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Hydrolysis of sweet sorghum bagasse and eucalyptus wood chips with liquid hot water

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ABSTRACT

The chemical composition, hydrolysis products, and kinetics during liquid hot water pretreatment of sweet sorghum bagasse (SSB) and eucalyptus wood chips (EWC) were investigated. Under optimal conditions, a total xylose recovery of 79.6% and 55.6% for SSB and of 74.9% and 84.4% for EWC was achieved after pretreatments in a step-change flow rate reactor (184 °C, 20 ml/min, 8 min, and 10 ml/min, 10 min) and batch stirred reactor (184 °C, 5% w/v, 18 min), respectively. More than 90% of the xylose was recovered as oligomers from SSB, independent of the type of reactor employed. The activation energies of xylan decomposition of SSB in the step-change flow rate reactor was 6.5-fold greater than that of EWC in the batch stirred reactor due to accumulation of acidic products. These findings show that sugar recovery is dependent on the reactor configuration for specific substrates.

1. Introduction

The high sugar content of sweet sorghum stalks and the high content of cellulose in fast-growing eucalyptus make these biomasses a promising feedstock for cellulosic ethanol production. It has long been recognized that lignocellulosic biomass' recalcitrance to enzymatic and microbial degradation is the major barrier to fermentable sugar production (Sarkar et al., 2012; Szczerbowski et al., 2010) and that pretreatment is necessary.

Liquid hot water (LHW) pretreatment using pressure to maintain water in a liquid state at elevated temperatures is an attractive approach because it does not require the addition of chemicals such as sulfuric acid, lime or ammonia. LHW processing does not only allow the recovery of most of the pentosans, but also achieves nearly theoretical cellulose enzymatic digestibility (Díaz et al., 2011; Yu et al., 2010; Qiang et al., 2010). Two types of hydrolysis reactors, batch-stirred and flow-through reactors, are utilized for the LHW process. Liu and Wyman (2003) treated corn stover with LHW in a batch-stirred and flow-through reactor and found that increasing the flow rate significantly enhanced removal of hemicellulose and lignin for pretreatment with compressed hot water at elevated temperatures. Other studies indicated that flowing water could enhance mass transfer and improve sugar recovery (Yu et al., 2011b).

Furthermore, Yang and Wyman (2008) found that increasing the flow rate from 0 to 2 and then to 25 ml/min affected the size distribution of the xylan oligomers (DP < 30) released from corn stover but not from oat spelt xylan and also increased overall hemicellulose sugar solubilization.

The authors speculated that lignin and lignin-xylan compounds play an important role in the hydrolysis of lignocellulosic biomass; however, no further research has been performed to determine the behavior of different biomass hydrolysis in different reactors.

Wet chemical methods are commonly used to determine the major constituents (cellulose, hemicellulose, lignin, extractives and ash) of raw materials. Unfortunately, these techniques do not reveal the real structure of the original biomass due to chemical modifications and are laborious and time-consuming. Solid-State ^{13}C Cross-Polarization Magic Angle Spinning Nuclear Magnetic Resonance (CP/MAS-NMR) spectroscopy has a significant advantage since samples can be analyzed in their native state without isolation or fractionation of components, and all chemical changes in the structure that may occur by wet chemical treatment are avoided (Li, 2003).

In the present study, the composition and structure of SSB and EWC were characterized by ^{13}C CP/MAS-NMR, and the reaction products and kinetics in batch-stirred and flow-through reactors were investigated. These studies are important for understanding differences in composition and hydrolysis behaviors between SSB and EWC in LHW and for providing a reference for the choice of hydrolysis reactor in the pretreatment of different biomasses of herbaceous and woody species by LHW technology.

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