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Biochemical Conversion of Biomass

Hydrothermal Pretreatment, By-Product Formation, Conditioning, Enzymatic Saccharification, and Fermentability

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Abstract

Lignocellulosic residues have great potential as feedstocks for production of bio-based chemicals and fuels. One of the main routes is biochemical conversion, which typically includes pretreatment, enzymatic saccharification, microbial fermentation of sugars, and valorization of hydrolysis lignin. Utilization of a broad variety of lignocellulosic feedstocks and development of more efficient conversion processes are advantageous for making bio-based commodities affordable. Biochemical conversion of lignocellulosic biomass was investigated with the overall aim to understand how variations in pretreatment conditions affected yields, formation of bioconversion inhibitors, enzymatic digestibility of pretreated materials, and fermentability. Experiments included estimation of pseudo-lignin content and quantitation of recently discovered microbial inhibitors, such as formaldehyde and p-benzoquinone. Conditioning of pretreated material to improve the efficiency of reactions with biocatalysts was further investigated.

Hydrothermal pretreatment of sugarcane bagasse was investigated by using both autocatalyzed and sulfuric-acid-catalyzed pretreatment and by varying temperature and time in such a way that the severity factor was maintained at one of three predetermined values. For autocatalyzed pretreatments, the enzymatic digestibility of the pretreated solids was directly proportional to the severity. Pretreatment conditions that were just harsh enough to almost quantitatively solubilize hemicelluloses gave the best results.

Potential effects of the redox environment during hydrothermal pretreatment were investigated by addition of oxygen gas or nitrogen gas in experiments with sugarcane bagasse and Norway spruce. The investigation demonstrated that gas addition, and especially addition of oxygen gas, can be used to modulate the severity of acidic hydrothermal pretreatment.

Hydrothermal pretreatment of wheat straw was investigated to evaluate the impact of pretreatment conditions on newly discovered inhibitors, enzymatic digestibility, and fermentation. An increase of the temperature up to 190 °C in autocatalyzed pretreatment led to high combined glucose and xylose yields; up to ~480 kg/ton (dry weight) raw wheat straw. A correlation between enzymatic digestibility and removal of hemicelluloses was observed.

A techno-economical evaluation of several conditioning methods for slurries of steam-pretreated spruce indicated that treatment with sodium sulfite was the most favorable option. Treatments with sulfite and dithionite successfully decreased the concentration of formaldehyde. Results also indicate that increased temperature in conditioning of hydrolysate could to some extent compensate for using lower dosages of sodium dithionite.

Keywords

lignocellulosic biomass, hydrothermal pretreatment, enzymatic digestibility, ethanolic fermentation, microbial inhibitors, conditioning

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