AgriCos e-Newsletter
ISSN: 2582-7049
AgriCos e-Newsletter
Open Access Multidisciplinary Monthly Online Magazine
Volume: 03 Issue: 08 August 2022 Article No: 24

Generation of Biodegradable Plastic Using Food Waste

Vinod B. R.[1], Chethan Kumar K. B.[2] and Sanketh G. D.[3]
[1]PhD Scholar, Division of Food Science & Postharvest Technology, ICAR- IARI, New Delhi
[2]PhD Scholar, Division of Plant Genetic Resources, ICAR- IARI, New Delhi
[3]PhD Scholar, Division of Agronomy, ICAR- IARI, New Delhi

SUMMARY

When food waste from various sources is disposed of improperly, it generates a serious environmental burden. Thus, one of the most recent uses in the research field of bioplastics manufacturing is food waste as feedstock. The use of such a technique is predicted to lower the cost of producing bioplastic. Several food wastes, including most fruit and vegetable wastes, have been employed as raw materials for the manufacturing of bioplastics to date. This article focuses on bioplastic's biobased content and biodegradability, as well as their mechanical and physical characteristics and, lastly, the manufacturing of bioplastic from food waste.

INTRODUCTION

The word bio-based product applies to material developed entirely or partially from renewable resources (biomass). With regards to biodegradability, a material is biodegradable if it degrades by biological processes during composting to release carbon dioxide, water, inorganic compounds, and biomass at a rate similar to that of other known, compostable materials and leaves no identifiable or harmful residue. Bioplastics are one such material crafted wholly or in part from renewable biomass sources such as sugarcane and corn, or from microbes such as yeast. Some bioplastics are biodegradable or even compostable, under the right conditions. Bioplastics made from renewable resources can be naturally recycled by biological processes, thus limiting the use of fossil fuels and protecting the environment. The European Bioplastics Organization (EBO) defines a material as a bioplastic if it is bio-based, biodegradable, or possesses both traits.

Classification of bioplastic

Bioplastics can be divided into three types based on their biodegradability and bio-based content (Fig. 1). Non-biodegradable bioplastics are derived from renewable sources and are comparable to traditional plastics in terms of the time required for total environmental degradation. This class of polymers is also known as "drop-in" bioplastics. Bio-PET (bio-polyethylene terephthalate) is a common example of a drop-in bioplastic (Oroski *et al.*, 2014). PET is manufactured by an esterification process between terephthalic acid (PTA) and ethylene glycol (EG), followed by polymerization *via* a polycondensation reaction with water as a by-product (Xiao *et al.*, 2015). In the case of bio-PET, EG or both, monomers are derived from renewable sources. While drop-in bioplastics are commonly known on the market, non-drop-in bioplastics *i.e.*, plastics that are biodegradable, bio-based, or derived from fossil sources, are less established. These biodegradable polymers are grouped into four broad categories based on their origin as agro-polymers, polymers of microbial origin, polymers of biotechnological yield, and blend of biopolymer and commercial polyesters (Kumar & Thakur, 2017). Starch, cellulose, pectin plus animal and vegetable proteins like casein and gluten are well-known feedstock for agro-polymer-based bioplastics. Furthermore, numerous polymers could be created by a variety of microbes cultured under various nutrient and climatic circumstances. PHAs, for example, are linear thermoplastic polymers having hydroxyalkanoic acid as a monomer unit that can be produced intracellularly as insoluble cytoplasmic inclusions by heterotrophic bacteria like *Cupriavidus necator* (Campos *et al.*, 2014). Bacterial microbes, on the other hand, can be employed to create in a biotechnological way. PLA-based bioplastics are produced through a fermentative process that begins with the conversion of corn or other carbohydrate sources into dextrose, followed by fermentation/conversion into lactic acid (Reddy *et al.*, 2013). Thus, lactic acid is separated and polymerized to produce PLA with a low molecular weight. The Blends of biopolymers and synthetic polymers made from fossil fuels make up the final class of biodegradable materials.

