

# Waste Biomass Management – A Holistic Approach

Lakhveer Singh • Vipin Chandra Kalia  
Editors

# Waste Biomass Management – A Holistic Approach

 Springer

*Editors*

Lakhveer Singh  
Faculty of Engineering Technology  
Universiti Malaysia Pahang (UMP)  
Gambang, Kuantan, Malaysia

Vipin Chandra Kalia  
CSIR - Institute of Genomics and Integrative  
Biology  
New Delhi, India

ISBN 978-3-319-49594-1

ISBN 978-3-319-49595-8 (eBook)

DOI 10.1007/978-3-319-49595-8

Library of Congress Control Number: 2017935490

© Springer International Publishing AG 2017

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer International Publishing AG

The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

*Dedicated to my Parents*

# Preface

All living beings have quite efficient metabolisms. Plants are the basic producers of almost all things, which are available for consumption by human beings. Animals and human beings are able to digest most of the plant parts, however, a few components go undigested and are excreted out. A few other components of plant origin, which are not fit for human consumption, find their way to the landfills. Here, microbes play an active role in further degradation of wastes of biological origin. Microbes work either in isolation or in association with others. Anaerobic digestion is a wonderful process which involves different sets of microbes with highly specialized metabolic activities. These networks of different biochemical pathways result in almost complete degradation of organic matter present in the biowastes. The different intermediates can be either used as feed for the next set of microbes or may end up as bioproducts with unique applications. Although such processes are already operative in Nature, however, we need to work hard to elucidate the mechanisms and then exploit them for the benefit of human beings. Specialized pretreatments either physico-chemical or enzymatic help to make the process of waste degradation a bit easier. For enzymatic treatment, microbes with high hydrolytic process are required. Thermochemical conversion—liquefaction of biomass generates high value byproducts. These processes for waste biomass management result in producing oil, ethanol, biodiesel, sugars, biogas, activated carbon, etc. The last century has seen a transition from chemical to biological processes, primarily because of their eco-friendly nature. The Green Technologies are expected to save Earth. Scientific efforts are constantly needed to realize the significance of these approaches. Here, the rising stars of tomorrow—the young researchers and scientists need to make innovative contributions. This book intends to feed the young ignited minds and provoke them to contribute scientifically for the economic benefits of the society. In this book, scientists with strong academic backgrounds and practical experience have shared their research works carried out over the last few decades. This book is a reflection of the dedication of the scientific community towards human welfare. I am truly humbled by the contributions of each of the respected authors. I am extremely indebted to them for their

efforts. Words are not sufficient enough to truly and adequately acknowledge the worthiness of their efforts. My true inspirations to write this book were bestowed in me and the constant faith and support of—my mother (Late Mrs. Kanta Kalia), who passed away, during the preparation of this book, and my father (Mr. R.B. Kalia), Amita (wife), Sunita, and Sangeeta (sisters), Ravi, Vinod, and Satyendra (brothers), Daksh and Bhriгу (sons), my teachers especially Dr. A.P. Joshi, my friends—Rup, Hemant, Yogendra, Rakesh, Atya, Jyoti, Malabika, Neeru, and Ritusree. I must also acknowledge the support of my young friends—Asha, Sadhana, Sanjay, Mamtesh, Subhasree, Shikha, Jyotsana, Ravi, Priyanka and Rahul.

Delhi, India

Vipin Chandra Kalia

# Contents

<b>Anaerobic Digestion</b> . . . . .	1
Sevcan Aydin	
<b>Using Pretreatment and Enzymatic Saccharification Technologies to Produce Fermentable Sugars from Agricultural Wastes</b> . . . . .	15
Caoxing Huang, Ben Jeuck, and Qiang Yong	
<b>Various Sludge Pretreatments: Their Impact on Biogas Generation</b> . . . .	39
J. Rajesh Banu and S. Kavitha	
<b>Hydrolysis of Lignocellulosic Biomass for Recovering Hemicellulose: State of the Art</b> . . . . .	73
I.S.M. Rafiqul, A.M.M. Sakinah, and A.W. Zularisam	
<b>Latent Potential of Microalgal Biomass: Research Efforts and Challenges</b> . . . . .	107
Pau Loke Show, Arumugasamy Senthil Kumar, Sue Wen Siow, Siti Sabariah Din, Vidya Sundaram, and Kulandai Arockia Rajesh Packiam	
<b>Treatment of Dye Wastewater for Water Reuse Using Membrane Bioreactor and Biofouling Control</b> . . . . .	121
Muhammad Faisal Siddiqui, Lakhveer Singh, and Zularisam Ab Wahid	
<b>Economic and Market Value of Biogas Technology</b> . . . . .	137
Abu Yousuf, Maksudur Rahman Khan, Domenico Pirozzi, Zularisam Ab Wahid, and Samson Mekbib At naw	
<b>Biomass Gasification</b> . . . . .	159
Samson Mekbib At naw, Shaharin Anwar Sulaiman, and Suzana Yusup	
<b>Activated Carbon from Renewable Sources: Thermochemical Conversion and Activation of Biomass and Carbon Residues from Biomass Gasification</b> . . . . .	187
Davide Bergna, Henrik Romar, Sari Tuomikoski, Hanna Runtti, Teija Kangas, Pekka Tynjälä, and Ulla Lassi	

