ENZYME ASSISTED DEGRADATION OF POLYAMIDE 6

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ABSTRACT

The increasing production of polymeric materials has resulted in the accumulation of microplastics, especially those derived from textiles. The application of enzymes has emerged as a promising solution. To this probleam, although polyethylene terephthalate (PET) has received the most attention the enzymatic degradation of polyamides, such as nylon, is still little explored. Enzymes such as laccases and proteases show promise for breaking down engineering polymers such as polyamides, offering a new approach to solid waste management. The study in question proposed an innovative strategy, seeking to use enzymes, such as proteases, to enhance the action of laccase in the degradation of textile waste. The experiment followed a standard methodology, using the same temperature and pH parameters for 7 days. Preliminary results indicate that around 10% of the material was degraded, as observed by mass loss and FTIR and SEM analyses. The observed mass loss highlights the complexity of the degradation process of commercial polymeric materials, indicating the necessity for further research and optimization of the methodology to improve the results obtained. Advances in this field are essential for effective textile waste management and for mitigating the environmental impact associated with these materials

Keywords: Polyamide; Enzymatic depolymerization; Plastic recycling.

1 INTRODUCTION

Polymeric materials, primarily derived from petroleum sources, it is lightweight and those chemically and physically stable [1]. However, the sustainable use of polymers requires the implementation of a correct and efficient recycling system. Unfortunately, due to the absence of recycling programs in many countries, a substantial quantity of plastics is disposed of in the environment. This leads to the fragmentation of plastics which exacerbates significant environmental challenges [2]. Current waste management methods, such as landfill disposal and incineration, are both expensive and harmful to the environment [3].

Alternative treatments using enzymes are gaining significant attention from both industry and academia as they offer safe, cost-effective, and environmentally friendly methods. Moreover, these enzyme-based approaches are considered "green" when compared to traditional catalytic methods, further driving their appeal in the pursuit of sustainable and economically viable solutions [4].

This study builds on previous research into the degradation of PET and the enzymatic digestion of this polymer. It also considers concerns regarding plastic waste from the textile industry, specifically polyamide production. The objective of this work was to utilize polyamide 6 fabric fibers and apply protease enzymes for material functionalization, followed using laccases, in conjunction with a mediator such as ABTS, to achieve degradation.

2 MATERIAL & METHODS

The objective of the study was to investigate the use of laccases (*Trametes Versicolor*) assisted by the ABTS mediator, while varying the concentration between 0.1, 0.5, and 1.0 mM, for degrading polyamide 6 fabric (91,5% polyamide and 8,5% elastane) samples. Proteases such as papain (*Carica papaya*) were used to pre-treat the samples to cleave the amide group and convert them into amine group, thereby facilitating the action of laccase. The experiment was conducted in triplicate for each variation in enzyme mediator concentration over 7 days.

Every 2 days, samples were removed, washed, and dried in an oven at 60°C using the constant weight technique, meaning they were dried until completely dry. After 7 days of experimentation and once all samples were dry, they were characterized by gravimetric analysis, Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM).

3 RESULTS & DISCUSSION

The result obtained from the ABTS variation test showed a degradation of approximately 14% for the 0.5 mM concentration, Figure 1 The error bars in the graphs were calculated using the standard deviation of all the experiments conducted, indicating that the results presented are outside the experiment's margin of error. On days 2 and 5, the samples showed little mass loss at the 0.5 and

