

Preface

Energy is one of the major elements for the sustenance of life. It is the driver of life and can be obtained from different sources-conventional and non-conventional and renewable and non-renewables. There are several renewable energy resources including biomass, solar, wind, tidal, hydro, geothermal, etc., which can be exploited to meet the energy demand of the burgeoning global population. Biomass is one of the renewable resources which is available abundantly and is almost evenly distributed across the globe. Biomass resources can partially offset the ever-increasing energy demand for power, process steam, home-heating and transportation. However, the use of biomass for a particular purpose or for the production of a single product may not be economical and viable. The harnessing of biomass and its utilization for multiple uses such as energy, chemicals/solvents/intermediates and other products can make the process economically viable.

Biorefinery, based on the concept of the conventional grass-roots crude oil refinery and petrochemicals complex, may open up multiple options for the production of various forms and classes of fuels, platform chemicals, chemical intermediates for downstream processing, and heat and power generation from a myriad of biomass materials.

Biomass can be transformed and converted into a number of products through various routes. Such routes may be physical, biochemical, chemical, thermal and their combinations. These processes can be divided based on the steps involved in the process. For example, if microbial or biological entities are involved in the process, the process is called the biochemical conversion process. Likewise, if high temperature and pressure are involved, we call it the thermochemical conversion process. If a catalyst is involved, it is called a catalytic conversion process. The application generally dictates the selection of the biomass feedstock and the appropriate conversion process.

The biochemical conversion processes can be aerobic, anaerobic and facultative depending on the kind of microbial strains and the environmental conditions prevailing in the system. For example, we can process the biomass to produce biofuels such as ethanol, butanol, biogas, and hydrogen through fermentation

and/or anaerobic digestion. However, the complex structure of the biomass makes its biochemical processing difficult as the microbial species involved in the fermentation processes are unable to decompose the complex molecular structure of the biomass into simple sugars which can then be converted into desired products biochemically. The breakage of the complex structure can be achieved by using cellulolytic enzymes, which themselves are produced by microorganisms. However, the process is beset with the low rate and low activity of lignocellulolytic enzymes on the raw biomass. This necessitates the pretreatment or preprocessing of the biomass, which may break the complex structure of the biomass molecules, increase the surface area and make the cellulosic polymers accessible to enzymes and amenable to enzymatic attack. This enhances the rate and the efficiency of the breaking down of the complexity of the biomass molecules into fermentable sugars. The pretreatment can be physical, thermal, biological, chemical, and their combinations.

Thermochemical conversion processes comprise combustion, gasification and pyrolysis of the biomass to produce thermal energy/electrical power, liquid fuel, gas, and char. These processes generally do not require much pretreatment. However, the use of densified biomass propels up the process efficiency. Densified biomass such as wood pellets, briquette, etc. can be used. Thermochemical gasification of biomass produces gas which can be used in the gas turbine to produce power or it may be upgraded through various operations downstream for use as the syngas for the production of various chemicals downstream. Chemical conversion processes involve the catalytic conversion of biomass including vegetable oils (non-edible to be used due to food security concern) and lignocellulosics to produce biodiesel and green diesel through trans-esterification and hydrothermal liquefaction.

Other than biofuels, platform chemicals from cellulosic/ hemicellulosic fractions and lignin can be produced using biochemical, thermochemical and/or chemical processes. The products may include polyols, organic acids, polymers, cyclic compounds, etc.

The present book is an attempt to make a reader familiar with biomass characteristics, treatment and conversion processes and the challenges one faces in exploiting various biomass materials. It is a comprehensive book dealing with different aspects of processing of the biomass materials for the production of biofuels and other chemicals and to tackle technical challenges associated with the processes. The book is the joint effort of the contributing experts and researchers and covers different areas including Biorefinery in General, Thermochemical, Chemical and Biochemical Conversion Processes, Algal Biorefinery, Techno-economic Assessment, Modelling, and Simulation.

The first chapter describes the general biorefinery concept. The authors have focused on the characteristics of the biomass, global distribution of biomass, conversion technologies and challenges, and the biorefinery concept. The authors have also highlighted the importance and classification of biorefineries based on feedstocks.