<b>Pyrolysis of Biomass</b> . . . . .	215
Dooshyantsingh Oochit, Anurita Selvarajoo, and Senthil Kumar Arumugasamy	
<b>Liquefaction of Biomass for Bio-oil Products</b> . . . . .	231
Hua-jun Huang, Xing-zhong Yuan, and Guo-qiang Wu	
<b>Intensified Synthesis of Bioethanol from Sustainable Biomass</b> . . . . .	251
Saurabh M. Joshi and Parag R. Gogate	
<b>Current Approaches in Producing Oil and Biodiesel from Microalgal Biomass</b> . . . . .	289
Marcondes M. Pacheco, Michele Hoeltz, Diego de Souza, Lisianne B. Benitez, Rosana C.S. Schneider, and Maria V.G. Müller	
<b>Intensified Synthesis of Biodiesel from Sustainable Raw Materials Using Enzymatic Approach</b> . . . . .	311
Preeti B. Subhedar and Parag R. Gogate	
<b>An Integrated Approach for Efficient Energy Recovery Production from Livestock and Agro-Industrial Wastes</b> . . . . .	339
Sandra Silva, Ana Cristina Rodrigues, Ana Ferraz, and Joaquim Alonso	
<b>Microbial Fuel Cells: Types and Applications</b> . . . . .	367
Ravinder Kumar, Lakhveer Singh, and A.W. Zularisam	
<b>Index</b> . . . . .	385



## About the Editors

**Vipin Chandra Kalia** is presently working as Emeritus Scientist. 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, AcSIR, who obtained his M.Sc. and Ph.D. in Genetics, from 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 (FAMI), and. His main areas of research are Microbial biodiversity, Bioenergy, Biopolymers, Genomics, Microbial evolution, Quorum sensing, Quorum quenching, Drug discovery and Antimicrobials. He has published more than 100 papers in Scientific journals such as (1) Nature Biotechnology, (2) Biotechnology Advances, (3) Trends in Biotechnology, (4) Annual Review of Microbiology, (5) Critical Reviews in Microbiology, (6) Bioresource Technology, (7) PLoS One, (8) BMC Genomics, (9) International Journal of Hydrogen Energy, and (10) Gene. He has authored 14 book chapters. His works have been cited 3712 times with an h index of 32 and an i10 index of 71 (<http://scholar.google.co.in/citations?hl=en&user=XaUw-VIAAAAJ>). He has Edited three books: (i) Quorum Sensing versus Quorum Quenching: A Battle with No End in Sight (2015), <http://link.springer.com/book/10.1007/978-81-322-1982-8>, (ii) Microbial Factories Vol. 1: Biofuels, Waste treatment (2015) <http://link.springer.com/book/10.1007%2F978-81-322-2598-0>, and (iii) Microbial Factories Vol. 2: Biodiversity, Biopolymers, Bioactive Molecules (2015) <http://link.springer.com/book/10.1007%2F978-81-322-2595-9>. He is presently the Editor-in-Chief of the Indian Journal of Microbiology and editor of: (1) Journal of Microbiology and Biotechnology (Korea), (2) International Scholarly Res. Network Renewable Energy, (3) Dataset Papers in Microbiology, and (4) PLoS One. He is a life member of the following Scientific societies: (1) Society of Biological Chemists of India; (2) Society for Plant Biochemistry and Biotechnology, India; (3) Association of Microbiologists of India; (4) Indian Science Congress Association; (5) BioEnergy Society of India, and (6) the Biotech

Research Society of India (BRSI). He is also a member of the American Society for Microbiology. He can be contacted at: vckalia@igib.res.in; vc\_kalia@yahoo.co.in.

**Lakhveer Singh** is presently working as senior lecturer at Faculty of Engineering Technology, Universiti Malaysia Pahang, Malaysia. He received his B.Sc. and M.Sc. in Chemistry from Himachal Pradesh Universiti Shimla and Punjab Universiti Chandigarh, India, in 2007 and 2009, respectively and Ph.D. in Industrial Chemistry from Universiti Malaysia Pahang (UMP) 2013. He has teaching, research and Industries experience with Universities and Industry in India. His main areas of interest are Bioenergy production, Bioreactors development, Wastewater treatment, MFC and Green Technology. In addition to research activities, he teaches undergraduate courses and guides doctoral students at Universiti Malaysia Pahang. He has a more than 30 number of international publications in high impact journals. His works have been cited 309 times with an h index of 10 and an i10 index of 10 (<https://scholar.google.com/citations?user=TK3C9WEAAA&hl=en>). He has authored three book chapters and one book. He also holds a four patent filing application for his research. He is a reviewer of Elsevier, Wiley and Springer International journals. Presently he is the editor of Advance in Chemical and Biological Engineering journal, managing editor of International journal of engineering technology (IJETS) and guest editor of International Journal of Energy Engineering. He is also a member of International Water Association (IWA). He can be contacted at: lucki.chem09@gmail.com lakhveer@ump.edu.my.