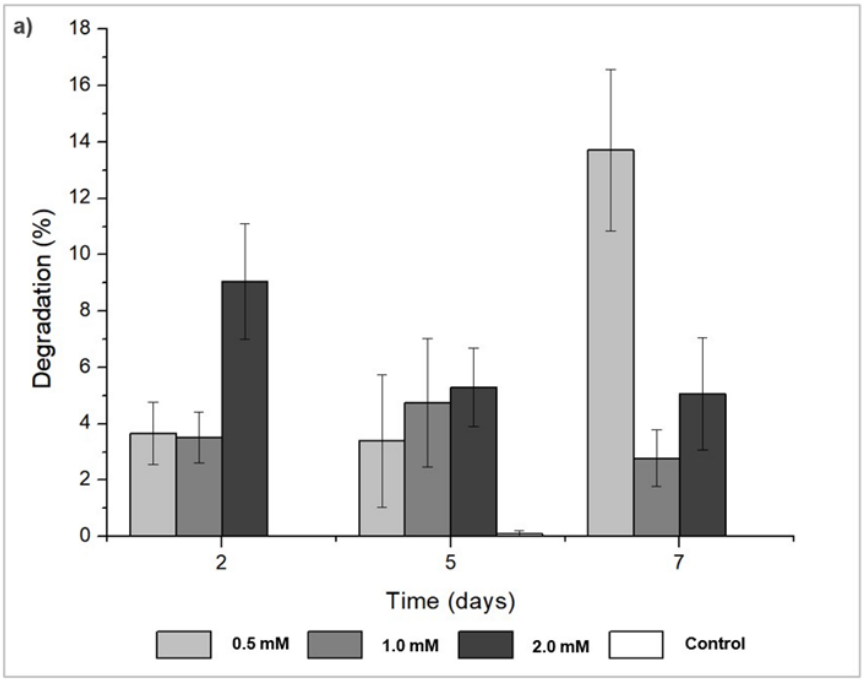

Figure 1 Degradations (wt%) of PA fabrics with laccase variation and mediator ABTS. The control shown in the graph demonstrates that the observed mass loss is consistent with the actual results, as the same samples were attached to the control with buffer solution, and no changes in mass loss were measured by gravimetry.

Figure 2 shows the results of the FTIR analysis, demonstrating that although the changes in the peaks were essentially the same across all spectra, there were no differences between the ABTS concentrations used. This indicates changes in the most important groups, namely the amide groups and the carbon-carbon structural bonds. Therefore, the observed changes suggest alterations in the chemical structures of the polyamide samples, and the mass loss presented in the gravimetric analysis is consistent with the actual results. However, since the changes were similar across concentrations, the lowest concentration was chosen, as using the highest concentration would not be justified.

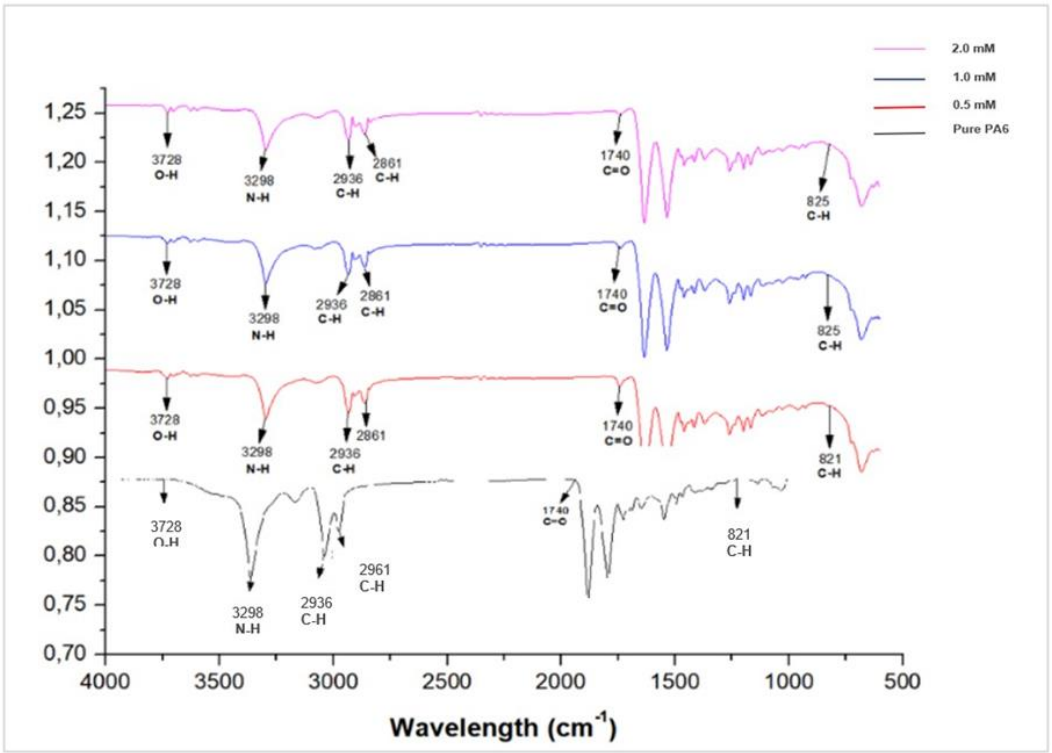

Figure 2 FTIR of PA modified samples with ABTS variation

Figure 3 shows changes in the surface of the polyamide yarn degraded with laccase and ABTS compared to the untreated polyamide sample. It can be observed that the surface exhibits cracks and alterations in some areas, apparently due to the action of the enzymes, confirming the mass loss shown in Figure 1.

