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Biofuels: From Microbes to Molecules | Book

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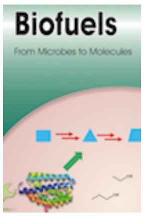

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The increasing worldwide demand for energy combined with diminishing fossil fuel reserves and concerns about climate change have stimulated intense research into the development of renewable energy sources, in particular microbial biofuels. For a biofuel to be commercially viable, the production processes, yield and titre have to be optimised; this can be achieved through the use of microbial cell factories. Using multidisciplinary research approaches and through the application of diverse biotechnologies such as enzyme engineering, metabolic engineering, systems biology and synthetic biology, microbial cell factories have begun to yield some very encouraging data. Microbial biofuels have a very promising future.

In this book a panel of international experts reviews the most important hot-topics in this area to provide a timely overview. The production of different biofuel molecules including hydrogen, methane, ethanol, butanol, higher chain alcohols, isoprenoids and fatty acid derivatives, from genetically engineered microbes, is comprehensively covered. Special focus is given to the use of metabolic engineering of microbes, including bacteria, yeast and microalgae, to enhance biofuel production. In addition authors discuss current research progress, technical challenges and future development trends for biofuel production.

Essential reading for research scientists, graduate students, and other specialists interested in microbial biofuels, the book is also recommended reading for environmental microbiologists, chemists and engineers.

Chapter 1 Purchase chapter
Metabolic Engineering: Key for Improving Biological Hydrogen Production
Dipankar Ghosh and Patrick C. Hallenbeck
Hydrogen is a renewable, efficient and clean fuel. Photobiological and fermentative microorganisms hold great promise as a means for biological hydrogen production. Different metabolic pathways come into play for hydrogen evolution in various microbes depending upon the available substrate, enzyme activity, environmental conditions and growth kinetics of the microbial system. Known microbial systems are unable to achieve the theoretical maximal for either molar hydrogen yield or cumulative or specific hydrogen productivity. The major reasons for this are thermodynamic and physiological barriers related to the metabolisms of the different microorganisms. Here we review the development of metabolically engineered microorganisms for improved biohydrogen production.

Chapter 2 Purchase chapter
Biogas Producing Microbes and Biomolecules
Kornél L. Kovács, N. Ács, T. Böjti, E. Kovács, O. Strang, R. Wirth and Z. Bagi
Biogas, essentially a mixture of methane (CH_4) and carbon dioxide (CO_2), can be used to generate electricity and heat or as bio-methane (bio-CH_4). Bio-CH_4 can be utilized in all applications in which natural gas is used today. Biogas is generated by a complex microbial community in nature and in man-made biogas reactors. An understanding of the interactions between the members of such communities and the build-up of the networks of microbial complex systems is extremely important. Culture-dependent methods cannot supply sufficient information about the life of microbial community. However, since the birth of molecular biology, more accurate taxonomic and physiological relationships between the individual microbes and within their communities can be studied and better understood. The methodology developed for molecular identification and physiological studies and recent results are reviewed. Strategies to generate biogas from unconventional substrates such as proteins, lignocelluloses and algae are discussed.

Chapter 3 Purchase chapter
Engineering Recombinant Organisms for Next-generation Ethanol Production
Eugéne van Rensburg, Riaan den Haan, Daniël C. la Grange, Heinrich Volschenk, Willem H. van Zyl and Johann F. Görgens
Development of microbes for the production of fuel ethanol continues at a rapid pace, for established first generation processes relying on sugar- and starch-based foodcrops, and second generation processes for conversion of lignocellulose to ethanol by pretreatment-hydrolysis-fermentation. The production of bio-ethanol is dominated by *Saccharomyces cerevisiae* as fermentative organism, although *Escherichia coli*, *Zymomonas mobilis* and *Kluyveromyces marxianus*, among others, were considered for second generation processes. For *S. cerevisiae*, key developments for fermentation of raw and cooked starch, as well as lignocellulose, include consolidated bioprocessing (CBP) where enzyme production for substrate hydrolysis and fermentation of released sugars are performed by a single organism. Further yeast developments required for second generation ethanol include engineering of xylose utilization capability, to increase yields from lignocellulose, and increasing the resistance of yeasts to inhibitory compounds formed during lignocellulose pretreatment prior to hydrolysis and fermentation. The present chapter will review the full scope of organism development for ethanol production, followed by examination of *S. cerevisiae* strain development for xylose utilization, CBP and hardening, as well as metabolic engineering, application of –omics technologies, and synthetic biology as examples of global efforts in organism development for ethanol production.

