Microfluidic Formation of Lignin Nanoparticles: Influence of Processing Parameters on Colloidal Properties for Cosmetic Applications

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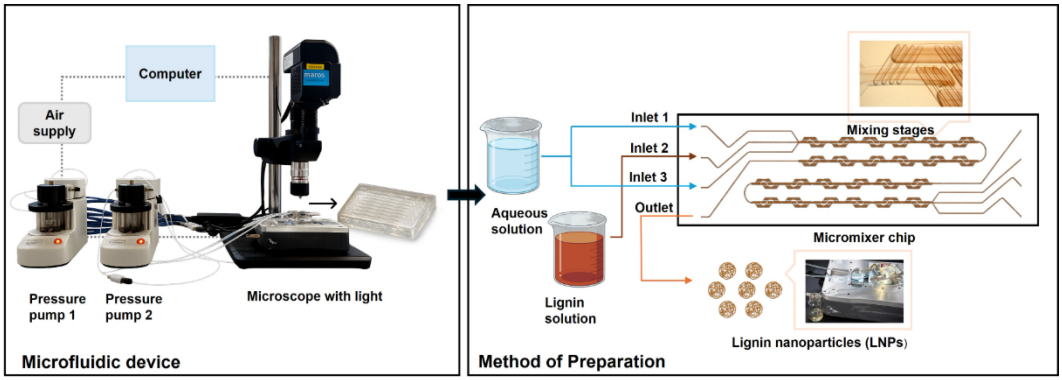
The increasing demand for safe, sustainable, and high-performance ingredients in cosmetic formulations has intensified interest in bio-based nanomaterials. Lignin is a naturally abundant aromatic biopolymer with intrinsic multifunctional protective properties, including antioxidant and UV-absorbing potential for advanced skin care applications. In this work, lignin nanoparticles (LNPs) were synthesized from kraft lignin and its hydrophobically modified derivative using microfluidic technology to achieve precise control over particle formation. The influence of lignin molecular structure, concentration, solvent system, and flow-rate ratios on particle size, surface charge, and morphology was investigated using dynamic light scattering (DLS) and transmission electron microscopy (TEM). Optimized microfluidic conditions enabled the production of spherical, monodisperse nanoparticles with tunable sizes suitable for topical delivery. The functional performance of LNPs was evaluated through cosmetic-relevant assays, including antioxidant capacity, photoprotective potential, thermal stability, and encapsulation efficiency of lipophilic vitamins such as tocopherol. The release behavior of encapsulated active and its skin penetration potential were investigated using in vitro diffusion methods. The results highlight the potential of LNPs as safe and multifunctional nanocarriers for skin care formulations and sustainable alternatives to conventional cosmetic nanomaterials. Overall, this work provides a versatile microfluidic platform for the design and optimization of lignin-based nanocarriers and advances their application in next-generation skin care systems.

Keywords:
Lignin nanoparticles, lignin for cosmetics, microfluidics, nanoparticle size control



Preparation of Lignin Nanoparticles