Assessing the feasibility and sustainability of surfactin bioprocesses: A techno-economic and environmental analysis

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Surfactants are attractive for numerous applications due to their surface-active properties. However, petroleum-based chemical surfactants are non-renewable and are likely to have negative environmental impacts. Therefore, a shift towards bio-based surfactants can be observed, especially biosurfactants originated from microorganisms, which have been a subject of research in the last decades. This has led to industrial-scale approaches to produce biosurfactants for everyday use, e.g. as laundry or dishwashing detergents. A key advantage of biosurfactants is that they can be produced using renewable resources and are reportedly less toxic and biodegradable, which is usually the basis of considering them as a sustainable alternative. The lipopeptide surfactin, derived from *Bacillus* spp., is often claimed to be one of the most effective biosurfactants. However, sound knowledge about the economics of the bioprocess and its environmental impact are not yet adequately described. Therefore a techno-economic and environmental assessment was conducted in this study. In a first step, a simulation in Aspen Plus was considered using actual experimental data of an existing pilot-scale production process for the manufacture of surfactin. In this approach, a high cell density fed-batch fermentation was realized employing *Bacillus subtilis* JABs32 (3NA) with titers of up to 26.4 g/L surfactin (Klausmann et al. 2021). A literature search supplemented this information to fill the necessary parameters and process steps. Subsequently, the mass flows were scaled up from an initial volume of 20 L to 65 m^3, which resulted in a surfactin production of 35.1 kg/h. After mass balances, the Aspen Energy Analyzer was used to calculate the energy consumption, and the Aspen Economic Analyzer was applied to evaluate the economic efficiency of the process. The economics of this process were used as a comparison for the years 2021 and 2022 to account for the impact of rising energy prices in Europe. Accordingly to the results, the production cost in 2021 would be 25.99 USD/kg and 29.33 USD/kg in 2022. The environmental assessment was developed through LCA in SimaPro using a "cradle to gate" way based on inventory data for the European context using glucose as raw material. This resulted in a CO_2 footprint of 51.7 kg CO_2 equivalent. In general, the process showed a very good economic performance based on the net present value analysis (considering a market price of 615 €/kg of surfactin). However, the environmental impact should be part of further discussion, especially regarding process and yield optimization to ensure sustainable production in the context of the bioeconomy.

References

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