Industrial Biorefineries and White Biotechnology introduces modern biorefineries as an alternative and as an amendment to industrial crude oil and gas refineries, giving a complete review of the driving forces in modern industrial biotechnology and biochemistry. This book fills a gap in the current knowledge base and will play a key role in advancing technological perspectives in the field.

There has been a tremendous amount of recent scientific and technological development in the area of biorefining, including industrial processes and product development using "green technologies," often referred to as White Biotechnology. This book addresses key requirements for modern and innovative processes in the field of biorefining. It will be of immense use for students and researchers, including biotechnologists and bioengineers. The book also appeals to chemists and biochemists as well as marketing and product development managers in the chemical industry who are looking for summary reviews of the latest developments in biorefining and biotechnology.

Key Features:
- Provides information on the most advanced and innovative treatment processes and technologies for biomass
- Covers information on lignocellulosic and algal biomass to work on the principles of biorefinery
- Gives an update of current biorefinery concepts including wood, algae, lignocellulosic, and hybrid biorefineries
- Discusses integration of processes and technologies for the pretreatment of biomass in an industrial scale
- Details fermentation and metabolic pathways to microbial fuels, chemical intermediates, chemical specialties, and biopolymers

Edited by Ashok Pandey, Rainer Höfer, Mohammad Taherzadeh, K. Madhavan Nampoothiri, and Christian Larroche.
INDUSTRIAL BIOREFINERIES AND WHITE BIOTECHNOLOGY

Edited by
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Although the beginnings are shrouded in the mists of human prehistory, viniculture\(^1\) as well as beer brewing\(^2\) and sourdough bread-making\(^3\) are early domestic technologies. In this sense, yeast microbes reckon among the earliest domesticated organisms and methods of White Biotechnology have accompanied mankind since the very beginnings of civilization. Renewable raw materials have been utilized by mankind through the millennia as food, to feed domesticated animals, to clothe themselves, or as firewood, construction material, and to make articles for daily use. The replacement of craft activity by power-driven machines such as steam engines that were fueled by the fossil raw material coal together with the associated changes in economic and social organization that began in Great Britain in the late eighteenth century represent the beginning of the Industrial Age, characterized inter alia by the improved logistics for people and goods by railways and steam ships. The triumph of fossil raw materials began when, in addition to coal, crude oil (also called petroleum) was discovered from the middle of the nineteenth century as a resource, first for lamp oil (in the USA widely sold as kerosene\(^4\)) and since the early 1900s to produce appropriate hydrocarbon fractions that could fuel internal combustion engines, such as diesel engines (compression-ignition engines), Otto motors (spark-ignition engines), and combustion turbines (jet engines). However, untreated crude is virtually useless, just good to be burned thereby producing an awful smell and a great deal of smoke. Only in a refinery the complex mixture of hydrocarbon molecules in crude oil is separated and converted by fractionation, cracking, reforming, isomerization, hydrotreating operations into petroleum products, which can be used as fuels, lubricants, and as feedstock in petrochemical processes. Today, the fossil raw materials coal, crude oil, and natural gas remain the dominant world energy sources accounting for roughly 80% of world energy supply.\(^5\) However, the Club of Rome’s report published in the year 1972 together with the first oil crisis, which erupted in 1973, already created awareness that the fossil resources on which the industrial base depends are limited and will run out with no major change in the physical, economic, or social relationships of society.\(^6\) The message was further developed when in 1987, the Brundtland commission created the sustainable development concept.\(^7\)

This concept was meant to provide a long-term balance between the environment, the economy, and the social well-being of humanity. As a result, in 1992, the UN Conference on Environment and Development (UNCED), more commonly known as the Rio Earth Summit, established a number of initiatives to promote the uptake of sustainable development worldwide. Contemporaneously, anthropogenic climate change emerged on the public agenda in the mid-to-late 1980s and year 1990, the first report of the Intergovernmental Panel on Climate Change (IPPC) ascertained that (besides the “natural greenhouse effect which already keeps the Earth warmer than it would otherwise be”) “emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases such as carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide. These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth’s surface.” The steadily growing global energy demand on the one side and, on the other, the finite nature and instability of fossil fuel supply and, because of their exploitation, the ever-increasing atmospheric concentration of the carbon dioxide greenhouse gas have initiated a turnaround away from fossil fuels toward the utilization of biomass as a renewable raw material and energy resource. Conceptually, the processing of biomass to produce fuels, power, heat, and value-added chemicals would be done analogous to today’s petroleum refineries in conversion facilities called biorefineries. Biomass comprises the entire terrestrial vegetation, defined as the “mass of live or dead organic matter” or, somewhat more specifically, as “the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste.” The immense variety of natural resources requires a preselection of refinery feedstock and allows for a well-adapted design of value chains. Insofar, biorefineries will distinguish from petrochemical refineries in order to conform to the complexity in composition and regional distribution of living matter at the same time linking with agriculture and arable farming as key elements for a secure supply and a genuine, large expansion of available biomass feedstock. Significant progress has been made during the last decade with

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regard to the industrial utilization of biomass and the manufacture of bio-based building blocks. Bio-based intermediates such as 1,3-propanediol, isobutanol, succinic acid, and 1,4-butanediol, which all were at laboratory level still in 2006 have meanwhile entered world-scale production.\textsuperscript{13}

Part A of Industrial Biorefineries & White Biotechnology provides a comprehensive survey of biorefinery concepts and updated information about individual biomass refining unit operations, regional key aspects, and the road maps toward marketable products and energy in comparison to petrochemical refineries and process chains. Part B is dedicated to highlight White Biotechnology\textsuperscript{14} (also known as Industrial biotechnology or biotechnology applied to industrial processes) as a particularly promising gateway to a sustainable future. White biotechnology has positioned itself distinctly from Red biotechnology, which is aimed at medical processes and from Green biotechnology, which is biotechnology applied to agricultural processes such as genetically modified crops and plants.\textsuperscript{15} Part B of Industrial Biorefineries & White Biotechnology summarizes the achievements made by research and industry in microbial and enzymatic catalysis and throughout organic specialty chemicals, bioplastics, and in the utilization of biotechnology for food and personal care applications.

The editors would like to thank all the authors, who by their origin and their academic or industrial spheres of activity showcase the global scope of modern chemistry, for their commitment and for bringing in their knowledge, their professional experience, and their expertise.

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Industriai Biorefineries and White Biotechnology

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There has been a tremendous amount of recent scientific and technological development in the area of biorefining, including industrial processes and product development using "green technologies," often referred to as White Biotechnology. This book addresses the requirements for much-needed design concepts in modern biorefineries. Edited by a world-renowned collection of experts, the text merges industrial biorefinery and white biotechnology and is of immense use for students and researchers, including biotechnologists and bioengineers. The book also appeals to chemists and biochemists as well as marketing and product development managers in the chemical industry who are looking for summary reviews of the latest developments in biorefining and biotechnology.

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