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Book Review

THE ROLE OF GREEN CHEMISTRY IN BIOMASS PROCESSING

Haibo Xie, Nicholas Gathergood (Eds.)

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The book edited by Haibo Xie and Nicholas Gathergood focuses on one of the most important scientific issues of the 21 century which is the replacing fossil fuel with sustainable alternatives such as biomass. Fossil fuels are conventional raw materials for many industrial sectors including chemical and energy production. Usage of fossil fuel is limited by their availability, price and carbon footprint. Biomass is a renewable resource globally available, cheaper and carbon sequestering. Step by step shifting towards biomass processed products usage in all industrial areas including transportation increases their sustainability and reduces overall environmental impact.

The first chapter of the book is dedicated to the familiarization of the reader with the biomass and biorefinery concepts which are both defined in larger means. The chapter also stands as a justification of the research need in the field of replacing of petroleum and coal based supply chains with biobased ones is particularly emphasized. The biorefinery technologies and biorefinery systems are discussed in general but concise terms together with critical look over the economic profitability and environmental aspects. A secondary book chapter provides information on the general green chemistry issues. The principles of green chemistry are enounced, commented and exemplified, by thus providing a more complete understanding of their importance, in chapter two. The principles of green engineering, which are derived from the green chemistry ones, are also highlighted.

The third chapter gathers information on ionic liquids (IL) as important emerging new agents (solvents and catalysts) for fractionation of the lignocellulosic biomass. The concept of a possible IL technological approach is illustrated together with the mechanism of biomass polymers dissolution. These are further usable as feedstock into different chemical processing facilities to obtain different sustainable materials or fuels. Toxicity of IL is an important issue therefore an important range of microbial and other living organisms are generally used for testing. Most of the studies have evidenced a negative environmental impact of most of the potentially useful ionic liquids. These are reasons that lead to the need of sustainable management strategies for IL use, recovery, recycling or final disposal. Moreover, research should focus on finding lower toxicity IL.

Searching for solutions to water use as a biorefinery agent is justified by reasons like safety and environmentally friendliness. One important advantage of water use is that water contained by biomass can be removed in liquid state without vaporization. Chapter four is mostly dedicated to lignocellulosics water treatment. The final targets of these pretreatments are the liberation of sugars, pulp fibers and lignin derived chemicals. Water biomass pyrolysis and gasification target on transformation of solid materials into liquid forms easier to transport. Such processes have been developed and studied by different laboratories all over the world. An important part of this chapter is dedicated to the mechanisms involved in supercritical water conversion processes.

Chapter five reviews the most promising Carbon dioxide biomass converting technologies. An example of such a process is the production of ethanol by fermentation processes. These CO_2 should be considered on collection and storage since it's purity it's rather high. CO_2 has interesting properties

as extraction solvent in certain conditions and has potential to replace fossil fuel derived solvents. Supercritical CO_2 may be used for extraction of much valued flavors and aromas from spices and for food and pharmaceutical industry. Waxes and resins may be also extracted from wood and further valued in cosmetics, lubricants, coatings or other applications. The major impediment in CO_2 usage seems to be linked to direct or indirect costs such as labor or financing costs. Biomass pelletizing promises the reduction of volume of investments.

Cellulose is the most abundant natural polymer, but an important milestone in its valorization was the lack of its solubility in common solvents. Dissolution of cellulose, discussed in chapter six, opens multiple paths towards its processing. NaOH/urea aqueous solution is a new solvent system of lower cost and better environmental performance. In this way, chapter 6 of the book reviews the most recent advances on the mechanism of cellulose dissolution in aqueous NaOH/urea system and solutions properties. Materials such as novel cellulose fibers, films, gels or derivatives are possible to be obtained by regeneration of cellulose from these new solvent solutions.

