Life-Cycle Assessment of Levan Nanoparticles Preparation

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Introduction

Biopolymers are compounds that attract a lot of interest from various industries. Biopolymers with similar properties to synthetic polymers are produced in fermentation processes carried out by various types of microorganisms. However, still a large proportion of production processes have an effect on the environment. In order to design a process with the lowest possible environmental impact, many different factors must be taken into account. Such processes are not only eco-friendly, but also often allow for optimization of production costs. One of the promising biopolymers is levan, synthesized by bacteria such as *Bacillus subtilis*, *Zymomonas mobilis* or *Halomonas smyrnensis* [Domżał-Kędzia et al. 2019, Silbir et al. 2014, Tohme et al. 2014]. Its properties make it ideal for use primarily in the cosmetics, food and pharmaceutical industries.

The process of obtaining levan nanoparticles was designed in two variants. Both were analyzed for their environmental impacts using LCA methodology.

Materials & Methods

Levan nanoparticles were obtained according to two variants: from the precipitated polymer after fermentation with *Bacillus subtilis* KB1, which was redissolved (scenario II), or directly from the post-culture supernatant (scenario I).

The LCA is undertaken in SimaPro Developer v. 9.1.1.1 LCA software using Ecoinvent 3.3 inventory databases and ILCD Midpoint+ V1.11 / EC-JRC Global, equal weighting method. The LCA was performed based on a "cradle-to-gate" perspective, which means that only the production phase was considered. The function of the process is the synthesis of 220 l levan nanoparticles in the reactor 500 LSF, therefore the functional unit FU was used as a reference to quantify all inputs and outputs and is defined as 1 full cycle of the levan nanoparticles production which gives 1 portion of a product (220 l of an input to the autoclave reactor 500 LSF). Technological readiness was also determined according to Kaczmarska et al. (Kaczmarska et al. 2015) Preliminary assessment of production efficiency was carried out using methodology proposed by Kotliński and Golińska (2011). The Life-Cycle Assessment was performed according to the standard practice as defined by ISO 14040:2006. The inventory data of mass and energy flow are extracted from the experimental data of the levan production process. To identify all hot spots and environmental burdens of this process the following sixteen impact categories were estimated for both scenarios. The LCA was performed based on a "cradle-to-gate" perspective.

