

Innovative bio-based pathways for cleaner production of levan nanoparticles

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Streszczenie

This study compared two downstream processing routes applied to the same 220 L *Bacillus subtilis* fermentation batch in 500 L bioreactors for levan (a biodegradable fructan polymer with several applications) nanoparticle production: an ethanol-free membrane route comprising microfiltration and reverse osmosis (Scenario I) and ethanol precipitation followed by lyophilisation and redissolution (Scenario II). A batch-based attributional life cycle assessment was combined with process-time and technology-maturity screening. Under the defined functional unit, Scenario I showed lower deterministic ReCiPe 2016 midpoint results in all reported categories. Global warming was 1258.6 and 1507.9 kg CO₂-eq per batch for Scenarios I and II, respectively, corresponding to a 16.5% reduction. Scenario I used 13.5% less electricity, 19.2% less inventory water, and 51.6% less total recorded energy when electricity and process heat were combined. Its production-stage duration was 61.9% shorter. Electricity was the primary concern in both routes, while fresh ethanol makeup and solvent recovery operations added additional burdens in Scenario II. Monte Carlo analysis supported the Scenario I ranking for global warming, marine eutrophication, land use, mineral resource scarcity, and fossil resource scarcity.

Słowa kluczowe

Life cycle assessment (LCA), Cleaner production, Bio-based nanopolymers, Technology readiness level (TRL), Sustainable bioeconomy, Process optimisation

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