BIOTECHNOLOGICAL MODIFICATION AND UNCTIONALISATION OF PET SURFACES

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ABSTRACT

Synthetic fibres form an important part of the textile industry, the production of poly(ethylene terephthalate) (PET) alone surpassing that of cotton. A disadvantage of synthetic fibres is their low hydrophilicity. Polyester fibres are particularly hydrophobic. This affects the processability and functionalisation of the fibres. A novel and promising alternative is the use of enzymes in surface modification of synthetic fibres. Synthetic materials have generally been considered resistant to biological degradation; recent developments at different research groups demonstrate that enzymes are very well capable of hydrolysing synthetic materials.

Key Words: textile biotechnology, enzymes, surface functionalisation, surface modification, poly(ethylene terephthalate)

1. INTRODUCTION

White biotechnology has great potential in the industrial production of textiles. The global market for industrial enzymes increases annually, and is forecasted to grow to US$ 2.75 billion in 2012. Approximately 10% of the industrial enzymes find their application in industrial textile processing.

The importance and potential of enzyme technology in textiles production has been assessed in the by different research groups [for recent reviews see e.g. 1-3]. Enzyme technology proved to be profitable in industrial processing of natural materials, e.g. desizing using amylases, as well as depilling and ageing of cotton using cellulases. However application of enzymes is not limited to biological materials; recent developments at different research groups demonstrate that enzymes are very well capable of hydrolysing synthetic materials such as poly(ethylene terephthalate) (PET).

Synthetic fibres form an important part of the textile industry: the global annual production of polyester surpasses that of cotton [4]. This justifies research into effective production of polyester. The low hydrophilicity of synthetic fibres affects for example the processability of the fibres; the surfaces are not easily wetted, hence impeding the application of finishing compounds and a hydrophobic material hinders water from penetrating into the pores of fabric during production. Cutinase has been reported to increase hydrophilicity of polyesters by hydrolysis of ester bonds. Cutinases (EC 3.1.1.74) are serine hydrolases specific for the hydrolysis of cutin. Cutin is a polymer, composed of hydroxyl and epoxy fatty acids, in the cuticle of higher plants. Cutin is a bio-polyester. Cutinases are extracellular esterases mainly produced by pathogenic fungi and pollen, though some cutinases are produced in bacteria. Cutinase from *Fusarium solani pisi* is the most studied cutinase. Cutinase from Fusarium solani pisi is a one-domain molecule, i.e. there is no quaternary structure. It is a relatively small enzyme with a weight of 22,000 g/mol and it is approximately 45x30x30 $Å^3$ in size.

Cutinase can accept a wide range of substrates such as poly(ethylene terephthalate) and polyamide. Crystallinity affects the capability of cutinase to hydrolyze the ester bonds [5]. Cutinase displays relatively high activity towards amorphous polyester and little activity on highly crystalline substrates. Hydrolysis of PET by cutinase is via an endo-mechanism, resulting in new carboxyl and hydroxyl groups in the polymer surface [6]. NaOH hydrolysis is via hydrolysis of end groups which results in little or no increase of new carboxyl and hydroxyl groups in the polymer surface. An advantage of a cutinase treatment is that it does not result in pitting corrosion, as seen in alkaline treatments, but a more or less homogeneous surface treatment of PET [6]. The enzymatic process therefore facilitates functionalisation processes. Enzymes will not penetrate into the material, and therefore not affect the favourable bulk properties contrary to chemical treatments.

2. CHALLENGE

The aim of our research is to functionalise PET materials using modern biotechnology. Enzymatic surface modification of textile materials involves processing of fibres or (bio)polymers to modify the physical chemical surface properties or the introduction of functional groups on the surface. The research presented focuses on specific targeted enzymatic surface modification of PET to obtain functional structured surfaces. In this work the potential of cutinases in surface modification and functionalsiation of PET will be reported.

The research will result in new, specific knowledge and technologies to create biotechnologically modified textile materials with unique properties. The research contributes to bio-based economy through the development of novel processes for textiles exhibiting the desired functionalities and through development of novel enzyme technology for structuring and functionalisation of surfaces.

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4. REFERENCES

1. Nierstrasz, V.A., and Warmoeskerken, M.M.C.G., Chapter 4: Process Engineering and industrial enzyme applications. *In* Cavaco-Paulo A and Gübitz G M, ‘*Textile Processing with Enzymes*’, Cambridge, Woodhead Publishing Ltd, 2008.
2. Nierstrasz, V.A., Chapter 7: Enzymatic surface modification. *In* Wei Q. ‘*Surface modification of textiles*’ Cambridge, Woodhead Publishing Ltd., 2009.
3. Gübitz, G.M., and Cavaco-Paulo, A., Enzymes go big: surface hydrolysis and functionalisation of synthetic polymers, *Trends in Biotechnology*, 2008, 26(1), 32-38.

4. Oerlikon, *The fiber year 2008/09. A world survey on textile and nonwovens industry*. Volume 9, May 2009. Remscheid, Oerlikon Textile GmbH & Co. KG.
5. Vertommen, M.A.M.E., Nierstrasz, V.A., Veer, M.V.D., and Warmoeskerken, M.M.C.G., Enzymatic surface modification of poly(ethylene terephthalate), *Journal of Biotechnology,* 2005, 120(4), 376-386.
6. Donelli, I., Taddei, P., Smet, P.F., Poelman, D., Nierstrasz, V.A., and Freddi, G., Enzymatic surface modification and functionalization of PET. A water contact angle, FTIR, and fluorescence spectroscopy study, *Biotechnology and Bioengineering*, 2009, 103(5), 845-856.