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Circular Recycling of 2,5-furandicarboxylic Acid from Designed Biobased Polymers

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Abstract

2,5-furandicarboxylic acid (FDCA) is a fascinating example of new monomer, successfully derived from renewable resource, suitable for the realization of novel biobased polyesters settling as competitive alternatives to terephthalic acid-based polymers. Among furan-based polyesters, poly(pentamethylene 2,5-furandicarboxylate) (PPeF) is one of the most interesting, showing outstanding gas barrier properties and high flexibility (Guidotti et al. 2019). PPeF has been successfully combined with another well-known biobased polymer, poly(lactic acid) (PLA), expanding its suitability for flexible food packaging applications, thus, overcoming PLA intrinsic limitations, such as brittleness and poor thermal stability.

By playing with composition and chemical architecture, the design of new biomaterials was accomplished (Bianchi et al. 2023, Rigotti et al. 2021). Although presenting numerous advantages, polymer blends and copolymers entail a big challenge when they come to recycling. In this view, enzymatic hydrolysis constitutes an outstandingly valuable solution, due to its substrate specificity, allowing separation and recovering of the single components and monomers. On the basis of previous studies (Gigli et al. 2019), Thermobifida cellulositilytica cutinase was selected to preferentially hydrolyse PPeF from PLA/PPeF blends and PLA-PPeF copolymer. The polymer films were incubated in the presence of the cutinase for different times (3, 6 and 7 days). The recovered samples were subjected to weight loss determination, SEM and FTIR analyses, while the hydrolysis products were quantified by HPLC and NMR analyses. The results revealed the selective attack of the enzyme towards the furanic component both in the blends and in the copolymer. The FDCA monomer was successfully recovered from the hydrolysate as white powder, with a high purity level (as confirmed by NMR and TGA analyses), and reused for PPeF re-synthesis (yield 95%). The polymer synthesized from the recovered monomer has been reprocessed in form of film presenting the same functional properties of PPeF obtained from commercial FDCA. The results confirmed the fully circularity of bioplastics, from production to after-life recycling and finally re-synthesis (Siracusa et al. 2023).

Keywords: furandicarboxylic acid, biopolyesters, chemical design, enzymatic degradation, green recycling

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