Bio-based content and biodegradability attributes of bioplastics

A material's biobased content is the proportion of biomass-derived carbon to total organic carbon content. Radiocarbon analysis (14^C isotope) is used to assess the carbon content of biobased materials (Quarta, 2013). The ability of a material to degrade after interactions with biological factors is referred to as biodegradability. Polymer biodegradation consists of three steps *viz*., bio-deterioration, bio-fragmentation, and assimilation (Lucas *et al*., 2008) (Fig. 2). Bio-deterioration is the alteration of a polymer's mechanical, chemical, and physical properties caused by the growth of microorganisms on or inside the polymer's surface. Microorganisms fragment polymers into oligomers and monomers, which are then available as carbon, energy, and nutritional sources in the next absorption stage, with CO_2, water, and biomass as by-products (Emadian *et al*., 2017).

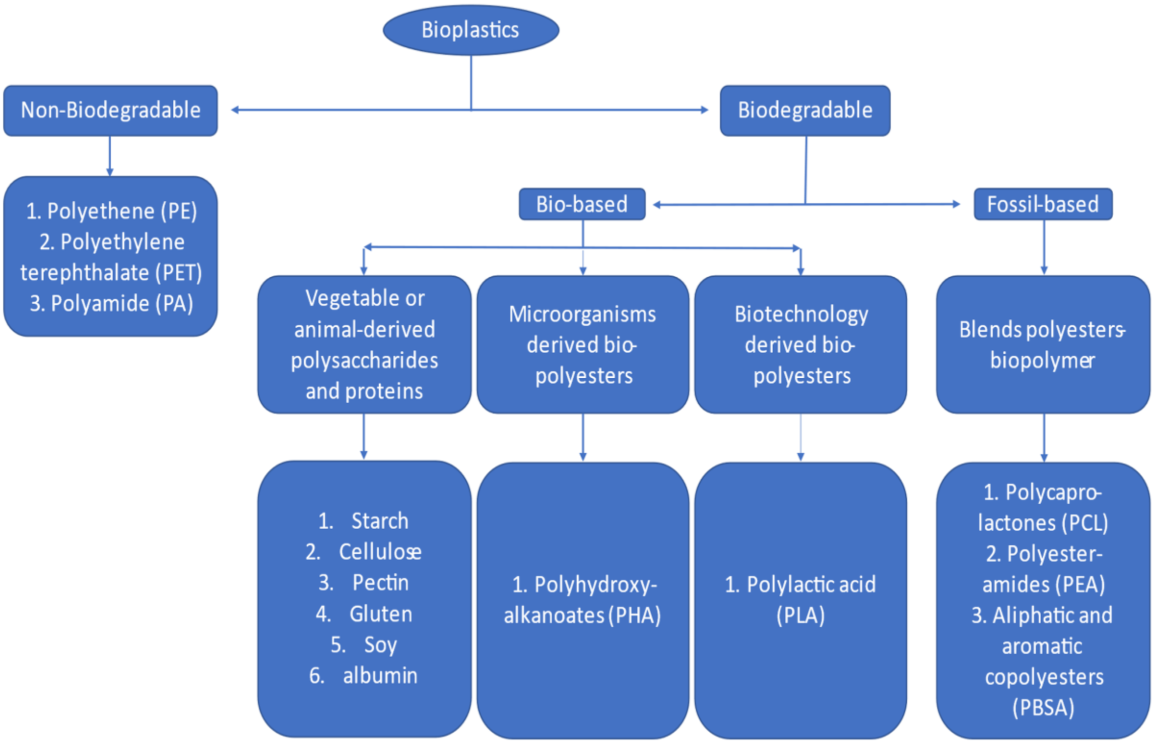
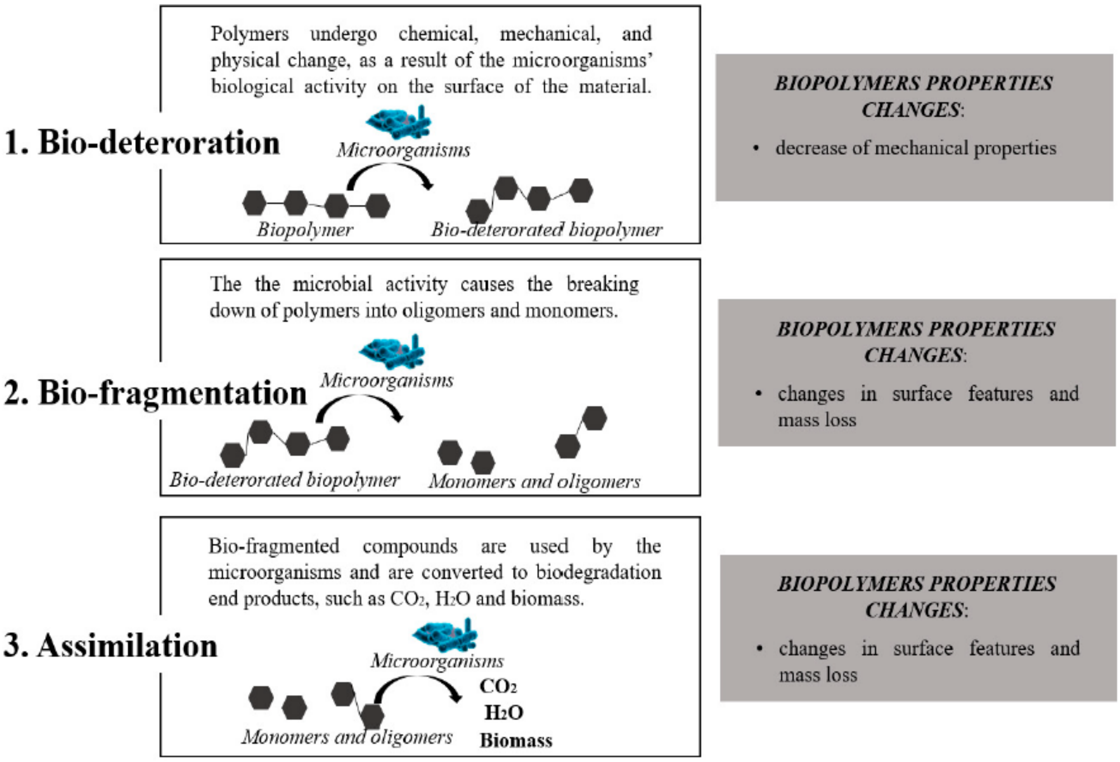


