Bioresource Technology 128 (2013) 679–687

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

Enzymatic hydrolysis of microcrystalline cellulose and pretreated wheat straw: A detailed comparison using convenient kinetic analysis

Mareike Monschein [a], Christoph Reisinger [b], Bernd Nidetzky [a,c,*]

[a] Austrian Center of Industrial Biotechnology (ACIB) GmbH, Petersgasse 14, 8010 Graz, Austria
[b] Clariant AG, Staffelseestraße 6, 81477 Munich, Germany
[c] Institute of Biotechnology and Biochemical Engineering, Graz University of Technology, Petersgasse 12/I, 8010 Graz, Austria

HIGHLIGHTS

- Purpose-built kinetic descriptors for hydrolysis of lignocellulosic substrates.
- Slow hydrolysis rate is identical for pure cellulose and pretreated wheat straw.
- Fast initial hydrolysis rate depends on substrate and enzyme loading.
- Transition from fast to slow hydrolysis rate reflects enzyme–substrate interactions.

ARTICLE INFO

Article history:
Received 16 May 2012
Received in revised form 23 October 2012
Accepted 25 October 2012
Available online 3 November 2012

Keywords:
Enzymatic hydrolysis
Adsorption
Hydrolysis rate
Lignocellulose
Microcrystalline cellulose

ABSTRACT

Marked slow-down of soluble sugar production at low degree of substrate conversion limits the space–time yield of enzymatic hydrolysis of ligno-cellulosic materials. A simple set of kinetic descriptors was developed to compare reducing sugar release from pure crystalline cellulose (Avicel) and pretreated wheat straw by *Trichoderma reesei* cellulase at 50 °C. The focus was on the rate-retarding effect of maximum hydrolysis rate at reaction start (r_{max}), limiting hydrolysis rate (r_{lim}) at extended reaction time (24 h), and substrate conversion, marking the transition between the r_{max} and r_{lim} kinetic regimes (C_{trans}). At apparent saturation of substrate (12.2 g cellulose/L) with enzyme, r_{max} for pretreated wheat straw (~9.6 g/L/h) surpassed that for Avicel by about 1.7-fold whereas their r_{lim} were almost identical (~0.15 g/L/h). C_{trans} roughly doubled as enzyme/substrate loading was increased from 3.8 to 75 FPU/g, suggesting C_{trans} to be a complex manifestation of cellulase–cellulose interaction, not an intrinsic substrate property. A low-temperature adsorption step preceding hydrolysis at 50 °C resulted in enhanced cellulase binding at reaction start without increasing r_{max}. C_{trans} was higher for pretreated wheat straw (~30%) than for Avicel (~20%) under these conditions.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Lignocellulosic biomass is a potential source of fermentable sugars for production of biofuels and other biochemicals; however, full-scale process commercialization has been plagued by technical and economical obstacles concerning the release of the sugars from lignocellulosic feedstock (Himmel et al., 2007). Identification of key system properties and quantification of their contribution to overall process efficiency would be important in the development of more cost-competitive technologies (Bansal et al., 2009). Lignocellulose bioconversion is usually achieved through a suitable combination of substrate pretreatment and enzymatic saccharification. Both steps constitute mechanistically and technologically complex unit operations where each accounts for about one-third of the total process costs (Wyman, 2007). Despite pretreatment, soluble sugar formation still occurs at relatively low space-time yields, often requiring high enzyme loadings in the saccharification step. Enhancement in saccharification efficiency is therefore key in an integrated approach to process optimization. Recalcitrance of lignocellulosic biomass and efficacy of the cellulose-degrading enzymes (cellulases) are highly interdependent system parameters that crucially impinge on process performance and hence costs. The critical relationship of the two parameters is not well understood at the molecular level and therefore, process development must rely on semi-empirical descriptors that are of practical use for optimization purposes.

Among the multitude of known lignocellulose pretreatment procedures (Agbor et al., 2011; Alvira et al., 2010; Hendriks and Zeeman, 2009), thermo-chemical acid-based processes were

* Corresponding author. Tel.: +43 316 873 8400; fax: +43 316 873 8434.
E-mail address: bernd.nidetzky@tugraz.at (B. Nidetzky).

0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.10.129