Fungal cellulase production on textile waste by solid state fermentation

Y. Hu [1], C. Du [2], C.S.K. Lin [1,*]
[1] School of Energy and Environment, City University of Hong Kong, Kowloon, Hong Kong
[2] School of Applied Sciences, University of Huddersfield, Huddersfield, United Kingdom
Keywords: Textile waste, solid state fermentation, fungal cellulase
Presenting author email: yunzihu2-c@my.cityu.edu.hk

Introduction

On global average, 32 kg of textile wastes are discarded per capita each year, of which around 85% end up in landfill (EPA, 2015). According to the survey by Waste & Resource Action Programme (UK), 95% of landfilled textile waste is recyclable whereas only 14-15% recycling has been achieved at this stage (WRAP, 2012). As textile comprises 35-40% or higher ratio of cellulosic part, it holds a high potential to serve as a feedstock for production of biological products. Based on it, this study developed a novel method to utilise cotton/polyester (PET) based textile waste as substrate for fungal cellulase production through solid state fermentation (SSF). The harvested cellulase could be applied as an effective enzyme source in cellulose digestion.

Materials and methods

Textile waste and fungal strains

The textile wastes used in this study were collected by H&M (Far East) Ltd. from H&M plants in China, with different compositions in terms of materials (e.g. cotton and polyester) and dye stuffs as listed in Table 1.

Table 1. Textile waste used in this study.

Sample No.	1	2	3	4	5	6
Component	100% Cotton	80% Cotton 20% PET	60% Cotton 40% PET	40% Cotton 60% PET	100% PET	Jeans (99% cotton)
Dye stuff	Indigo	Reactive print	Reactive print	Reactive print	Disperse dyestuff	Indigo

Six kinds of cellulase producing fungal strains were used in this study: *Aspergillus niger* N402, *Aspergillus niger* CKB, *Aspergillus oryzae*, *Trichoderma reesei* ATCC 24449, *Trichoderma longibrachiatum* and *Rhizomucor variabilis*.

Cellulase production by solid state fermentation (SSF)

Six kinds of cellulase producing fungal strains were incubated on textile waste at 28 °C for 7 days. The incubation condition was under 80% moisture, at an inoculum ratio of 10^7 spores g^{-1}, pH 7 and with yeast extract 2.5 w/w% in Mandel’s medium (Xin and Geng, 2010). After SSF, the produced fungal enzyme was extracted using citric acid buffer for cellulase activity analysis.

Cellulase activity determination

The cellulase activity was determined as filter paper units (FPU) according to the procedure developed by Adney and Baker (1996) (Adney and Baker, 1996) .

Results and discussion

Selection of fungal strains

Cellulase activity varies in a wide range and mainly depends on fungal strain and substrate. In order to select a fungus with good ability in cellulase production on textile substrate, six different fungal strains collected from various sources were incubated on pure cotton fabric (sample No. 1) in this study. Fungal growth and spores generation could be observed from day 1 and day 2 in consequence. The cellulase samples obtained on day 7 were collected to test the filter paper activity as shown in Figure 1 (a). It was found that *A. niger* CKB and *A. niger* N402 generated cellulase with higher filter paper activity than that from other strains. In comparison, *Trichoderma* species presented an obviously poor adaption to textile substrate as indicated by the low cellulase activity. The highest cellulase activity was 0.42 - 0.43 FPU g^{-1} obtained from *A. niger* CKB, which was thereby selected as the proper fungal strain in subsequent investigation.

Cellulase production on different types of crude/modified textile waste

Six types of textile waste were applied as different substrate in SSF. The selected fungus *A. niger* CKB was incubated to produce cellulase. The fungal growth could be observed on all types of textile materials. The cellulase activity determination results (Figure 1b) revealed that the textile of cotton/PET 80/20 generated relatively higher cellulase activity, 1.09 FPU g^{-1}, as compared to that from other types of textile substrate. The produced cellulase could be used in textile hydrolysis directly for sugar recovery.