Fig.1: Scheme of bioplastics classification (Acquavia *et al*., 2021)


Polymers undergo chemical, mechanical, and physical change, as a result of the microorganisms' biological activity on the surface of the material.

The the microbial activity causes the breaking down of polymers into oligomers and monomers.

Bio-fragmented compounds are used by the microorganisms and are converted to biodegradation end products, such as CO_2, H_2O and biomass.

Fig.2: The main three steps through which the biodegradation of polymers occurs (Adopted from Acquavia *et al*. 2021)

Mechanical and physical peculiarities of bioplastics

An evaluation of a biomaterial's mechanical-physical qualities is required to determine its suitability for a certain sector and the estimated service life. The ultimate tensile strength, Young's modulus, and elongation at break are the key mechanical parameters that are routinely measured after the manufacturing of a bioplastic. The ultimate tensile strength, or simply tensile strength, represents the maximum stress that a material can bear before breaking, whereas Young's Modulus, commonly known as elastic modulus, describes a material's stiffness: the greater the value, the stiffer the material (Granda *et al.*, 2016). The elongation at break values is a measure of material ductility and is affected by the rate (crosshead speed) and temperature. For brittle materials, the elongation at break value is typically very small and close to zero. All of these qualities are influenced by the chemical structure, the degree of polymer orientation, and the crystallinity of the material, as well as the existence of fibres that act as reinforcement or plasticizers (Sanjay *et al.*, 2015). Besides mechanical properties, biomaterials have physical properties such as water vapour permeability (WVP), oxygen permeability (OP), and water contact angle (WCA). These metrics indicate how easy water vapour or oxygen can pass through a biodegradable substance. Water contact angle, which is defined as the angle between the baseline of a drop deposited on the material's surface and the tangent at the drop boundary, increases as surface hydrophobicity increases (Tihminlioglu *et al.*, 2010). Because the degree of hydrophobicity of the surface is critical for ensuring effective barrier qualities, the evaluation of WVP, OP, and WCA is required.

