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Polyhydroxyalkanoates: Sustainable Production and Biotechnological Applications II

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Preface

Plastics, with their unique physical and chemical characteristics, can be molded into extensively used products. These have thus become an integral part of our daily lives. This uniqueness of plastics is what makes them so intriguing and interesting. Despite their extensive usage, the major limiting factor is their non-biodegradability, thus accumulating at an unprecedented rate. It is a significant cause of concern for administrators of the environmental and health sectors. An obvious solution to this environmental issue is to follow the principle of the 3Rs: Reduce, Reuse, and Recycle. This strategy to manage plastic waste has met with very little success, reducing waste quantum by around 10%. An alternative to non-biodegradable plastics was to look for biopolymers, which have the unique characteristics of degrading within a short span and under normal environmental conditions. At the beginning of the twentieth century, scientists found *Bacillus* species to possess intracellular bodies to contain biopolymers, which had properties quite like those of synthetic polymers. This fascinating scientific journey attracted many scientists who brought this field of biopolymers into global prominence. Around 300 species of bacteria have been identified with the potential to produce biopolymers, especially polyhydroxyalkanoates (PHAs) from biowastes as feed material. Bacteria preferentially produce polyhydroxybutyrates (PHBs), which can potentially replace plastics. PHBs, being homopolymers, have certain inherent shortcomings that limit their applications. In contrast, bacteria can be manipulated to produce copolymers of PHAs, which circumvent the limitations of the PHBs, and thus have been exploited for diverse biotechnological applications. Attempts have been made quite frequently to address the issues that need to be overcome, such as the difficulties encountered during the large-scale and sustainable production of PHAs. There is a need to search for robust organisms that can withstand adverse environmental conditions, channel carbon, and energy fluxes, inhibit competing pathways, produce copolymers, and improve downstream processing. Although books have been published on these themes, with the pace with which research and development activities are going on around the world, the need to update the information is required, especially for the benefit of young researchers who are fascinated by biopolymers. Most recent exhaustive review articles published in scientific journals of repute have been focusing on one or more of the following topics: biodiversity, feedstocks, PHA structures, metabolic engineering, manipulating morphology, enhancing biomass, and recovery, Thus, to switch from curiosity-driven research that is proving uneconomical to design and device mechanisms for high-value processes and products, this book is targeted to present a comprehensive updated status of the R&D activities.

The book (Volume 1) focuses on microbial biodiversity and their metabolic potential to produce biopolymers. It provides opportunities to exploit wastes of biological origin to produce biopolymers and discusses the potential strategies for bioengineering of microbes for the sustainable production of bioplastics. The other two books focus on biotechnological applications of biopolymers in agriculture, industry, the environment (Volume II), and the biomedical sector (Volume III). It provides potential opportunities for environmental bioremediation and biotechnological bioprocesses for their potential translation into globally competent business proposals.

The book intends to help researchers channel their time, energy, and funds into areas with the greatest potential for achieving Sustainable Polyhydroxyalkanoate Production. Funding agencies will get information on prospective scientific R&D areas so that the researchers can develop globally competent business proposals. The most important component is the contributions made by well-established and reputed scientists. For society, it provides novel concepts about eco-friendly and economic benefits. The book would not have been published without the support and encouragement of Amita (my wife), Dr. Nivedita and Jolina (my daughters), and Daksh and Bhrigu (my sons). I must acknowledge the life bestowed upon me by my parents: Kanta and Ras Behari Kalia.

Seoul, Republic of Korea Vipin Chandra Kalia

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About the Editor

Vipin Chandra Kalia is presently working as a Professor at the National Research Foundation (Korea), Department of Chemical Engineering, Konkuk University, Seoul, Republic of Korea. Previously, he worked as an Emeritus Scientist at the Council of Scientific and Industrial Research (CSIR). He has been the Chief Scientist and the Deputy Director at Microbial Biotechnology and Genomics, CSIR-Institute of Genomics and Integrative Biology, Delhi. He is a Professor at the Academy of Scientific and Innovative Research (AcSIR), and he obtained his M.Sc. and Ph.D. in Genetics from the Indian Agricultural Research Institute, New Delhi. He has been elected as (1) Fellow of the National Academy of Sciences (FNASc), (2) Fellow of the National Academy of Agricultural Sciences (FNAAS), and (3) Fellow of the Association of Microbiologists of India (FAMSc). His main research areas are Microbial biodiversity, Bioenergy, Biopolymers, Genomics, Microbial evolution, Quorum sensing, Quorum quenching, Drug discovery, and Antimicrobials. He has published more than 200 papers in scientific journals such as *Nature Biotechnology*, *Biotechnology Advances*, *Trends in Biotechnology*, *Renewable and Sustainable Energy Reviews*, *Science of the Total Environment*, *Annual Review of Microbiology*, *Critical Reviews in Microbiology*, *Bioresource Technology*, *Seminars in Cancer Biology*, *BMC Genomics*, *Polymers*, and *Ecotoxicology and Environmental Safety*. He has authored 35 book chapters. His works have been cited 15179 times with an h-index of 68 and an i10 index of 184. He has edited 16 books published in Springer. He has been the Editor-in-Chief of the *Indian Journal of Microbiology* (2013 through 2023) and is still serving as the Editor/Academic Editor for multiple reputed journals. He has been a member of the American Society for Microbiology (2010–2015). He has been conferred the following awards: (i) Prof. S.R. Vyas Memorial Award, Association of Microbiologists of India (2016); (ii) American Society for Microbiology – Indo-US Science and Technology Forum (ASM-IUSSF)—Professorship Program, USA (2014); (iii) INSA Bilateral Exchange Programme, Indian National Science Academy, India (2006); (iv) DBT Overseas Associateship, Department of Biotechnology, Government of India (2005–2006); (v) Dr. J.V. Bhat Award, Association of Microbiologists of India (2012, 2015, 2016, 2017) and Faculty Research Award in Microbiology, 2018. He can be contacted at: vckaliaku@gmail.com.

Potential Perspectives of Microbial-PHA Biopolymers Produced by Using Agro-Wastes for Food Packaging Applications

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Abstract

Fermentation processes such as solid-state fermentation and submerged fermentation are helpful for the production of PHA (polyhydroxyalkanoates) polymer at a large scale. These polymers have been extensively used in biotechnological applications, from medical implants to nanodrugs, agriculture mulch film, to heart valves. PHA-based bioplastic, when degraded in soil, can also be used as a biofertilizer. Bioplastic fertilizers, or BpF, have been used in farming and gardening for a long time. The best among them were PHAs utilized as a food packaging material. Traditionally food packaging systems were based on plastic food packaging cellulose-based, starch-based, protein-based, etc. Production of food packaging with the help of PHA polymer has become one of the most promising research, which also booms the bioplastic industries. The fermentation process maximizes PHA production and reduces the cost of PHA production using carbon-rich agro-wastes. These PHA biopolymers are produced from microbes and are extracted using different extraction methods; ATPS is the most promising extraction method for the maximum recovery of PHA. Besides having the properties of food packaging and disposable tableware, PHA biopolymer can also be used in numerous biotechnological applications. It can be used in agriculture as crop protection films, biofertilizers, therapeutic applications as a nanodrug carrier, tissue engineering, etc.

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