Recalcitrance of Wood to Biochemical Conversion - Feedstock Properties, Pretreatment, Saccharification, and Fermentability

Zhao Wang

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorsexamen framläggs till offentligt försvar i Lilla Hörsalen, KB.E3.01, KBC-huset,
fredagen den 16 Mar, kl. 10:00.
Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Professor, Brett Pletschke,
Department of Biochemistry and Microbiology, Rhodes University, Grahamstown, South Africa.

Department of Chemistry
Umeå University
Umeå 2018

Organization
Umeå University
Department of Chemistry

Document type
Doctoral thesis

Date of publication
16 Mar 2018

Author
Zhao Wang

Title
Recalcitrance of wood to biochemical conversion - feedstock properties, pretreatment, saccharification, and fermentability.

Abstract

Lignocellulose is an inexpensive and abundant renewable resource that can be used to produce advanced biofuels, green chemicals, and other bio-based products. Pretreatment and efficient enzymatic saccharification are essential features of bioconversion of lignocellulosic biomass. The aims of the research were to achieve a better understanding of the recalcitrance of woody biomass to bioconversion, to explore different pretreatment techniques that can be used to decrease the recalcitrance of the biomass and improve the digestibility of the cellulose, and to investigate by-products of acid pretreatment that cause enzymes and microorganisms to work less efficiently.

The recalcitrance of wood from aspen, birch, and spruce was investigated before and after acid pretreatment. Before pretreatment, birch exhibited the highest recalcitrance, which was attributed to structural factors. After pretreatment, spruce showed the highest recalcitrance, which was attributed to chemical factors, such as high lignin content. Deacetylation of hybrid aspen in planta by a CE5 acetyl xylan esterase decreased the recalcitrance, and the glucose yield of enzymatic saccharification of non-pretreated wood increased with 27%.

Pretreatment options based on ionic liquids and steam explosion were further explored. The effects of the anionic constituents of a series of imidazolium-based ionic liquids on pretreatment of aspen and spruce were investigated. $[HSO_4]^-$ was efficient only for aspen, which was attributed to acid degradation of xylan. $[MeCO_2]^-$ was efficient for both aspen and spruce, which was attributed to its capability to create a disordered cell wall structure rather than to removal of lignin and hemicellulose. A comparison was made between using sulfuric acid and sulfur dioxide for pretreatment of spruce. Although sulfur dioxide resulted in a pretreatment liquid that was more inhibitory to both enzymes and yeast, it was still superior to pretreatment with sulfuric acid, a phenomenon that was attributed to the particle size of the pretreated material.

In a comparison of microbial inhibitors in pretreatment liquids from steam explosion of spruce, formaldehyde was found to be the most important inhibitor of yeast. Enzyme inhibition by catalytically non-productive adsorption to lignins and pseudo-lignin was investigated using quantitative proteomics. The results indicate that protein adsorption to pseudo-lignin can be as extensive as adsorption to real lignin.

Keywords
Recalcitrance, pretreatment, enzymatic saccharification, ionic liquid, steam explosion, enzyme inhibition, non-productive binding, microbial inhibitors

Language
English

ISBN
978-91-7601-853-8

Number of pages
64 + 6 papers