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Towards sustainable polyester resins: from vitrimerization to bio-based additives for a greener thermoset and composite manufacturing

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Unsaturated Polyester Resin (UPR) is a widely used thermosetting material for its excellent thermo-mechanical properties and chemical resistance, primarily attributed to the use of styrene as a curing agent. However, the high toxicity and potential carcinogenicity of styrene have prompted the exploration of safer and more sustainable alternatives, such as vegetable oils, polyphenols, and carbohydrates. In this study, we firstly synthesized the unsaturated polyester resin and then we cured it by using a blend of acrylated epoxidized soybean oil (AESO), 2-hydroxyethyl methacrylate (HEMA), and a lower content of styrene to mitigate environmental impact while preserving material performance. The synthesized thermosets were also exploited as matrix for flax fibers to produce green composites, and subsequent investigation of mechanical and thermal properties demonstrated promising results compared to commercially available products. Additionally, we explored the potential for implementing exchange mechanisms in UPR, inspired by advancements in epoxy thermosets obtained from petrochemical feedstocks. By reducing styrene content from 40% to 25% and introducing Zinc (II) acetylacetonate to promote transesterification processes, we were able to provide an enhanced self-healing and recycling capabilities of the developed laminates. Comprehensive characterization revealed that the resulting resins maintained mechanical properties, glass transition temperature, and thermal stability comparable to commercial counterparts containing higher styrene content. Thanks to a strategic combination of renewable and non-renewable feedstocks, along with transesterification catalysts, we aimed to further improve the sustainability of UPR thermosets, as in our previous work. This study contributes to the development of greener thermosetting materials by integrating sustainable alternatives such as vegetable oils, and exchange mechanisms such as CANs to enhance performance and environmental sustainability.