Chapter 6
Production of Sustainable Bioplastics Through Biomass Wastes Valorization to Mitigate Carbon Footprint Emissions

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ABSTRACT

This chapter focuses on the production of bioplastics such as polyhydroxyalkanoates (PHAs) via biomass wastes valorization. The high production costs of PHAs, particularly substrate of the base material, has limited its application. The utilization of biomass wastes from agro-industrial such as molasses, banana trunk juice, palm oil waste effluent, and animal derived chitin from crustacean as an alternative carbon feedstock is explored by many researchers, due to the abundancy, inexpensive, contains high sugar and oil contents. These industrial biomass wastes can be further exploited for lowering the production costs, simultaneously reduce biomass waste accumulation, and accelerate the application of the bioplastics at large scale. This chapter also covers the challenges of utilizing industrial waste as feedstocks for PHA production and its impact on carbon footprint mitigation. These initiatives are in parallel with various Sustainable Development Goals such as number 12, 13, 14, and 15.

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INTRODUCTION

Bioplastics such as polyhydroxyalkanoates (PHAs) offered many benefits such as complete biodegradable, biocompatible, nontoxic, antioxidant, immunotolerant, and ability to be produced from various waste streams. The physical properties of PHAs are very similar to those of commercial conventional plastics packaging (Alper et al., 1963; Gowda & Shivakumar, 2019). Although PHAs offers many benefits over the conventional plastics, the production costs of PHAs are financially infeasible as compared to the conventional petrochemical-derived plastics such as polyethylene (PE). The production cost of PHAs is approximately 4-10th fold higher as compared to PE per kg. The high price of carbon source utilize during fermentation stage is the main factors contribute to the high production cost (Nonato et al., 2001; Roland-Holst et al., 2013). Approximately 50% of the production cost is allotted to the supply of raw materials, especially in terms of the carbon source (Koller et al., 2005). The carbon sources used for PHA production are expensive because of purified sugars, fatty acids, or edible plant oils as those are relevant to human nutrition (Sen & Baidurah, 2021). Therefore, the final production cost of PHAs depends on the cost of the carbon source. The utilization of low-cost carbon source from industrial biomass wastes touted as the most viable strategy to reduce the production cost of PHA (Koller et al., 2012; Koller & Braunegg, 2018).

The initiative to utilize the biomass wastes from industry sector are in parallel with Sustainable Development Goals 12, whereby to ensure the sustainable consumption and production patterns. There are various attributes that must be met in order to determine an economical carbon source for fermentation. The economic feasibility of preferred carbon sources is characterised to have an adequate supply, uniform substrate composition, same quality from batch to batch, the ease for transportation, storage, resistance to spoilage, and no competition with food and feed. Additionally, other fermentation factors should be considered, including substrate fermentability by specific bacteria, carbon supply concentration, and the presence of PHAs accumulation inhibitors (Koller & Braunegg, 2018).

Biomass waste can be defined as the organic matter derived from plants, animals, and microorganisms that can be utilized as a source of energy, materials, and chemicals. The industry sector generates a significant amount of biomass waste, which can be utilized for the production of various biobased products, including PHAs (Ooi et al., 2023). The example of biomass wastes from the industry sector that can be utilized for PHAs production includes crude glycerol, wastewater and waste cooking oil from the food processing industry, seafood processing industry, as well as lignocellulosic waste from the pulp and paper industry.

Among of the most noteworthy PHAs makers include *Cupriavidus necator*, *Bacillus megaterium*, and *Pseudomonas* sp. Bacteria produce PHAs biopolymers as carbon and energy storage materials under nutrient limiting conditions such as low nitrogen, oxygen, sulphur, phosphate, magnesium, and potassium in conjunction with an abundant carbon source. PHA accumulates intracellularly as cytosolic granules and is found in protein- and lipid-bound subcellular organelles. The quantity and size of the granules differed between bacterium species and growth conditions (Alper et al., 1963).

Various analytical methods are available and practical to elucidate the complex composition of PHAs and its degradation mechanisms such as physical methods (SEM, TEM, weighing analytical balance, etc.), chromatographic methods (GC, THM-GC, SEC/GPC), spectroscopic methods (NMR, FTIR, XRD, XRF), respirometric methods, and thermal methods (DSC, DTA, TGA) [10].