Flowthrough Pretreatment to Characterize Biomass Deconstruction

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Project Goals: The BioEnergy Science Center (BESC) is focused on the fundamental understanding and elimination of biomass recalcitrance. BESC's approach to improve accessibility to the sugars within biomass involves 1) designing plant cell walls for rapid deconstruction and 2) developing multitalented microbes for converting plant biomass into biofuels in a single step (consolidated bioprocessing). BESC researchers in characterization, modeling, and data management areas are engaged in 1) applying advanced technologies to analyze chemical and structural changes within biomass and 2) storing, tracking, analyzing and integrating data and understanding across the Center.

The conversion of lignocellulosic biomass to ethanol requires recovery of sugars contained in hemicellulose and cellulose with high yields. High temperature water-only pretreatment can hydrolyze and solubilize hemicellulose and prepare cellulose left in the solids for enzymatic hydrolysis to glucose. As hemicellulose and lignin are thought to be key barriers to enzymatic hydrolysis, their alteration and/or removal are frequently cited as important pretreatment goals. However, there is limited knowledge about hemicellulose and lignin behavior during pretreatment. Lignin may be removed by depolymerization, melting, or solubilization. The hydrolysis of xylan, a key component in hemicellulose, has been modeled as a first order homogeneous reaction but the effectiveness of such models is limited. It has been difficult to follow lignin and xylan removal in batch pretreatment reactors because the final cooling may cause precipitation from the liquid phase. In comparison, biomass pretreatment by flowing water through a fixed biomass bed in a flowthrough mode removes these products from the reactor prior to final cooling, facilitating tracking its history. Both flowthrough and batch reactors are being applied to study the effects of pretreatment on birchwood xylan, lignin isolated from poplar, and poplar itself over a range of times and temperatures. Ultra high pressure liquid chromatography, gas chromatography mass spectrometry, and high pressure liquid chromatography are used to measure xylooligomers, phenols, and the total sugar content of hydrolyzate samples. The composition of lignin before and after pretreatment is characterized using gel permeation chromatography and heteronuclear single quantum coherence NMR. Based on the presence of phenol monomers in the liquid phase, loss of characteristic lignin bonds, side chains, and functional groups, and higher than expected number average and weight average molecular weight of polymers in the pretreated lignin solid, it seems likely that lignin is removed from and redeposited to the solid phase through a reactive mechanism. The substantial differences in lignin and xylan removal from native poplar and model substrates suggest that lignin-carbohydrate interactions enhance lignin removal while limiting the release of xylan.

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