Organosolv biomass treatment methods described in chapter seven include interesting new ways of organic solvent (with or without presence of catalysts) separation of wood or nonwood lignocellulosics components. Altough conventional technologies such as kraft, soda or sulphite are still at great spread in pulping industry, organosolv methods promise a higher environmental compatibility combined with increased economic and technological potential. Most of organosolv processes utilize alcohols (especially ethanol), organic acids, phenols and amines. The employed catalysts are alkalis, acids and salts. The products should be high quality cellulose, lignin as well as other chemicals such as furfural and organic acids. The chapter also provides important insights on the chemistry of lignin and polysaccharides reactions during organosolv pulping. Interesting aspect such as mass balance, enzymatic digestibility of the obtained cellulose substrate and properties of the obtained lignins are also included.

Pyrolysis of biomass is regarded as its thermal decomposition in absence of oxygen, and is presented in chapter eight. Thermal treatment at temperatures up to 450-500°C generates products such as solid char, liquids and gases. The chemical composition of liquids includes products such as water, organic acids, aldehydes and ketones, phenols. The liquid phase, also called bio-oil, may be furthered distilled or extracted to recover valuable components. Other ways of adding value to the bio-oil are hydrogenation, cracking, steam reforming or emulsification. The generated gas phase is rich in methane, carbon monoxide and carbon dioxide as well as other chemical compounds and may be used as fuel or synthesis gas.

Using of microwave energy in chemistry is attractive due to the high efficiency of energy transfer, selectivity or significant reduction of reaction time. This subject is covered by chapter nine. By treating wood or nonwood biomass with microwaves, its enzymatic digestibility is improved. Adding catalysts, such as peroxomolybdates, to the process further enhances biomass pretreatment efficiency. The major obstacle in industrial applicability of microwave based technology is the cost of the irradiation equipment.

The tenth chapter of the book discusses the possibility of "harvesting" the products of microbial growth on different biomass substrates. Different microorganism species may be employed to produce bioethanol, biobutanol or biodiesel mainly by yeasts. Commodity chemicals such as lactic acid and succinic acid may be produced by different bacteria. The main obstacles in microorganisms' may be overcome by genetic engineering or adaptation techniques.

Catalysts have long been recognized as green chemistry agents. The eleventh chapter describes the potential applications of the heterogeneous catalysis in biomass conversion and includes the recent advances in the field. Heterogeneous catalysis may be a suitable route for conversion of lignocellulosic components to polyols or for the production of biodiesel. The continuity of subject is ensured by the presence of the twelfth chapter dedicated to catalytic conversion of glycerol as a byproduct of soaps, fatty acids and biodiesel industry. Glycerol is valued as the raw material in the production of diols, acrylic acid, acrolein and syngas.

Ultrasonic energy utilization in biodiesel production is described in the thirteenth chapter. High frequency high energy ultrasounds are responsible of cavitation, heating, acoustic streaming, cavitation and free radical generation. These effects may be used to facilitate the biomass processing by size reduction, increase in specific surface and better mass transfer.

The complexity of the mixtures obtained by different treatment methods requires similar complexity in separation o valuable products. Membrane technologies offer immediate solutions for a wide range of product separation needs. Membrane technologies have already proven their advantages over conventional separation methods. Chapter fourteen reviews the most important advances in the field of membrane application in accomplishing biorefinery needs. Ethanol separation or inhibitor removal using membrane filtration units are just two of the most important application examples provided by authors.

The last chapter provides a more complete analysis on the ecotoxicological and environmental effects of biomass processing to obtain fuels, chemicals, and other materials. Since the chemical composition of biomass processing streams is rather complex, most of the research is focused on the identification of the potentially harmful components or on the synergistic effects. In this context, different assays are to be performed to evaluate toxicity or mutagenic action of different biomass derived

substances. The authors conclude that knowledge would further contribute on the optimization of the existing processes.

The book edited by Haibo Xie and Nicholas Gathergood sets the newest trends in environmental chemistry applications such as biomass conversion to energy, fuels, chemicals and materials.

By providing interesting outlooks on a subject of such high debate and importance in both industry and research, the work of the editors sets itself as foundation for all those interested in development of new and sustainable means of bioresources processing.

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