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Overexpression of a *Paenibacillus campinasensis* xylanase in *Bacillus megaterium* and its applications to biobleaching of cotton stalk pulp and saccharification of recycled paper sludge

Hongchen Zheng [a,d,1], Yihan liu [a,c,d,1], Xiaoguang Liu [b,d], Yang Han [a,d], Jianling Wang [c,d], Fuping Lu [a,b,d,*]

[a] Key Laboratory of Industrial Fermentation Microbiology, Education Ministry of China, Tianjin 300457, China
[b] National Engineering Laboratory for Industrial Enzymes (NELIE), 300457 Tianjin, China
[c] Tianjin Key Laboratory of Industrial Microbiology, 300457 Tianjin, China
[d] College of Biotechnology, Tianjin University of Science & Technology, 300457 Tianjin, China

HIGHLIGHTS

- A *Paenibacillus campinasensis* xylanase gene was overexpressed in *Bacillus megaterium*.
- The recombinant strain produced 2.1-fold higher xylanase activity than the wild type.
- XynG1-1R can reduce chlorine consumption by 50% in biobleaching of cotton stalk pulp.
- Saccharification efficiency of recycled paper sludge was enhanced by XynG1-1R.

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ABSTRACT

A xylanase gene (*xynG1-1*) from *Paenibacillus campinasensis* G1-1 was expressed in *Bacillus megaterium* MS941 and a high level of extracellular xylansae activity (304.26 IU/mL) was achieved after induction with 0.5% xylose. The purified recombinant xylanase (XynG1-1R) revealed optimal activity at 60 °C and pH 7.0 and retained 79% and 81% activity after incubation without substrate at 60 °C, pH 5.0 and pH 8.0 for 3 h, respectively. Application of XynG1-1R (15 IU/g pulp) to cotton stalk pulp bleaching increased brightness by 3.65% over that of the control without the xylanase and reduced the need for chlorine compounds by 50% without loss of brightness and pulp fiber qualities. When XynG1-1R (80 IU/g paper sludge) was used in combination with mixed cellulolytic enzymes, the saccharification efficiency of recycled paper sludge was increased by 10%. These results indicated that XynG1-1R is a promising candidate for various industrial applications such as biobleaching and bioenergy conversion.

1. Introduction

As a major source of environmental pollution, the pulp and paper industry has to seek alternative environmentally friendly technologies to replace the use of harsh chemicals. Biobleaching with microbial xylanases was identified as an effective process to decrease the amount of undesirable substances in the effluent and to enhance the brightness of pulp without leading to a loss in its viscosity and strength (Ziaie-Shirkolaee et al., 2008). Moreover, paper sludge, the solid residue arising from paper pulping and bleaching, is currently disposed of in landfills or burned, resulting in environmental pollution. However, the high lignocellulosic content of the sludge material makes it a promising feedstock for production of second-generation bioethanol (Peng and Chen, 2011). Currently, a major challenge for bioethanol production is the yield of monomer glucose from the cellulose fraction of the feedstock. Therefore, attempts using xylanase to hydrolyze hemicellulose which is wrapped around the cellulose were made to increase the glucose yield. Endo-1,4-β- xylanase (EC 3.2.1.8), the key enzyme for the hydrolysis of the backbone of xylan, can degrade xylan in reprecipitated lignin–carbohydrate complexes (LCC) on the fiber surface to facilitate extraction of cellulose and lignin (Beg et al., 2001; Subramaniyan and Prema, 2002).

Based on amino acid sequence homologies and hydrophobic cluster analysis, the majority of xylanases belong to glycosyl

* Corresponding author. Address: Industrial Microbiology Laboratory, College of Biotechnology, Tianjin University of Science & Technology, No. 29, 13th Avenue, Tianjin Economic and Technological Development Area, Tianjin 300457, China. Tel.: +86 22 60600160; fax: +86 22 60602298.
E-mail addresses: lfp@tust.edu.cn, lfp001@yahoo.cn (F. Lu).
[1] These authors contributed equally to this work.

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