Bioresource Technology 129 (2013) 135–141

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

Xylan as limiting factor in enzymatic hydrolysis of nanocellulose

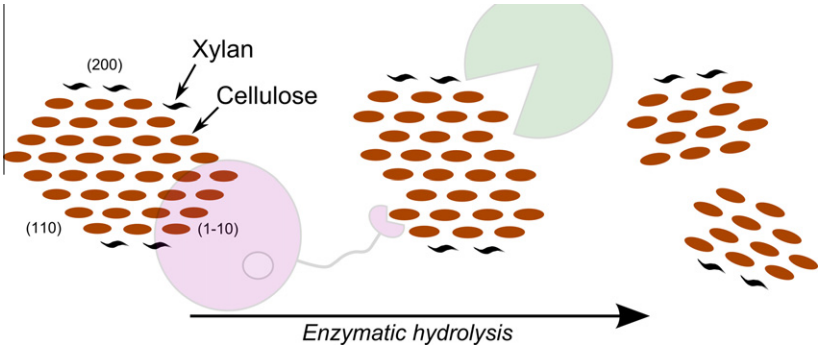
Paavo A. Penttilä [a,*], Anikó Várnai [b], Jaakko Pere [c], Tekla Tammelin [c], Lennart Salmén [d], Matti Siika-aho [c], Liisa Viikari [b], Ritva Serimaa [a]

[a] University of Helsinki, Department of Physics, P.O. Box 64, FI-00014 Helsinki, Finland
[b] University of Helsinki, Department of Food and Environmental Sciences, P.O. Box 27, FI-00014 Helsinki, Finland
[c] VTT Technical Research Centre of Finland, P.O. Box 1000, FI-02044 Espoo, Finland
[d] Innventia AB, P.O. Box 5604, SE-11486 Stockholm, Sweden

HIGHLIGHTS

- Fibrillated cellulose with varying xylan content was hydrolysed with enzymes.
- Xylanase pre-hydrolysis removed the easily accessible and less bound xylan fraction.
- Crystalline cellulose was poorly hydrolysed in substrates with original xylan content.
- Enzymes acted efficiently and simultaneously in substrates with reduced xylan content.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 31 August 2012
Received in revised form 1 November 2012
Accepted 2 November 2012
Available online 19 November 2012

Keywords:
Enzymatic hydrolysis
Hemicellulose
Nanocellulose
Dynamic FT-IR spectroscopy
Wide-angle X-ray scattering

ABSTRACT

The role of xylan as a limiting factor in the enzymatic hydrolysis of cellulose was studied by hydrolysing nanocellulose samples prepared by mechanical fibrillation of birch pulp with varying xylan content. Analyzing the nanocelluloses and their hydrolysis residues with dynamic FT-IR spectroscopy revealed that a certain fraction of xylan remained tightly attached to cellulose fibrils despite partial hydrolysis of xylan with xylanase prior to pulp fibrillation and that this fraction remained in the structure during the hydrolysis of nanocellulose with cellulase mixture as well. Thus, a loosely bound fraction of xylan was predicted to have been more likely removed by purified xylanase. The presence of loosely bound xylan seemed to limit the hydrolysis of crystalline cellulose, indicated by an increase in cellulose crystallinity and by preserved crystal width measured with wide-angle X-ray scattering. Removing loosely bound xylan led to a proportional hydrolysis of xylan and cellulose with the cellulase mixture.

1. Introduction

Lignocellulosic biomass has a high potential as a raw material for sustainable production of alternative fuels (Himmel et al., 2007; Jørgensen et al., 2007). However, its conversion to biofuels is hindered by economical and technical obstacles. The most costly as well as rate limiting step of this process is the enzymatic degradation of cellulose, which needs to be improved in order to obtain economically feasible conversion processes for large scale applications.

During enzymatic hydrolysis of lignocellulose, the reaction rate gradually decreases until the reactions eventually stop. Several factors related both to the enzymes and the substrate itself have been proposed to be responsible for this phenomenon (Igarashi et al., 2011; Mansfield et al., 1999; Zhu et al., 2008). Substrate-related, structural limiting factors hindering the hydrolysis of cellulose include the aggregation or tight association of cellulose microfibrils

* Corresponding author. Tel.: +358 9 191 50628; fax: +358 9 191 50639.
E-mail address: paavo.a.penttila@helsinki.fi (P.A. Penttilä).

0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.11.017