials Science and Engineering (Vol. 980, No. 1, p. 012082). IOP Publishing.
Reshmy, R., Philip, E., Vaisakh, P. H., Raj, S., Paul, S. A., Madhavan, A., Sindhu, R., Binod, P., Sirohi, R., Pugazhendhi, A., Pandey, A. 2021. Development of an eco-friendly biodegradable plastic from jack fruit peel cellulose with different plasticizers and Boswellia serrata as filler. The Science of the total environment, 767, 144285.
Reshmy, R., Philip, E., Paul, S., Madhavan, A., Raveendran, S., Parameswaran, B., Pandey, A., 2020. A green biorefinery platform for cost-effective nanocellulose production: investigation of hydrodynamic properties and biodegradability of thin films. Biomass conversion and Biorefinery 9, 1-10.
Rosentrater, K.A., Otieno, A.W. 2006. Considerations for manufacturing bio-based plastic products. J. Polym. Environ. 14, 335–346.
Salemdeeb, R., Zu Ermgassen, E. K., Kim, M. H., Balmford, A., Al-Tabbaa, A. 2017. Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options. Journal of cleaner production, 140, 871-880.
Sandhya, M., Aravind, J., Kanmani, P. 2013. Production of polyhydroxyalkanoates from Ralstonia eutropha using paddy straw as cheap substrate. International Journal of Environmental Science and Technology, 10, 47-54.
Sanyang, M.L., Sapuan, S.M., Jawaid, M., Ishak, M.R., Sahari, J. 2016. Effect of Plasticizer type and concentration on physical properties of biodegradable films Based on sugar palm (Arenga pinnata) starch for food packaging. J. Food Sci.Technol. 53 (1), 326–336.
Shafqat, A., Al-Zaqri, N., Tahir, A., Alsalme, A. 2021. Synthesis and characterization of starch based bioplatics using varying plant-based ingredients, plasticizers and natural fillers. Saudi journal of biological sciences, 28(3), 1739–1749.
Spiridon, I., Teaca˘, C.A., Bodîrla˘u, R., Bercea, M., 2013. Behavior of Cellulose Reinforced Cross Linked Starch Composite Films Made with Tartaric Acid Modified Starch Microparticles. J. Polym. Environ. 21 (2), 431–440.
Sujuthi, R.A.F., Liew, K.C., 2016. Properties of Bioplastic Sheets Made from Different Types of Starch Incorporated With Recycled Newspaper Pulp. Trans. Sci. Technol. 3 (1–2), 257–264.
Sun, R., Tomkinson, J., 2005. Separation and characterization of cellulose from wheat Straw. Sep. Sci. Technol. 39, 391–411.
Tang, X., Alavi, S. 2011. Recent advances in starch, polyvinyl alcohol based polymer blends, nanocomposites and their biodegradability. Carbohydrate polymers, 85(1), 7-16.
Tokiwa, Y., Calabia, B.P., Ugwu, C.U., Aiba, S., 2009. Biodegradability of plastics. Int. J. Mol. Sci. 10 (9), 3722–3742.
Tsang, Y. F., Kumar, V., Samadar, P., Yang, Y., Lee, J., Ok, Y. S., Jeon, Y. J. 2019. Production of bioplastic through food waste valorization. Environment international, 127, 625-644.