Bioresource Technology 130 (2013) 117–124

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Kinetic modeling of xylan hydrolysis in co- and countercurrent liquid hot water flow-through pretreatments

Xiongjun Shao [a], Lee Lynd [a,b,*]

[a] Thayer School of Engineering at Dartmouth College, 8000 Cummings Hall, Hanover, NH 03755, United States
[b] Mascoma Corporation, 67 Etna Road, Suite 300, Lebanon, NH 03766, United States

HIGHLIGHTS

- Declining xylan hydrolysis rate constant is superior to constant hydrolysis rate constant.
- Direct xylooligomer degradation is necessary to describe observed degradation behavior.
- Countercurrent flowthrough pretreatment performs better than cocurrent pretreatment.
- Temperature gradient along the reactor axis is beneficial to reduce xylan degradation.
- Biomass bed shrinking increases exit xylooligomer concentration compared to non-shrinking.

ARTICLE INFO

Article history:
Available online 11 December 2012

Keywords:
Pretreatment
Kinetic model
Flow-through
Countercurrent
Xylan hydrolysis

ABSTRACT

A kinetic model for xylan hydrolysis in liquid hot water flow-through pretreatment was developed. The model utilized a declining xylan hydrolysis rate constant with increasing conversion in combination with direct xylooligomer degradation. The model was able to describe experimental results from flow-through pretreatment of corn stover and triticale straw at various pretreatment temperatures, and was applied to predict and compare the performance of xylan hydrolysis in co- and countercurrent flow-through pretreatments. Countercurrent pretreatment resulted in higher concentration of solubilized xylan and 3–6-fold less degradation. Maintaining a temperature gradient along the reactor axis reduced degradation compared to a fixed reactor temperature. Biomass bed shrinking during pretreatment increased the final concentration of solubilized xylan by about 10%. Model predictions were sensitive to the packing density of biomass bed. The model is useful for evaluating biomass flow-through pretreatments and has utility in design of flow-through reactors.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Lignocellulosic biomass is of interest as a sustainable source of organic fuels, chemicals, and materials because of its large scale potential availability, low purchase cost, and more desirable environmental attributes compared to row crops (Lynd, 2008). Natural lignocellulose is recalcitrant to the action of cellulase enzymes due to its limited accessibility, arising from factors including association with hemicellulose and the presence of lignin (Himmel et al., 2007; Zhang and Lynd, 2004). Pretreatment of lignocellulosic biomass is necessary to make cellulose accessible to attack by cellulase.

Various pretreatment technologies have been studied (Hsu, 1996; Mosier et al., 2005; Wyman et al., 2005; Zheng et al., 2009). Flow-through pretreatment, in which the solids residence time is longer than that of the liquid, has been shown to effectively dissolve more hemicellulose and lignin at a given severity compared to pretreatments in which liquid and solids have the same residence time. This method also generates solids that are more reactive upon enzymatic hydrolysis (Liu and Wyman, 2003, 2005; Nagle et al., 2002; Zhu et al., 2004). However, continuous flow-through operation is thought to use an excessive amount of water and energy, and practical processing of liquid hemicellulose-rich hydrolyzate from continuous flow-through pretreatment has been considered to be a challenge for subsequent sugar fermentation due to its dilute concentration (Bobleter, 1994; Liu and Wyman, 2003). “Partial flow” and “recirculation flow” operations have been studied to reduce water consumption and energy use, but these strategies also have a negative impact on pretreatment performance (Bobleter, 1994; Liu and Wyman, 2005).

Countercurrent flow-through pretreatment, in which liquid and lignocellulosic biomass flow in opposite directions, could be

* Corresponding author at: Thayer School of Engineering at Dartmouth College, 8000 Cummings Hall, Hanover, NH 03755, United States. Tel.: +1 6036462231; fax: +1 6036462277.

E-mail address: lee.lynd@dartmouth.edu (L. Lynd).

0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.11.109