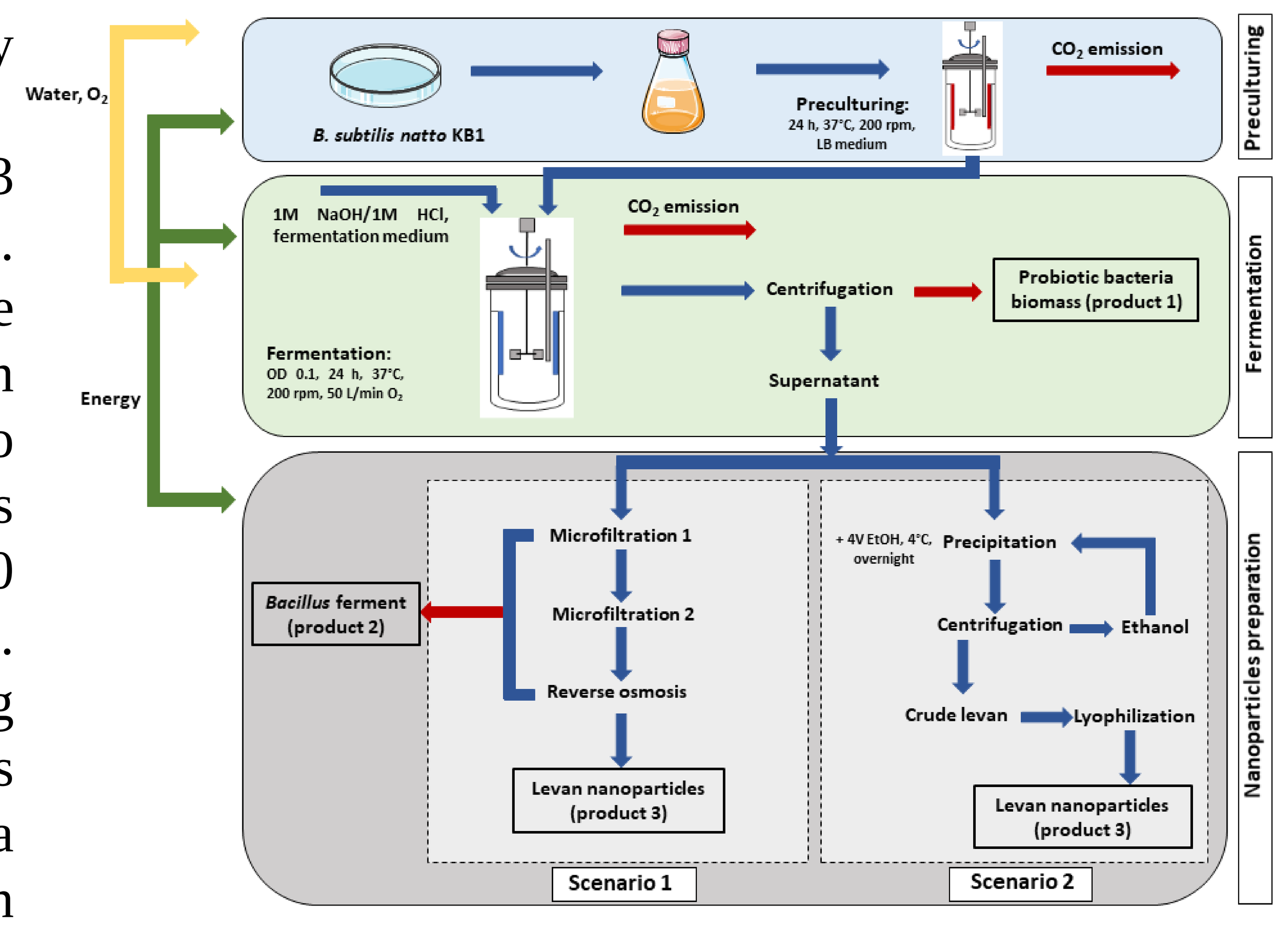

Fig. 1. Different scenarios for levan nanoparticles production

Results & Discussion

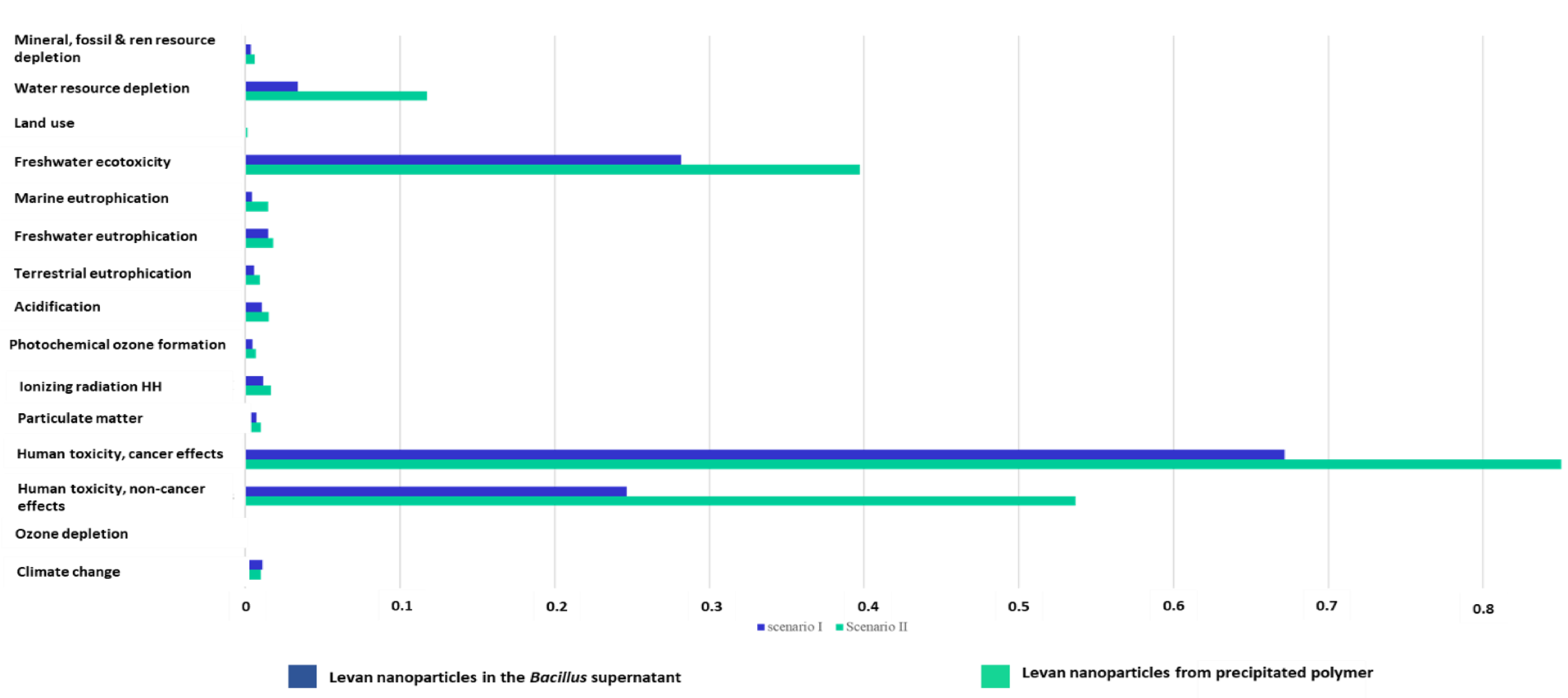

Fig. 2. Environmental impact of two different scenarios using ILCD method [Pt] in impact categories

Tab. 1. Life Cycle Inventory

INPUTS			
Materials/fuels	Scenario I	Scenario II	Unit/FU
Water, deionised, market	1 047	1 295	kg
Enzymes, market	45	45	g
Fodder yeast, ethanol production from whey	22.5	22.5	g
Packaging glass, white production	6	6	g
Magnesium sulfate, market	110	110	g
Sodium phosphate, market	1 200	1 200	g
Sodium hydroxide, without water, in 50% solution state, market	1 660	1 660	g
Hydrochloric acid, without water, in 30% solution state, market	424	424	g
Silicone product, market (antifoamer)	15	15	g
Sodium chloride, powder, at plant	45	45	g
Polystyrene, extruded, market	20	20	g
Tap water, market (recycled)	95 000	95 000	g
Molasses, from sugar beet, market	22 924	22 924	g
Glycerine, market	38 824	-	g
Benzyl alcohol, market	2 316	-	g
Propylene glycol, liquid, market	11 579	-	g
Butane, market	-	77 530	g
Nitric acid 50% solution state, market	1 500	1 500	g
Ethanol, without water, in 95% solution state, from fermentation	-	97 899.12	g
Electricity/heat	AMOUNT		Unit/FU
Electricity, medium voltage PL, market	1 083.2	1 273.85	kWh
OUTPUTS			
Wastewater, average, market	834	834	dm^3
Hazardous waste, for incineration, market	20	20	g
Tap water, market (recycled)	95 000	95 000	g

Based on the analyses, it was determined that obtaining nanoparticles directly from the fermentation solution (scenario I), among others:
-has shorter production time of one batch; it is 61.9% shorter compared to the second scenario;
-time spent on preparatory and completion work and service works is shorter by 43.5%;
-the ratio of time devoted to preparatory and finishing works to production time is almost 1.5 times greater for scenario I than for scenario II;
-removal of ethyl alcohol from the levan production cycle helps to reduce the environmental burden;
-the efficiency and effectiveness is significantly higher for the production of levan according to scenario I.

Conclusions

- ✓ Removal of ethyl alcohol from the levan production cycle helps to reduce the environmental burden.
- ✓ The general direction of the development of levan production technology is the reduction of electricity consumption and the use of techniques with low energy consumption. Therefore, it is necessary to shorten the processes in which electricity is used to heat liquids and thermostat devices.
- ✓ To reduce the environmental impact of the electrical stress, reduce the parameter HTCE.
- ✓ In order to reduce the environmental impact of factors used in the production of levan, it is worth reducing the amount of preservative compounds, increasing production efficiency and effectiveness
- ✓ The state of product development according to scenario II is significantly more advanced
- ✓ The efficiency and effectiveness is significantly higher for the production of levan according to scenario I.

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