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Bio-based Polyesters from Itaconic Acid and L-Histidine as Sustainable Alternatives to Fossil-based Polymer Carriers

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Water-soluble, fossil-based polymers such as poly(vinylpyrrolidone) (PVP) represent an important class of carbon-carrier functional polymers in the chemical and pharmaceutical industries.[1-3] They are produced exclusively from petrochemical feedstocks and are not biodegradable[4,5],which means that under tightening sustainability regulations such as RED III, they are increasingly causing problems in the supply chain as well as in end-of-life disposal.[6] Replacing these materials with biobased, chemically recyclable alternatives requires both new monomers from renewable carbon sources and scalable, resource-efficient catalytic processes.

Within the framework of the catalaix research center, we report on the synthesis of two novel biomass-derived monomers and their polycondensation into functional hydrophilic polyesters as a direct, fossil-free alternative to PVP. Starting from itaconic acid and L-histidine, both of which are accessible from renewable feedstocks, the multifunctional dicarboxylic acid monomer histidine-pyrrolidone-dicarboxylic acid (HPDA) was synthesized under hydrothermal conditions using a Brønsted-acidic zeolite catalyst (HCZM-40) in yields of up to 91%. The complementary diol monomer pyrrolidone-serinol (PS) was obtained from serinol and γ-butyrolactone in yields of up to 84%. Both processes use water as the sole solvent and deliver crystalline products that can be isolated by straightforward procedures.

Melt polycondensation of HPDA and PS yielded a new class of hydrophilic polyesters in high yields (up to 95%). Molecular weights in the range of 2.1 to 4.1 kDa could be tuned systematically by varying catalyst loading, temperature, and reaction time. The amorphous polyesters exhibit acid-catalyzed hydrolytic degradation with approximately 40% mass loss after 30 days — a decisive advantage for disposal and chemical recycling.

Application testing demonstrates that, compared to the established fossil-based PVP, the new HPDA-based polyesters achieve a 27-fold increase in the aqueous solubility of ibuprofen, outperforming PVP (3.9-fold), Soluplus® (19.6-fold), HPMC (3.9-fold), and Lutrol® (4.7-fold). The underlying mechanism is analogous to that of PVP, yet embedded within a degradable, biobased polymer scaffold. Initial cytotoxicity studies further confirm biocompatibility at relevant concentrations.

This work demonstrates an atom-economical chemical transformation of biomass into functional polymer materials that are both high-performing and deliberately designed for end-of-life degradability, thereby contributing to the vision of closed carbon cycles.