Crimson Publishers
Wings to the Research

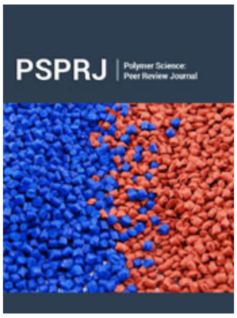
Mini Review

Insights into the Economical Production of Polyhydroxyalkanoates

Vecchiato V and Basnett P*

School of Life Sciences, University of Westminster, UK

ISSN: 2770-6613



***Corresponding author:** Pooja Basnett, School of Life Sciences, University of Westminster, London, W1W 6UW, UK

Submission: November 06, 2020

Published: December 04, 2020

Volume 1 - Issue 3

How to cite this article: Vecchiato V and Basnett P. Insights into the Economical Production of Polyhydroxyalkanoates. Polymer Sci Peer Rev J. 1(3). PSPRJ. 000511. 2020.
DOI: 10.31031/PSPRJ.2020.01.000511

Abstract

Polyhydroxyalkanoates (PHAs) are a group of biopolymers synthesized via bacterial fermentation. PHAs have emerged as a potential alternative to conventional plastics owing to their biodegradability and sustainable production process. The purpose of this review is to highlight key factors involved in the economical production of PHAs.

Keywords: Polyhydroxyalkanoates; Fermentation; Extremophile; Downstream recovery

Abbreviations: CO2: Carbon Dioxide; PHAs: Polyhydroxyalkanoates; PP: Polypropylene; PE: Polyethylene; WWF: Worldwide Fund for Nature

Introduction

In the year 1957, an Italian company Montecatini started the production of a revolutionary plastic material, known as Moplen Polypropylene, that became part of our daily lives. This discovery and commercial production of plastic led Giulio Natta and Karl Ziegler to be awarded with the Nobel Prize for Chemistry in 1963 [1].

Plastic is widely used in many different applications, since it is cheap, durable, and resistant; however, its negative impact on the environment cannot be ignored. According to WWF, 8 million tonnes of petroleum based plastic material escape the collection system and are dumped into the oceans every year. By the end of 2050, the production is expected to reach around 33 billion tonnes [2] and there could be more plastic in the sea than fish [3]. To overcome plastic pollution, concerted efforts focused on recycling and reducing the use of single use plastic is being made; nevertheless, the idea of a circular economy based on a sustainable, non-toxic and biodegradable plastic, derived from renewable feedstock is the need of the hour. Among the biopolymers, polyhydroxyalkanoates (PHAs) have recently gained attention, as a green alternative to oil-based plastic. PHAs are polyesters of hydroxyalkanoates (HAs), biosynthesized by bacteria as a carbon and energy storage.

Mini Review

These biopolymers are produced under specific conditions with an increasing amount of carbon to essential nutrients (such as nitrogen, phosphate, or oxygen) ratio [4]. Although these biopolymers have been well known since 1926, they do not offer a cost competitive performance yet, compared to the petroleum-based plastic, such as polypropylene (PP) or polyethylene (PE), which cost US $0.60-0.87/lb, while the cost of PHAs is US $2.25-2.75/lb [5]. This is due to its high production cost and low productivity coupled with instability in molecular weight and consequential properties [6]. Recent advancement has improved three fundamental steps in the large-scale production of PHAs such as the use of cheap carbon source, use of novel bacteria species and the implementation of new recovery processes.

For a circular, environmentally friendly pathway, use of cheap carbon substrate to produce high quality PHA is fundamental. Agriculture, food, dairy or cosmetic industries are among the major suppliers of cheap and renewable carbon waste [7]. To obtain maximum yield of PHAs, while maintaining its quality, an idyllic 100% carbon content in the raw material is required, therefore the impact of pre-treatment costs is prominent. The conversion from whey into galactose or glucose, for example, is necessary to improve the fermentation efficiency of PHAs [8]. Purification process is essential when it comes to obtaining crude glycerol from biodiesel, although the cost is partly counterbalanced by the maximum yield obtained, which is 75%, so far [9]. Another promising and eco-friendly feedstock for the production of PHAs is such as CO_2. Biopolymers were produced, in this case, through a dual heterotrophic autotrophic cultivation system, where CO_2 was used as an inorganic carbon substrate and glucose as the organic counterpart [10]. In addition to using cheap carbon sources, the choice of the bacterial strain is key in the economical production of PHAs. Recent studies that lie under the concept of "Next-generation industrial biotechnology (NGIB)", have focused on working with extremophiles (such as halophiles and thermophiles), as a potential solution to overcome high costs related to sterile fermentation operations [11]. Extremophiles have reduced risk of mesophilic microbial contamination, which allows operation under semi-sterile or even non-sterile conditions. It also enables production in a continuous mode for long periods. For industrial-scale production, these factors are positive in terms of efficiency and cost reduction [11,12].