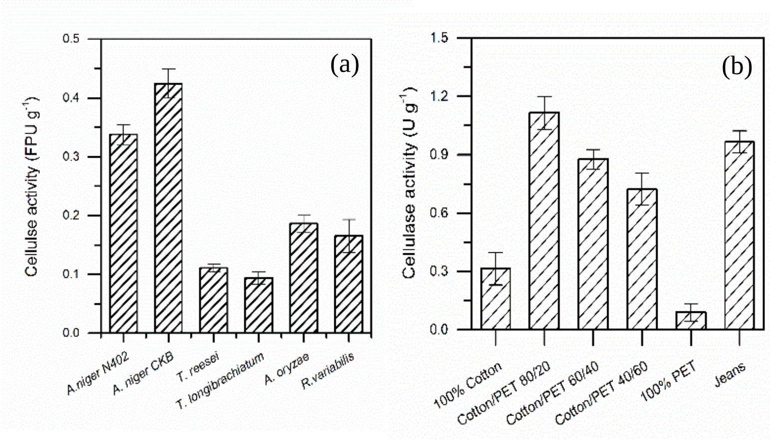

Figure 1. Cellulase production on textile waste by SSF.

Scanning electron micrograph of textile substrate

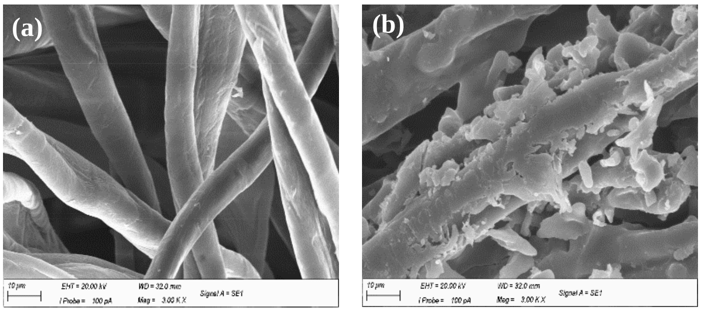

Figure 2. SEM pictures of textile substrate before (a) and after (b) SSF.

The fungal growth and morphological change of textile substrate (cotton/PET 80/20) were detected by scanning electron micrograph (SEM). Figure 2 (a) and (b) show the textile fibre before and after SSF, respectively. Figure 2 showed that textile was well colonized by *A. niger* CKB mycelium and spores after fermentation. Moreover, it could be observed that the crystalline structure of original textile was partially disrupted to a rough, unsmooth and rugged status, owing to the cellulose digestion by fungal enzymes.

Conclusions

Utilization of textile waste in solid state fermentation for cellulase production was investigated for the first time in this area. The fungus *A. niger* CKB was selected from various fungal strains and the highest cellulase activity 1.09 FPU g^{-1} was harvested from the fabric of cotton/PET 80/20. This study provides a novel and effective strategy in textile waste utilization and the cellulase product is of potential to be an alternative enzyme source in cellulose hydrolysis.

Acknowledgements

The authors are grateful to the Hong Kong Research Institute of Textiles and Apparel (HKRITA) and the Innovation and Technology Commission for the Innovation and Technology Fund (ITP/109/15TP). We acknowledge the sponsor H&M Conscious Foundation and H&M (Far East) Ltd. We are also grateful to Dr. Diannan Lu (Tsinghua University, China) for providing the fungal strains (*A. niger* CKB and *R. variabilis*).

References

Adney, B., Baker, J. 1996. Measurement of cellulase activities. *Laboratory analytical procedure*, **6**, 1996.

EPA. 2015. Advancing Sustainable Materials Management:: 2013 Fact Sheet. Environmental Protection Agency.

WRAP. 2012. Valuing our clothes: the true cost of our design, use and dispose of clothing in the UK. Waste & Resources Action Programme.

Xin, F., Geng, A. 2010. Horticultural waste as the substrate for cellulase and hemicellulase production by Trichoderma reesei under solid-state fermentation. *Applied Biochemistry and Biotechnology*, **162**(1), 295-306.