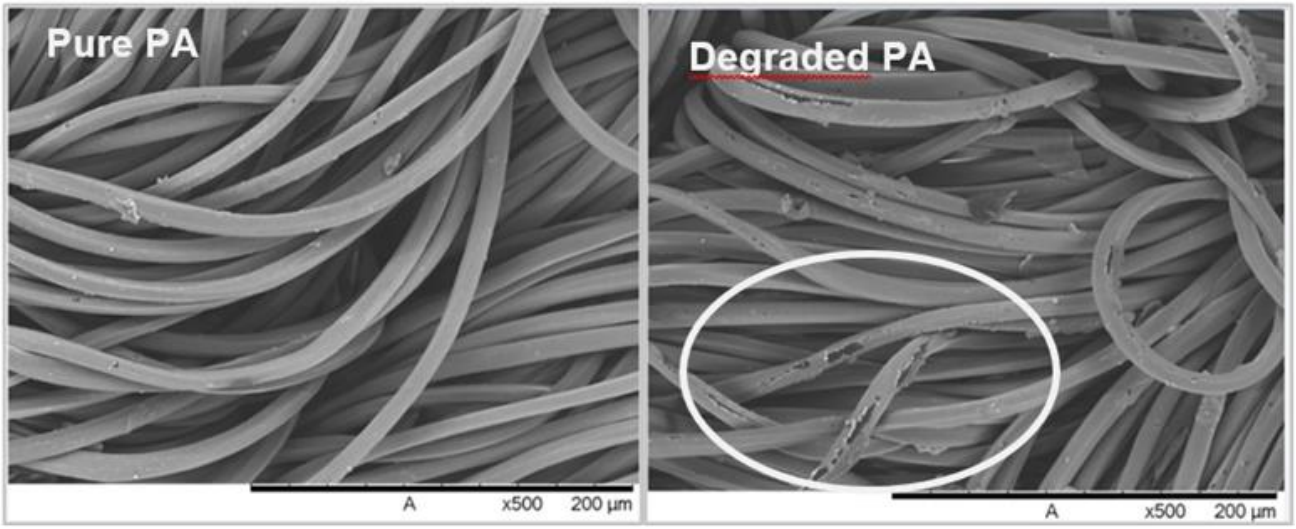

Figure 3 SEM micrographs of PA samples after 7-day of degradation with laccase + ABTS

The experiments were initially conducted using polyamide 6 fabrics. However, these fabrics have a challenging geometry and release fibers during the process, which can impact the degradation results. To validate the results obtained with the fabrics, 100% polyamide 6 fishing lines were used, testing under the same conditions and methodology applied in the fabric experiments. The results found in the polyamide fibers were satisfactory, demonstrating that modifications occurred and that the enzymes were able to alter the structure and properties of the tested samples.

4 CONCLUSION

In this study, approximately 14% degradation was observed with the use of the 0.5 mM ABTS mediator with laccase. This suggests that the mediator indeed enhances the enzyme's activity in the degradation process. Further analysis is required to confirm these findings. DSC and TGA analyses can aid in understanding the observed thermal changes. Tensile analysis can also provide valuable insights into the mechanical properties, helping to determine whether degradation affects the material's properties. Based on the results from the gravimetric analyses, along with the changes observed in the FTIR spectra and SEM surfaces, it can be stated that this study is significant for the field. To date, there are no published studies on the degradation of commercial polyamide 6 using a pretreatment with proteases in combination with laccase and an ABTS mediator.Therefore, the tests with polyamide samples have contributed to the emerging search for sustainable treatments for textile waste, including polyamides.

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