



Modeling of the separation of inhibitory components from pretreated rice straw hydrolysate by nanofiltration membranes

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ABSTRACT

The main objective of this work was to remove inhibitors and concentrate sugars in hydrolysates obtained from dilute acid-treated rice straw. The Donnan steric pore flow model (DSPM) was applied for membrane characterization and it captured the membrane transport adequately. The polyamide and polyethylene sulfate nanofiltration membranes of 150 Da molecular weight cut-off showed a separation factor of 3 for acetic acid over glucose and xylose and 7 over cellobiose for a simulated mixture at the optimum pH of 3. A separation factor of 3 was also found for the inhibitors hydroxymethyl furfural, ferulic and vanilic acids over sugars. The concentration of rice straw acid hydrolysate by a volume concentration ratio of 4 increased the concentrations of xylose, glucose, arabinose, cellobiose and inhibitor by 100%, 104%, 93%, 151% and 3%, respectively which indicates the membrane can be used for separating the inhibitors from acid-pretreated rice straw hydrolysate while simultaneously concentrating sugars.

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1. Introduction

The complex crystalline structure of lignocelluloses in plants is designed to resist enzymatic attack. To make this structure accessible to the cellulase in saccharification or simultaneous saccharification and fermentation (SSF) processes, lignocellulosic biomass must be pretreated (Iranmahboob et al., 2002). This step is the most expensive processing step in the bioconversion process. Steam explosion, hot water pretreatment, thermal pretreatment with acid treatment or alkalis treatment, solvent extraction with ethanol, methanol, acetone and ethylene glycol wet oxidation, ionic liquid pretreatment and biologic pretreatment have been explored (Tahezadeh and Karimi, 2008). Dilute acid pretreatment is the most commonly used method (Hendriks and Zeeman, 2009). The major problem encountered in this high temperature process involving acid is the production of potent inhibitors having toxic effects on fermentation microorganism in addition to sugars. These inhibitors include pentose-derived furfurals, hexose-derived hydroxymethyl furfural (HMF), lignin-derived phenolic compounds such as ferulic acid and vanilic acid, and several other acids such as acetic acid and formic acid (Kim et al., 2011; Weng et al., 2010). These inhibitors must be removed from hydrolysates for further use in fermentation. Vacuum evaporation, ion exchange, precipitation by lime and adsorption have been employed to reduce inhibitor levels (Converti et al., 2000); however, these

detoxification methods can reduce the content of the volatile compounds and increase that of non-volatile compounds (Parajo et al., 1997). Such methods are also energy intensive, thereby incurring high processing costs. Precipitation of toxic compounds by overliming and neutralization generates additional waste products resulting in an extra processing step. Ion exchange method is a very expensive step and adsorption is dependent on the adsorbent concentration, pH, temperature and contact time. Nanofiltration (NF) is a promising membrane separation technology due to its low energy consumption and unique separation properties. Although, NF has a wide range of applications in fermentation broth separation, its use for the separation of inhibitors from lignocellulosic prehydrolysates using NF has received only limited attention (Weng et al., 2010). A single inhibitor was separated from a synthetic solution using nanofiltration (Qi et al., 2011; Weng et al., 2009), but since a large number of inhibitors are generated after pretreatment of lignocellulosic materials, actual hydrolysates have to be studied. Also the separation of inhibitors like ferulic acid, vanilic acid and valuable oligosaccharide like cellobiose produced from cellulose due to incomplete hydrolysis has not been studied. Therefore, the objective of the present work was to investigate the feasibility of removing inhibitors such as acetic acid, furfural, ferulic acid, HMF and vanilic acid from model solution as well as acid-pretreated rice straw hydrolysate by different nanofiltration membranes. The focus was on characterization of different polyamide and poly ether sulfonate membranes, optimization of operating conditions for simulated mixture of sugars and inhibitors as well as actual hydrolysate solution and modeling of the separation process.

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