Food waste as provender stash of bioplastic production

Plant biomass's molecular complexity provides a plethora of natural bio-based polymers as well as monomeric feedstocks for bioplastic manufacturing. Currently, the majority of bioplastics are made from agricultural crop feedstocks (carbohydrates & protein). Due to competition for arable land, fresh water, and food production, these are not yet perfectly linked with sustainable development goals (SDGs). According to the United Nations Food and Agriculture Organization (FAO), an estimated 1.3 billion tonnes of food is lost globally each year at all phases of the food supply chain, including post-production, handling/storage, manufacturing, wholesale/retail, and consumption. Because landfilling food waste leads to undesired outcomes such as greenhouse gas (GHG) emissions and contamination of groundwater, valorising it through bioplastics production may offer a way to solve its disposal problem through renewable and sustainable techniques (Tsang *et al.*, 2019).

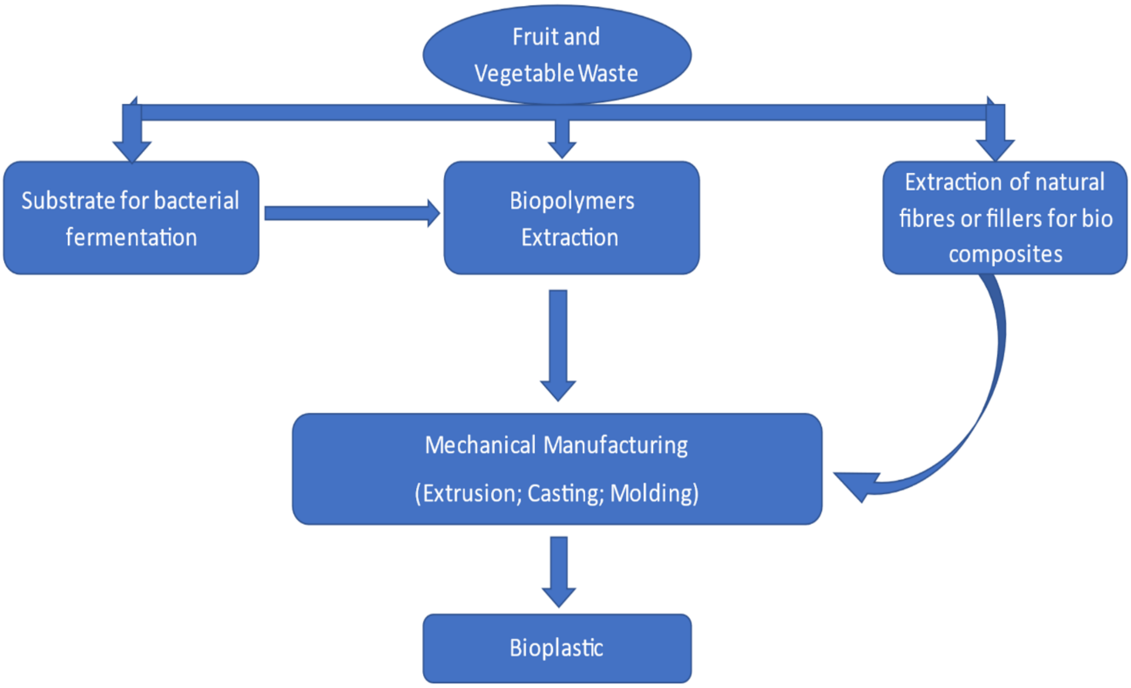


Fig. 3: Food waste could be converted into bioplastics by biopolymer extraction and mechanical manufacture (extrusion, casting, moulding, or a combination of them)

Food waste (FW) can be used to make bioplastics in a variety of means (Fig. 3). It is frequently used as a substrate for bacterial fermentation to produce natural polyesters such as PHA and polylactic acid (PLA). Other simple bioplastics production procedures involve the direct extraction of biopolymeric components from the food waste stream, which are then processed to produce the finished goods. More sophisticated procedures, on the other hand, necessitate additional steps in which the extracted biomass or biopolymers are utilised as reinforcements or fillers in the fabrication of biocomposites. However, both formulations, biopolymers and biocomposites, are finally treated to produce biofilms or three-dimensional structures using traditional mechanical procedures such as extrusion, moulding, casting, or a combination of these (Bashir & Manuswamy, 2015). Biopolymers derived from fruit and vegetable waste exhibit a variety of traits and attributes that make them more or less suited for the creation of environmentally friendly materials (Table 1). Biopolymer extraction from food waste could be accomplished chemically or enzymatically. Because they are solvent-free, enzymatic procedures are usually regarded as clean.

