Development of Green Extraction Technology for Sustainable Natural Product Recovery

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Conventional solvent extraction processes are widely used for the recovery of bioactive compounds from plant materials; however, these methods often involve the use of toxic organic solvents and high energy consumption. The reliance on petroleum-based solvents not only poses environmental and health risks but also contributes to greenhouse gas emissions during production, use, and disposal. As industries increasingly shift towards greener and more sustainable technologies, alternative extraction systems that minimise environmental impacts while maintaining high extraction efficiency are required. In this context, natural deep eutectic solvents (NADES) have emerged as promising green solvents due to their low toxicity, biodegradability, and tuneable physicochemical properties. This study investigates the application of NADES combined with ultrasonic-assisted extraction for the recovery of phenolic compounds from plant biomass. The integration of ultrasonic treatment enhances mass transfer by disrupting plant cell structures and facilitating the release of intracellular compounds. Several process parameters, including solvent composition, extraction time, and extraction temperature, were systematically optimised to maximise phenolic recovery while reducing energy consumption. The extracted compounds were analysed using spectrophotometric and chromatographic techniques to determine total phenolic content and compound profiles. The results demonstrate that the NADES-based extraction system significantly improves phenolic compound recovery compared with conventional solvent extraction methods. The enhanced extraction performance is attributed to the synergistic effect of NADES solvent properties and ultrasonic cavitation, which promotes efficient solute diffusion and improved solvent penetration. In addition, the NADES system reduces the use of hazardous organic solvents and requires milder operating conditions, thereby lowering overall energy requirements. Overall, the findings highlight the potential of NADES-assisted ultrasonic extraction as a sustainable and efficient approach for the recovery of valuable phytochemicals from plant biomass. This green extraction strategy offers significant opportunities for advancing sustainable engineering technologies within the bio-based industry while supporting the global transition towards a low-carbon and environmentally responsible economy. [Maximum 300 words].

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