

Sustainable Environmental Waste Management Strategies

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Bioenergy and Value Added Byproducts from Biomass Waste

 Springer

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ISSN 3005-1622

ISSN 3005-1630 (electronic)

Sustainable Environmental Waste Management Strategies

ISBN 978-3-032-22848-2

ISBN 978-3-032-22849-9 (eBook)

<https://doi.org/10.1007/978-3-032-22849-9>

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Chapter 4

Microbial-Based Bioenergy Production: Sustainable Biofuels from Organic Waste and Biomass



Akhtar Hussain, Irum, Gyanendra Tripathi, Ayush Saxena, Madhvi Singh, Alvina Farooqui and Mohammad Ashfaque

Abstract Microbial bioenergy production offers a sustainable approach to fuel generation by utilizing the metabolic capabilities of microorganisms to convert organic waste and biomass into biofuels. This process not only reduces dependence on fossil fuels but also provides an environmentally friendly alternative for waste management. Key biofuels including bioethanol, biodiesel, biogas, and advanced biofuels such as butanol and biohydrogen are synthesized through microbial fermentation, anaerobic digestion, and electrosynthesis. These processes rely on diverse microbial pathways, including enzymatic fermentation, lipid biosynthesis, and methanogenesis, which utilize feedstocks such as lignocellulosic biomass, agricultural residues, and industrial waste. Recent breakthroughs in genetic engineering, synthetic biology, and metabolic engineering have enhanced microbial efficiency and increased biofuel yields. Technologies such as omics-driven pathway optimization and microbial fuel cells further improve bioenergy production. However, several challenges persist, including scalability limitations, high pretreatment costs, and environmental concerns such as water and nutrient demands. Additionally, regulatory policies and land-use competition influence the feasibility of large-scale commercialization. To overcome these barriers, ongoing research and the adoption of innovative strategies such as synthetic microbial consortia and integrated biorefineries are essential. These approaches enhance efficiency by enabling multiple product streams and optimizing microbial interactions. Aligning microbial bioenergy production with global sustainability goals, such as greenhouse gas emission reduction and circular economy principles, highlights its role in addressing climate change. With continuous technological advancements and supportive policies, microbial bioenergy has the potential to drive the transition toward a cleaner and sustainable energy landscape.

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