Environmental Engineering and Management Journal, June 2006, Vol.5, No.2, 247-251
http://omicron.ch.tuiasi.ro/EEMJ/

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Book review

BIOREFINERIES – INDUSTRIAL PROCESSES AND PRODUCTS

Status Quo and Future Directions

Brigit Kamm, Patrik R. Gruber, Michael Kamm, (Editors), vol. 1
Wiley-VCH Verlag GmbH& Co. KGaA, Weinheim, Germany,
ISBN-13: 978-3-527-31027-2, ISBN-10: 3-527-31027-4, 2006,
XXXIV + 441 pages

The topic of biorefineries as means of processing industrial material and efficient utilization of renewable products is well known and applied worldwide, in almost every developed and emerging country. This tendency is motivated by the rising cost of oil and the need to move away from petrochemical-based systems.

This book, edited in two volumes, describes and discusses some aspects belonging to the topic of biorefineries, providing a general framework for the subject, types of biorefineries, the status of the technology, the principles and basics of biorefinery systems, industrial products which fall within the scope of biorefineries. The authors discuss not only the important scientific and technical issues, but also economics, infrastructure and policy, in order to ensure the sustainability of the system.

Volume 1 contains four parts and is structured into 17 chapters.

Part I, *Background and Outline – Principles and Fundamentals*, has four chapters: an overview of biorefinery systems; an analysis on the impact of biomass refining, considering the biobased economy of the 21st Century; development of biorefineries; a Dutch point of view in biorefineries for the chemical industry. In the view of ensuring sustainable development in the 21st century, sustainable economic growth requires safe and sustainable resources for industrial production, a long-term and confident investment and finance system, ecological safety and sustainable life and work perspectives for the public.

The first chapter highlights the need for conversion of large parts of the global economy into a sustainable biobased economy with bioenergy, biofuels and biobased products and its main supports. Also, the development of substance-converting basic product systems and poly-product systems – biorefineries – will allow the access to an integrated production of food, feed, chemicals, materials, goods, fuels of the future.

A historical technological outline and industrial resources include aspects on the beginnings of sugar production, starch hydrolysis, wood saccharification, formation and separation of furfural, cellulose and pulp production, synthesis of levulinic acid, lipids, vanillin from lignin, lactic acid fermentation. Some current aspects of biorefinery research and development since the beginning of the 1990's are presented, revealing that integrated processes, biomass refinery technology and biorefinery technology have become objects of research and development. Many of the currently used biobased industry products are results of direct physical or chemical treatment and processing of biomass: cellulose, starch, oil, protein, lignin, terpenes. Also, because of the help of biotechnological processes and methods, feedstock chemicals are produced, such as ethanol, buthanol, acetone, lactic and itaconic acid, aminoacids.

An US national vision, goal and plan for biomass technology are evidenced. Also, the vision, goals and plan for biomass technology in biomass technology in the EU is presented, together with the actions performed to generate a plan concerning the formulation of the objectives for bioproduction and bioproducts in Europe. The principles of biorefineries are discussed (fundamentals, definition, the role of biotechnology), as well as biorefinery systems and design (lignocellulosic feedstock biorefinery, whole-crop biorefinery, green biorefinery).

The global impact of biomass refining includes background and development aspects of the fossil carbon processing industries, the existing biobased economy (renewable carbon). A comparison of biomass feedstock costs with petroleum costs is provided. Sustainability of integrated biorefining systems, as a topic of the first part, includes aspects of agriculture/ forestry ecosystem modelling and analysis, and also technical and economic considerations underlining the importance of the biorefinery and the growing request for new products.

The fourth chapter analyses the Dutch point of view concerning biorefineries for the chemical industry. It presents an overview of the chemical products which the current industry produces. An overview covers the scope of chemical products and chemical intermediates which need to be produced from biomass, as well as the currently produced biomass – based chemical products. Biomass availability in the Netherlands is evaluated on the consideration that it is a small country where land is scarce.

Part II, *Biorefinery Systems*, contains 9 chapters.

Lignocellulose feedstock biorefinery includes issues on the strategy for returning to a sustainable source of fuels and industrial organic chemicals. The chemistry of the lignocellulosic depolymerisation and the resulting products are shown together with a short description of the processes which contributes to lignocellulosic biorefinery. The fifth chapter provides examples of integrated biorefinery applications: production of ethanol and furfural, management of municipal solid waste, biodiesel production.

The current high level of interest in lignocellulosic biomass conversion technology is driven by the potential to produce fuels and chemical to reduce dependence on petroleum, improve air quality and reduce greenhouse gas emissions. The sixth chapter discusses some of the early work which set the stage for current efforts to modernize and improve the lignocellulosic biorefinery, starting with pilot, up to commercialized lignocellulosic biomass conversion technologies (acid hydrolysis of biomass materials, enzymatic hydrolysis). Production of levulinic acid, furfural and formic acid from lignocellulosic feedstocks, presented in chapter 7, involves high temperature, acid-hydrolysis and is one of the most advanced and commercially feasible lignocellulosic-fractionating technologies currently available. The process involves the hydrolysis of polysaccharides to their monomeric constituents, converted into valuable platform chemicals. Here, the yield and efficiency of the process, as well as the methods involved, are described.

Chapter 8 presents a closed system for the manufacture of non-food products form cereals. The concept of the whole crop biorefinery is considered to be linked to cereals, as one of the most energy intense and chemically rich groups of agricultural crops. Current cereal fractionation processes break down the grain into macro and micro components that are used either as end-products, or as raw materials for secondary processing in many industries (food, pharmaceuticals, textiles, cosmetics, fermentation).