For the economical and environmentally friendly production of PHAs, developing new strategies of downstream recovery, which represents half of the total process cost is essential. Currently halogenated solvents, like chloroform, are mainly used for extraction; therefore non-toxic, cost-effective and eco-friendly alternatives have been considered including microwave assisted extraction, thermo-separating aqueous two-phase extraction (ATPE), or using recyclable solvents, like 1,2-propylene carbonate [6]. These strategies have led to high-purity polymers; however, polymer recovery has been low [13]. In addition to the cost and environmental impact, the composition and properties of the PHA material, the molecular weight and level of purity must also be considered during downstream processing [14].

Conclusion

The principal characteristics of PHAs include thermo-plasticity, hydrophobicity, high molecular weight, biodegradability. Their industrial applications range from being used as coating materials to packaging, agricultural sheets and inks [15]. Due to their non-toxic nature, they have been explored for a variety of medical applications such as biocontrol agents, drug carriers, biodegradable implants and in regenerative medicine [16]. As a result, PHAs are a promising group of biopolymers, tailored for a broad spectrum of applications. They could play a key role in the fight against plastic pollution and replace conventional plastics soon [17,18]. Further research should be done in the areas of fermentation strategies, cost-effectiveness while maintaining zero carbon footprint to meet the increasing industrial demand.

References

1. Turco F (2006) Treccani.
2. Dietrich K, Dumont MJ, Del Rio LF, Orsat V (2017) Producing PHAs in the bioeconomy-Towards a sustainable bioplastic. Sustainable Production and Consumption 9: 58-70.
3. WWF (2020).
4. Ciesielski S, Mozejko J, Przybyłek G (2010) The influence of nitrogen limitation on mcl-PHA synthesis by two newly isolated strains of Pseudomonas sp. J Ind Microbiol Biotechnol 37(5): 511-520.
5. Johnston B, Radecka I, Hill D, Chiellini E, Ilieva VI, et al. (2018) The microbial production of polyhydroxyalkanoates from waste polystyrene fragments attained using oxidative degradation. Polym 10(9): 1-22.
6. Gahlawat G, Kumari P, Bhagat N (2020) Technological advances in the production of polyhydroxyalkanoate biopolymers. Current Sustainable/Renewable Energy Reports 7: 73-83.
7. Koller M, Braunegg G (2018) Advanced approaches to produce polyhydroxyalkanoate (PHA) biopolyesters in a sustainable and economic fashion. Euro Biotech J 2(2): 89-103.
8. Amaro TM, Rosa D, Comi G, Lucilla L (2018) Prospects for the use of whey for polyhydroxyalkanoate (PHA) production. Front Microbiol 10: 992.
9. Castro IP, Wittmann C, Nikel PI (2019) Biochemistry, genetics and biotechnology of glycerol utilization in Pseudomonas sp. Microb Biotechnol 13(1): 32-53.
10. Gonzalez LG, De Wever H (2017) Valorization of CO_2-rich off-gases to biopolymers through biotechnological process. FEMS Microbio Lett 364(20).
11. Pernicova I, Novackova I, Sedlacek P, Kourilova X, Kalina M, et al. (2020) Introducing the newly isolated bacterium Aneurinibacillus sp. H1 as an auspicious thermophilic producer of various polyhydroxyalkanoates (PHA) copolymers-1. isolation and characterization of the bacterium. Polymers 12(6): 1235.
12. Zhang X, Lin Y, Chen GQ (2018) Halophiles as chassis for bioproduction. Adv Biosyst 2(11): 1-12.
13. Ong SY, Zainab LI, Pyary S, Sudesh K (2018) A novel biological recovery approach for PHA employing selective digestion of bacterial bio-mass in animals. Appl Microbiol Biotechnol 102(5): 2117-2127.
14. Mannina G, Presti D, Montiel Jarillo G, Suárez Ojeda ME (2019) Bioplastic recovery from wastewater: A new protocol for polyhydroxyalkanoates (PHA) extraction from mixed microbial cultures. Bioresour Technol 282: 361-369.
15. Poltronieri P, Kumar P (2017) Polyhydroxyalcanoates (PHAs) in Industrial Applications. Handbook of Ecomaterials. Springer, Germany.
16. Ray S, Kalia VC (2017) Biomedical applications of polyhydroxyalkanoates. Indian Journal of Microbiology 57(3): 261-269.
17. Schlegel HG, Gottschalk G, Bartha RV (1961) Formation and utilization of poly-beta-hydroxybutyric acid by knallgas bacteria (Hydrogenomonas). Nature 191: 463-465.
18. Steinbüchel A (2003) Metabolic engineering and pathway construction for biotechnological production of relevant polyhydroxyalkanoates in microorganisms. Biochem Eng 16(2): 81-96.