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Life Cycle Assessment (Cradle-To-Gate) of Bacterial Cellulose Production

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ABSTRACT

In a world, increasingly conscious of environmental issues, Life Cycle Assessment (LCA) is an important tool for estimating the environmental impact of processes and products. This work aims to determine the possible environmental impacts of the production of bacterial cellulose intended to be used as a food additive. For this, the LCA (cradle-to-gate) was simulated with GaBi Software, using ReCiPe 2016 method. Results show that the production of materials was responsible for the major part of the input and output flows (in kg). Wastewater treatment, materials production and cooling and heating agents production are responsible for major impacts in several impact categories.

Keywords: Bacterial Cellulose; Cradle-to-gate; Life Cycle Assessment; ReCiPe

1. INTRODUCTION

Worldwide, society is increasingly aware of the environmental impact of production and disposal of everyday products, pressing companies to design "greener" processes and products. Life Cycle Assessment (LCA) is a methodology used to quantify the consumed resources and emissions as well as the environmental and health impacts, and resource depletion issues, related to an industrial process. This methodology is standardized by the ISO 14040 and 14044, and in "The International Reference Life Cycle Data System (ILCD) Handbook" published by the Life Cycle European Platform.
Bacterial Cellulose (BC) is a a nanofibrillar exopolysaccharide produced mainly by Gram-negative acetic acid bacteria such as *Glunoacetobacter xylinum*, the most studied production model due to its capacity of producing BC with high yield and from a wide range of carbon/nitrogen sources [2]. BC structure consists of glucose monomers arranged in a unique 3D nanostructure, exhibiting numerous interesting properties, leading to a wide range of applications in different areas [3]. The commercial exploitation of BC has been used in two main branches: in food industry, usually employed as a food product (for example, "*nata de coco*") or as food addictive, and in high-value-added niche markets such as medical applications and cosmetic industry [4].

2. METHODS

Gabi Pro (ThinkStep) software using the ReCiPe 2016 model was used as the method for the Life Cycle Impact Assessment (LCIA) of BC production. LCIA translates emissions and resource extractions into a limited number of environmental impact scores (environmental impact categories) by means of the so-called characterization factors. The results are presented in 18 midpoints impact categories. [illegible]t used, but also the extraction of natural resources and their transformation and the disposal of the produced waste (*Cradle-to-gate*). The functional unit of this LCA was defined as 1 kg of BC (0,72%) in water packed in a plastic container and a carton box. The produced BC is intended to be used as a food additive.

The present LCA analysis of the BC manufacture was divided into 4 phases:

1. "Culture Medium (CM) Preparation", includes culture medium preparation and pasteurization;
2. "Inoculum Propagation", aiming to increase the quantity of biomass, performed in two batch reactors (100L and 1000L);
3. "Static Culture Fermentation", the main phase of the process, where the fermentation occurs under static culture conditions. This is performed in a clean room at 30ºC, operating for 7 days;
4. "Downstream Process", the last phase, involves the purification of the BC into the final product (washed and ground cellulose in plastic containers and carton boxes).

The data used to model the BC process chain (Foreground System) was taken from Dourado et al. [3], the remainder (energy resources, extraction, transformation and transport of resources) was modelled using databases provided by the Gabi Pro Software. Data related with the materials used for the production of biomass were dismissed due to the small amounts used. In the wastewater treatment process, heavy metals produced were removed.
The processes involved in the life cycle were categorized into: Bacterial Cellulose Manufacturing, Production of Materials, Cooling and Heating Agents Production, Equipment Production, Transportation, Electricity Production, and Wastewater Treatment.

3. MAIN RESULTS

3.1 Mass Balance

The mass balance includes input and output from both foreground (processes of manufacturing and packaging of a product) and background (includes in processes of manufacturing of materials or electricity and downstream processes such as recycling) systems. Input flows are categorized based on the type of resources (energetic or material) while output flows are categorized according to the disposal site (soil, water or air). The major parts of the input flows used are water and the residues emitted to fresh water. The production of materials, which includes the extraction of natural resources and the transformation into to the materials used, was responsible for the major part of the input and output flows, with several processes within this category being identified as *weak points*. Electricity production and wastewater treatment were also responsible for a significant part of both input and output flows.

3.2 ReCiPe 2016 (H)

Environmental impact results based on ReCiPe 2016 showed that the wastewater treatment category had a major impact in “Climate change, excluding biogenic carbon”, “Climate change, including biogenic carbon” and “Fossil depletion”, mainly due to the production of steam and calcium hydroxide required by the wastewater process. Materials production is responsible for significant impacts in the same impact categories and for major parts in the impact categories in “Human toxicity, non-cancer” and “Terrestrial ecotoxicity”. Cooling and heating agents production, in this case cooling water and steam, has a significant impact in the “Fossil depletion” and “Freshwater Consumption”.

4. CONCLUSIONS

Materials production (Background System) were responsible for most of natural resources used (water), and the emissions released to the environment, in this case emitted to fresh water (in kg). Together, the processes of wastewater treatment, materials production and cooling and heating agents production are responsible for the major environmental impacts in several impact categories, estimated by ReCiPe 2016 methodology.

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