Bioresource Technology 130 (2013) 570–577

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

A two-stage pretreatment approach to maximise sugar yield and enhance reactive lignin recovery from poplar wood chips

I.A. Panagiotopoulos, R.P. Chandra, J.N. Saddler *

Forest Products Biotechnology/Bioenergy Group, Faculty of Forestry, University of British Columbia, 2424 Main Mall, Vancouver BC, Canada V6T 1Z4

HIGHLIGHTS

- ▶ A 2-stage steam/organosolv pretreatment resulted in good sugar and lignin recovery.
- ▶ Close to 90% of the original xylan was recovered in a useable form.
- ▶ Close to 90% of the original cellulose could be hydrolysed at low enzyme loadings.
- ▶ The lignin recovered after 2-stage pretreatment was more reactive.

ARTICLE INFO

Article history:
Received 11 August 2012
Received in revised form 11 December 2012
Accepted 12 December 2012
Available online 21 December 2012

Keywords:
Steam pretreatment
Organosolv pretreatment
Poplar
Xylose recovery
Lignin

ABSTRACT

A two-stage pretreatment approach, employing steam followed by organosolv treatment, was assessed for its ability to fractionate and recover most of the hemicellulose, lignin and cellulose components of poplar wood chips. A mild steaming stage was initially used to maximise hemicellulose sugar recovery, with 63% of the original xylan solubilised and recovered after this stage and close to 90% recovered in total. Rather than hindering subsequent organosolv delignification, the prior steam treatment enhanced lignin solubilisation with more than 66% of the original lignin removed after the two-stage pretreatment. The extracted lignin contained at least equal or greater amounts of functional groups as compared to the lignin solubilised after a single-stage organosolv pretreatment. More than 98% of the original cellulose was recovered after the two-stage pretreatment and 88% of the cellulose could be hydrolysed to glucose at enzyme loading of 5 FPU/g cellulose after 72 h.

1. Introduction

A typical biomass-to-ethanol process usually has the major process steps of pretreatment, fractionation and recovery of the hemicellulose, lignin and cellulose streams, followed by enzymatic hydrolysis of the cellulose rich, water insoluble stream and fermentation of all of the biomass derived sugars to ethanol. The pretreatment step has a "domino effect" on all of the subsequent processing steps, influencing the recovery of the hemicellulose sugars, the ease of lignin extraction and use and the effectiveness of enzymatic hydrolysis of the cellulosic fraction when low enzyme loadings are used (Galbe and Zacchi, 2012). Ideally, any successful pretreatment should be low-cost, provide the clean fractionation and recovery of all of the initial biomass components in a usable form, while producing a cellulosic substrate at high substrate concentrations which can be readily hydrolysed at minimal enzyme loadings over a short period of time. Although there does not, as yet, seem to be any pretreatment process that meets all of these criteria, the work described below demonstrates the beneficial and complementary characteristics of stream and organosolv pretreatments.

Steam pretreatment is a relatively low-cost pretreatment method which is rapid, requires limited chemical and energy input and is currently being evaluated by a number of companies including Inbicon (Kalundborg, Denmark), Iogen (Ottawa, Canada), Abengoa (Salamanca, Spain) and Mascoma (Rome NY, USA). Unlike other pretreatment technologies such as hydrothermal and dilute acid which typically require additional size reduction steps, steam pretreatment has been used to process a variety of substrates such as chopped straw and conventional pulp chips (Grous et al., 1986; Ballesteros et al., 2006). Pioneering work on steam pretreatment exploited the inherent acetyl groups on the hemicellulose of hardwoods and agricultural feedstocks to "auto-catalyse" the pretreatment resulting in the solubilisation of hemicellulose and an increase in accessibility of the cellulose component (Grous et al., 1986). In this earlier work, so-called optimum steam pretreatment conditions were ones that helped increase the ease of enzymatic hydrolysis of the cellulose component regardless if this was

* Corresponding author. Tel.: +1 604 822 9741; fax: +1 604 822 8157.
E-mail addresses: ioannis.panagiotopoulos@ubc.ca (I.A. Panagiotopoulos), richard.chandra@ubc.ca (R.P. Chandra), jack.saddler@ubc.ca (J.N. Saddler).

0960-8524/$ - see front matter
http://dx.doi.org/10.1016/j.biortech.2012.12.093