Table 1: Main biopolymers extracted from fruits and vegetable wastes for bioplastics production

Biopolymer Name	Biopolymer Type	Fruits and Vegetable Wastes Used as Biopolymer Source
Cellulose	Polysaccharide	Banana peels, carrots waste, cauliflower waste, cocoa pod husks, orange peels, parsley stems, radicchio waste, rice hulls, spinach steams, and tea leaves waste.
Starch	Polysaccharide	Banana peels, cassava peels, potato peels.
Pectin	Polysaccharide	Apple pomace, banana peels, citrus waste, orange peels
Cutin	Polyester of hydroxy fatty acids	Tomato waste

CONCLUSION

The valorization of food waste can create opportunities to produce bioplastics, which represent an eco-friendly alternative to conventional petroleum-based plastics. Compatible with the “circular economy”, therefore with “zero waste”. Innovative, sustainable, renewable and environment-friendly approach.

REFERENCES

Acquavia, M.A.; Pascale, R.; Martelli, G.; Bondoni, M.; Bianco, G. Natural Polymeric Materials: A Solution to Plastic Pollution from the Agro-Food Sector. Polymers 2021, 13, 158.

Bashir, A.S.M.; Manusamy, Y. Recent Developments in Biocomposites Reinforced with Natural Biofillers from Food Waste. Polym. Plast. Technol. Eng. 2015, 54, 87–99.

Campos, M.I.; Figueiredo, T.V.B.; Sousa, L.S.; Druzian, J.I. The influence of crude glycerin and nitrogen concentrations on the production of PHA by Cupriavidus necator using a response surface methodology and its characterizations. Ind. Crops Prod. 2014, 52, 338–346.

De Almeida Oroski, F.; Chaves Alves, F.; Bomtempo, V. Bioplastics Tipping Point: Drop-in or non-drop-in? J. Bus. Chem. 2014, 11, 42–50.

Emadian, S.M.; Onay, T.T.; Demirel, B. Biodegradation of bioplastics in natural environments. Waste Manag. 2017, 59, 526–536.

Granda, L.A.; Espinach, X.; Méndez, J.A.; Tresserras, J.; Delgado-Aguilar, M.; Mutjé, P. Semichemical fibres of Leucaena collinsii reinforced polypropylene composites: Young’s Modulus analysis and fibre diameter effect on the stiffness. Compos. Part B Eng. 2016, 92, 332–337.

Kumar, S.; Thakur, K. Bioplastics-classification, production and their potential food applications. J. Hill Agric. 2017, 8, 118.

Lucas, N.; Bienaime, C.; Belloy, C.; Queneudec, M.; Silvestre, F.; Nava-saucedo, J. Polymer biodegradation: Mechanisms and estimation techniques. Chemosphere 2008, 73, 429–442.

Quarta, G. Determination of the Biobased Content in Plastics by Radiocarbon. Radiocarbon 2013, 55, 1834–1844.

Reddy, R.L.; Reddy, V.S.; Gupta, G.A. (2013). Study of Bio-plastics As Green & Sustainable Alternative to Plastics. Int. J. Emerg. Technol. Adv. Eng., 3, 76–81.

Sanjay, M.R.; Arpitha, G.R.; Yogesha, B. Study on Mechanical Properties of Natural-Glass Fibre Reinforced Polymer Hybrid Composites: A Review. Mater. Today Proc. 2015, 2, 2959–2967.

Tihminlioglu, F.; Atik, I.D.; Ozen, B. Water vapor and oxygen-barrier performance of corn—Zein coated polypropylene films. J. Food Eng. 2010, 96, 342–347.

Tsang, Y.F.; Kumar, V.; Samadar, P.; Yang, Y.; Lee, J.; Ok, Y.S.; Song, H.; Kim, K.H.; Kwon, E.E.; Jeon, Y.J. Production of bioplastic through food waste valorization. Environ. Int. 2019, 127, 625–644.

Xiao, B.; Zheng, M.; Pang, J.; Jiang, Y.; Wang, H.; Sun, R.; Wang, A.; Wang, X.; Zhang, T. Synthesis and Characterization of Poly (ethylene terephthalate) from Biomass-Based Ethylene Glycol: Effects of Miscellaneous Diols. Ind. Eng. Chem. Res. 2015, 54, 5862–5869.