Chapter 4 Purchase chapter
Production of Biobutanol, from ABE to Syngas Fermentation
Michael Köpke, Ryan E. Hill, Rasmus O. Jensen and Peter Düerre
Butanol is an important commodity chemical and due to its properties considered to represent an ideal advanced biofuel. In

recent years, in addition to petrochemical production of butanol, fermentation as a means of biobutanol production has been revived. This so called ABE fermentation is not a novel process, and has already been employed commercially for most of the first half of the 20th century. While most of the principles are the same, the rise of genetic tools and metabolic engineering allowed optimization of this process. Through synthetic biology, industrial workhorses as *E. coli* and yeast have been successfully modified for production of *n*-butanol, and through a non-fermentative pathway also for production of *iso*-butanol, a process that is currently commercialized. While all these approaches rely on use of sugar or starch, alternative processes have been developed for sustainable production of biobutanol from CO_2 and light with cyanobacteria or by fermenting syngas using acetogens.

Chapter 5 Purchase chapter

Higher Chain Alcohols from Non-fermentative Pathways

Jordan T. McEwen, Yohei Tashiro and Shota Atsumi

Utilizing microorganisms for production of biofuels is one approach being explored to accommodate energy need of an increasingly modern population worldwide and to remedy heightened CO_2 emissions. Although ethanol production is well established, higher (C3-C10) alcohols possess chemical properties that are more similar to gasoline. However, natural microorganisms do not naturally produce these alcohols efficiently. Diverse approaches have been applied to microorganisms for the production of higher chained alcohols. These include: design and construction of biosynthetic pathways, optimization of genetic and regulatory processes, and engineering of enzymes for non-native substrate activity. This chapter will focus on the current approaches and techniques for engineering microorganisms for production of C3-C10 alcohols.

Chapter 6 Purchase chapter

Isoprene-derived Biofuels from Engineered Microbes

Han Min Woo and Taek Soon Lee

Recently, biofuel researches have shown an increased emphasis on the advanced biofuels which are more direct replacements to petroleum-derived transportation fuels, and more compatible to the existing fuel infrastructure than the most popular biofuel, ethanol. Advanced biofuels are mostly produced from the existing hydrocarbon biosynthetic pathways such as fatty acid biosynthesis and isoprenoid biosynthesis. These hydrocarbon biosynthetic pathways generate a range of potential biofuels with characteristics suitable for gasoline, diesels, or jet-fuels, and among them, isoprenoid pathways are unique for their richness in the type of compounds they can generate. Here, we provide the insights of a class of isoprenoid compounds that can be produced in microbes by adequate microbial engineering. Subsequently, microbial cells have been constructed to produce isoprenoids using tools of pathway and host engineering, and optimized through metabolic engineering. To broaden the spectrum of microbial synthesis of target isoprenoids, synthetic biology and systems biology also have been applied to engineered microbes. Several engineered *E. coli* and yeast strains have been constructed and being optimized for industrial applications. Downstream-modification of isoprenoids produced from engineered microbes is necessary to satisfy the current fuel properties, and catalytic processes of target compounds must be combined with the development of isoprenoids-producing strains.

Chapter 7 Purchase chapter

Engineering Microbial Fatty Acid Biosynthetic Pathways to Make Advanced Biofuels

Tingting Ning and Tiangang Liu

Fatty acid derived biofuels production received more and more concerns during the last decades of years, since they are closer to diesel fuels in characteristics of high combustion value, low water solubility and higher biodegradability than other existing biofuels. Thus the biosynthesis pathway of fatty acid was elucidated and the metabolic engineering works to produce free fatty acids, fatty alcohols, fatty acid methyl/ethyl esters, and fatty alkanes/alkenes were introduced. And finally future perspectives of this kind of work were provided.

Chapter 8 Purchase chapter

Biofuel Production by Genetically Engineered Cyanobacteria

Xuefeng Lu, Zhimin Li, Xiaoming Tan, Tao Zhu and Weihua Wang

Cyanobacteria are a group of prokaryotes that perform plant-type oxygenic photosynthesis. In recent years, with the development of modern biotechnology, cyanobacteria have shown great potential for biofuel production directly from carbon dioxide and solar energy. Herein, the phylogenetic classification, cell structure and biotechnological and environmental applications of cyanobacteria will be introduced. After discussing the available molecular tools for the cyanobacterial genetic engineering and omic studies of cyanobacteria, biofuel production by engineered cyanobacteria is reviewed. At the end of this chapter, future trends for research on cyanobacterial biofuels and web resources are provided.

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