Potential whole-crop biorefineries based on wheat and oats are presented. Future biorefineries based on cereals aim to exploit the vast complexity of cereal grains by extracting valuable macro and micro components and converting the starch fraction into platform chemicals, biodegradable plastics and biofuels via microbial bioconversions, with important waste and cost reduction and the creation of some market outlets.

The production of fuel alcohol from cellulose biomass is analyzed in chapter 9 as Iogen's demonstration process for producing ethanol from cellulosic biomass. This chapter describes the process steps and related technologies: feedstock selection, pretreatment, cellulose enzyme production, cellulose hydrolysis, lignin processing, sugar fermentation and ethanol recovery.

Expectations on the development of industrial poly (3-hydroxybutytic acid) (PHB) production by the sugar cane agroindustry are illustrated in chapter 10. Due to their very interesting properties, such as: total and rapid biodegradability to carbon dioxide and water by many different microorganisms and the biocompatibility. PHB can also be produced in an environmentally safe way integrated to a sugar mill, with accessible thermal, mechanical and electrical energy obtained from renewable agricultural sources. The broad range possibilities for optimizing and reducing the cost of technology available for the extraction and purification of PHB are highlighted in this chapter.

An overview on biomass refineries based on hybrid thermochemical – biological processing is provided in chapter 11. Thermochemical processing of biomass to produce substrates suitable for fermentation is a relatively new and unexplored approach to biobased products. Following two distinct routes for

hybrid thermochemical – biological processing, gasification then fermentation of the syngas, and fast pyrolysis then hydrolysis and/or fermentation of the anhydrosugars in the resulting bio-oil, the process analysis is performed, as well as a comparison to enzymatic hydrolysis.

The green biorefinery concept is discussed in chapter 12. Green biorefineries are integrated technologies for production of materials and energy processing of green plants and parts of green plants, based on traditional technologies of green forage preservation, leaf-protein extraction, chlorophyll production, and modern biotechnological and chemical conversion methods.

There are presented the main raw materials for green biorefineries (green plants, immature grain or green plant parts). Also, all technological concepts include the separation of the cell juice from the plant framework. The discussion on economic and ecological aspects considers plant biomass as the only foreseeable sustainable source of organic fuels, chemicals, and other materials. Recommendations are made for establishing green biorefinery demonstration plants which are best suited for different regional rural structures of grassland agricultural and the cultural landscape.

Chapter 13 describes the possibility of using brown juice from the green crop-drying industry and potato juice from the potato starch industry as raw materials in Danish lactic acid production. They contain the entire nutrient necessary for lactic acid bacteria to convert carbohydrates to lactic acid. The fermented juice can be stored under anaerobic conditions and used as a substrate for a production of lactic acid, lysine and other fermentation products.

Part III, *Biomass Production and Primary Biorefineries* includes two chapters.

Biomass commercialization and agricultural residue collection analysis is based on case studies. It is underlined the fact that local conditions determine the potential feedstock quantities. The impact of different levels of surface removal depends on local conditions and practices. Sustainable removal of residues from soil is considered in relation with the benefits of the agricultural waste and residues processing by biorefineries. The perspectives are based on short-, mid-, and long-term estimations, considering that plant science will enhance the feedstock value and co-products from the biorefinery will become more significant in their economic impact on the product mix.

Chapter 15 discusses corn refining processes: wet mill refinery, dry mill refinery, as well as wastewater treatment. The modern corn refinery is seen as a model for developing future biorefineries, technologies and products, together with refinery economy. The flexibility in operating a corn refinery is given by the downstream processing of the primary product, the carbohydrate. Also, new commodity chemicals and materials capable of replacing non-renewable petroleum-derived products are manufactured more and more from corn derived glucose in such refineries, in a sustainable, environmentally acceptable manner.

Part IV, *Biomass Conversion: Processes and Technologies*, provides information on enzymes for biorefineries, as well as biocatalytic and catalytic routes for the production of bulk and fine chemicals from renewable resources.

The biorefining of agricultural residue materials, primarily focusing on recent advances in enzymatic catalysis in the conversion of biomass to fermentable sugars takes into account the biomass as a substrate from plant matter, the most abundant source of biomass on earth.

Biomass pretreatment focuses on physical disruptions, pretreatment that may continue with a chemical extraction designed to maximize subsequent enzymatic hydrolysis of the cellulose. Enzymes are very important to biomass degradation because the biodegradation products are food sources for bacteria, fungi, plants, protozoa, insects and herbivores. Cellulase development for biomass conversion is analyzed based on issues such as: optimization of the CBH-EG-BG System, proteins potentially beneficial for biomass conversion. I order to enable commercialization of various biorefineries, several major problems must be solved: raw biomass materials collected from various regions under diverse climates must be examined to assess the impact of biomass feedstock variability on pretreatment enzymatic conversion and fermentation.

The last chapter shows complete process development, starting with screening for an enzyme with the desired properties, its optimization by genetic engineering, immobilization and industrial application. Chemical routes from sugars to sugar acids are examples of increasing use of low-molecular-mass carbohydrates for production of chemical building blocks, being of great interest both economically and ecologically. Milestones in the chemical catalytic oxidation of carbohydrates are shown.

The topics presented in this volume are challenges of moving toward a sustainable society in which bio-based feedstocks, processes and products are fundamental pillars of the economy. One important feature of the book is that it discusses the necessary topics of economics, infrastructure and policy. The book can be a very valuable scientific support for the specialists interested in conservation of non-renewable resources and development of biorefineries – technologies for bio-conversion.

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