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Enzymatic hydrolysis of polyamide and elastane for textile recycling

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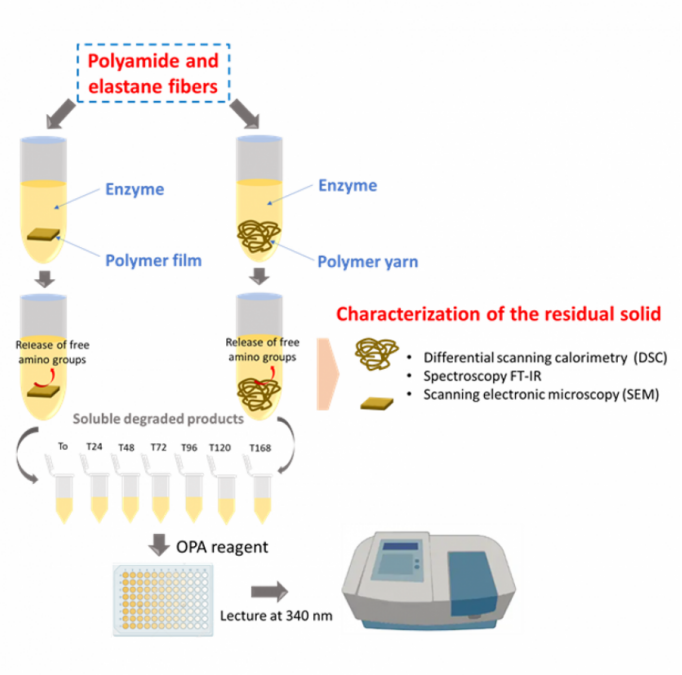
PURPOSE OF THE ABSTRACT
Currently, the textile industry is one of the most polluting in the world. The mixture of synthetic fibers and chemical additives makes recycling management difficult. However, the use of biotechnological tools could implement a greener, closed-loop recycling process.
The present study focuses on two synthetic fibers, polyamide and elastane fibers, which are widely used in the daily clothing. These two fibers are very often closely combined and have different physico-chemical properties that make them difficult to separate and recycle. Therefore, a process based on depolymerization catalyzed by enzymes is proposed in order to recover initial monomers .
Polyamide fibers contain amino and carboxylic groups that can be cleaved with hydrolytic enzymes such as proteases and specific amidases [1]–[3]. However, the crystalline structure of polyamide makes enzymatic attack difficult. The hydrolytic degradation by using enzymes starts on the surface towards amino groups which are present as end-group chains and led to the releasing of soluble oligomers [4].
Elastane fiber is a complex chemical structure composed of two segments, a soft segment containing polyols and a hard segment containing urethanes groups. These two segments are linked by chain extenders of low molecular weight (diols or diamines). This fiber is difficult to degrade with microorganisms and there are still no studies showing hydrolytic degradation with the use of enzymes.
In the present work, two commercial proteases and enzymatic extracts from fungi sp were used and their performances in hydrolytic degradation have been evaluated.
Hydrolyses of polyamide and elastane textile fibers (film and yarn) were quantified by measuring amino functional groups released during the enzymatic treatment (Figure 1). For this purpose, the ortho-phthalaldehyde (OPA) assay, based on a reaction with primary amino groups, has been used. Surface degradation of the solid residue has been followed by scanning electron microscopy (SEM) [5] and the modification of chemical structures has been investigated by spectroscopy infrared (FT-IR). Thermal analyses such as differential scanning calorimetry (DSC) were carried out in order to measure the degree of degradation in the amorphous phase of the polymer.
It has been demonstrated that the commercial enzymes are able to hydrolyze amide and urethane bonds of polyamide and elastane, respectively, with degradation only on the surface (Figure 2). The comparison of the hydrolytic degradation of polyamide and elastane synthetic fibers (film and yarn) shows the impact of the polymer surface area. The degradation rate depends on the surface area of the polymeric material.
Other studies for new enzymes isolation from fungi are in progress in order to produce more specific and more efficient biocatalysts.

FIGURES



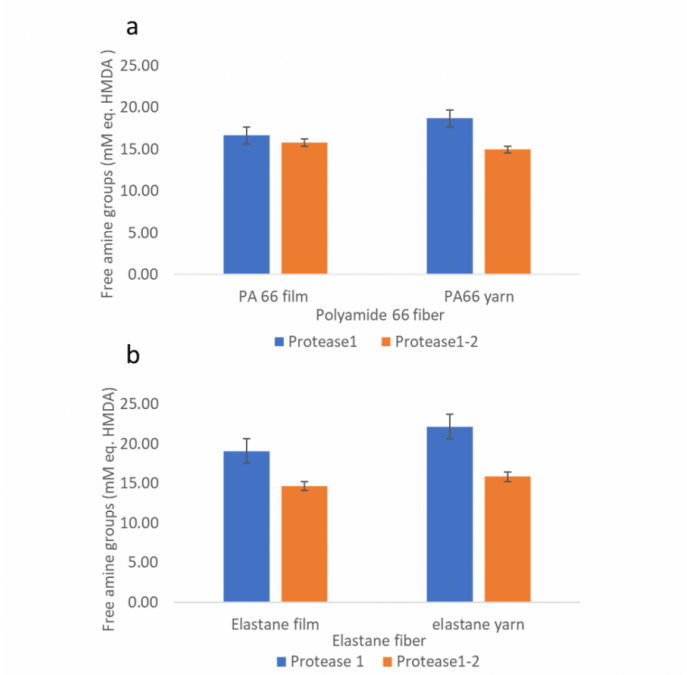


FIGURE 1

Methodology of surface enzyme hydrolysis of polymer film and yarn

Surface hydrolyses of polyamide and elastane textile fibers (film and yarn) is quantified by measuring amino functional groups released during the enzymatic treatment by OPA assay at 340nm. The residual solid is characterized by thermal analyses, FT-IR sp

FIGURE 2

Quantification of total of amines released with OPA

A) Surface enzymatic hydrolysis of nylon and B) Elastane fiber

KEYWORDS

enzyme hydrolysis | degradation | polyamide | elastane

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