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Optimization of microwave-assisted polycondensation for flexible biodegradable polyurethane in sustainable packaging applications

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Abstract

The proliferation of plastic waste presents a significant environmental challenge due to its persistence and ecological impact. This study explores biodegradable polyurethanes (PUs) as a sustainable packaging alternative, optimizing the microwave-assisted synthesis of polylactic acid (PLA)–diol from palm oil polyol and PLA under varying microwave power (500–700 W) and reaction times (30–45 minutes). Structural characterization was performed with proton Nuclear Magnetic Resonance (^{1}H–NMR) and Fourier Transform Infrared Spectroscopy (FTIR). Mechanical, thermal, and surface properties were investigated using tensile testing, Differential Scanning Calorimetry (DSC), and Scanning Electron Microscopy (SEM). Over 100 days of biodegradation studies were conducted to evaluate their environmental impact. Structural analysis confirmed PLA–diol formation with 92 % yield and a molecular weight (M_n) of 2500 g/mol under optimal conditions (700 W, 45 minutes), compared to 85 % yield and 2000 g/mol at 500 W for 30 minutes. FTIR analysis revealed characteristic absorptions at 3500 cm^{-1} (–OH) and 1750 cm^{-1} (–C[dbnd]O), while ^{1}H–NMR confirmed key signals at 1.58 ppm and 5.16 ppm. Among synthesized PUs, toluene diisocyanate (PU–TDI) exhibited the highest tensile strength (2.90 MPa). In contrast, hexamethylene diisocyanate (PU–HDI) showed superior flexibility with 144.5 % elongation at break and superior thermal stability (melting temperature of 131°C). Biodegradation studies revealed that PU–HDI degraded by 28 % over 100 days, with SEM confirming significant surface erosion. These results demonstrate the potential of optimized biodegradable PUs to address plastic waste challenges and advance sustainable packaging solutions. © 2025 Elsevier Ltd

Author keywords

Biodegradable plastic; Biodegradation; Green chemistry; Microwave-assisted synthesis; Polylactic acid (PLA)–diol; Polyurethane; Sustainable packaging

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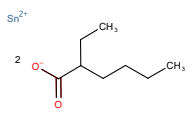

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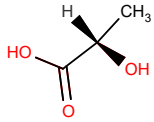

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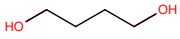

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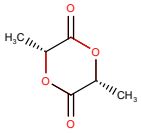

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