The second chapter deals with the biomass, its potential and applications. The authors discussed the liberal spectrum of biomass available in general and in India, in particular. This chapter also deals with the utilization of biomass under different technology pathways for various applications and operational issues. The data provided herein will be helpful in arriving at the correct technology for the use of a given biomass.

The third chapter deals with biomass gasification and sustainability assessment of biomass utilization. This chapter discusses the implication of gasification technology for all three pillars of sustainability. Section 1 discusses gasification in brief and its types. Section 2 covers discussion on sustainability and about three pillars—environmental sustainability, social sustainability and economic sustainability, through relevant studies. Section 3 provides a summary of the discussion while Sect. 4 provides the conclusion of the chapter.

The fourth chapter describes the advancement in transformation of lignocellulosic biomass to carbohydrate derived fuel precursors. The authors in this chapter have focused on carbohydrate transformation to monomers and the monomers to furanic chemical fuel precursors.

The fifth chapter deals with biodiesel synthesis using activated carbon as support of the catalysts. This chapter provides the comparison of the homogeneous, and heterogeneous catalysis and biocatalysis for biofuel production, taking into account the types of catalysts and the price factor.

The sixth chapter describes the utilization of biodiesel in compression ignition engines. The first section deals with fuel quality of biodiesel in comparison to the base diesel. The effect of biodiesel on the engine performance (power and torque, brake thermal efficiency) and emission characteristics (CO, HC, NO_x, and smoke) of diesel engines are also discussed.

The seventh chapter deals with the potential role of halophiles in crude glycerol based biorefinery. This Chapter provides a comprehensive summary of the recent research on the microbial assimilation of glycerol. The use of halophiles as the viable alternatives for valorization of crude glycerol is also discussed.

The eighth chapter describes the advent of bio-jet fuel in the aviation sector. The author has addressed the emerging challenges to meet the stringent specifications of aviation fuels and to the utilization of bio-jet fuel as fuel sustainable, cost effective, green aviation fuel.

The ninth chapter deals with the pretreatment of lignocellulosic biomass for biofuel production. The Authors have described different pretreatment processes for the down stream operations and processes for the conversion of biomass materials.

The tenth chapter describes the operational strategies for enzymatic hydrolysis. This chapter gives an overview of the enzymatic hydrolysis process, the effect of pretreatment on enzymatic hydrolysis, operational strategies, the reactor design and operation as well as the recent advances.

The eleventh chapter describes an overview of the butanol tolerant microbes, their solvent survival strategies, and the techniques to overcome the problem associated with high concentration of butane in the fermentation media.

The twelfth chapter describes the simultaneous saccharification and fermentation of lignocellulosic biomass. This chapter emphasizes on various aspects of SSF viz. lignocellulosic substrates for SSF, biological agents involved and the factors effecting the process, different modes of operation for commercialization, constraints in SSF, their mitigation strategies and the major commercial products generated during fermentation in SSF.

The thirteenth chapter deals with bioalkanes as an ecofriendly and alternate fuel in bioenergy research. This chapter discusses the conversion strategies of biomass to bioalkanes and bioalkenes with special emphasis on metabolic engineering approaches along with the bottlenecks which hinder their commercial scale production as well as the possible solutions to overcome these hurdles.

The fourteenth chapter describes the algal biorefineries for biofuels and other value-added products. This chapter describes the general characteristics of microalgae, and their potential to be used as a raw material in the biorefinery process. It also focuses on the products, mainly biofuels obtained from microalgae, and different pathways employed in the biomass fractionation for other valuable products.

The fifteenth chapter describes the economic and technical viability of biodiesel production in India. This chapter discusses availability of oil bearing plants/crops, biodiesel production technologies, and the current status of technology in India.

The sixteenth chapter deals with the kinetic modeling of ethanol production for substrate-microbe system. The kinetic model proposed in this chapter provides good predictions for growth of biomass, substrate consumption and ethanol production for all types of substrate-microbe systems.

This comprehensive volume provides a holistic view of biomass as a valuable resource for energy and chemicals, and will help readers in understanding the broad fundamental principles involved in the exploitation of biomass and various operations and processes involved in the production of various chemicals. The readers are encouraged to point out any error which might have crept in during the process of revision/typesetting, etc.

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