IWA 17th SWWS AND 9th ROS
10th–14th November, 2024
Curitiba-Brazil

Environmental impact assessment for obtaining carotenoids from algae produced in industrial wastewater

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Highlights:

- Environmental impact of the production and extraction of carotenoids from algae.
- Solvent as the main cause of the impact in the Human Health category.
- The use of wastewater contributes to reduce environmental damage.
- The search for new carotenoid extraction technologies is necessary.

Keywords: Microalgae; Carotenoids; Life Cycle Assessment;

INTRODUCTION

Carotenoids are bioactive pigments with applications in various industries and can be found in plants, algae, bacteria and fungi (Arashiro et al., 2022), stand out for their health benefits, and have been associated with anti-cancer properties and protection against oxidative stress (Xiang et al., 2022). Microalgae are promising sources of carotenoids, especially in cultivation systems that integrate their production and wastewater bioremediation, such as high-rate ponds (HRPs) (Li et al., 2019). Current studies have highlighted the potential of treating paint booth effluent (PBE) from the furniture industry via microalgae biotechnology, acting as a unique treatment system and with the possibility of simultaneously treating the wastewater produced in the establishment, in this case PBE and the domestic sewage (DS) (Braga et al., 2023).

This study evaluates, through a life cycle assessment (LCA), the potential for production value-added products, more specifically carotenoids, from microalgae cultivated in mixtures of PBE and DS in HRPs, seeking to analyze the environmental viability of the production and extraction of these compounds. With the work carried out, it is possible to obtain insights into the decentralized treatment of effluents, especially industrial effluents, and the possibility of valuing sanitation, with the obtaining

of resources of commercial value. Furthermore, through the use of management and planning tools, in this case LCA, the environmental viability of the production of carotenoids from microalgae is assessed.

METHODOLOGY

The production of algae biomass was carried out at the Federal University of Viçosa (Minas Gerais, Brazil). The scenario to obtain the carotenoids involved cultivating and drying algal biomass, rupturing the cells, saponification and extracting the lutein using ethyl acetate. It should be noted that high-rate pond and biomass harvesting by natural sedimentation technique were considered. LCA was applied to estimate the impacts of this process and identify critical areas from an environmental point of view found in the study. The scenario was modeled considering experimental data and secondary data obtained from the literature and the Ecoinvent database. Environmental damage was quantified using SimaPro® software (PRé Sustainability BV, Netherlands, version© 9.4.0.2). The ReCiPe 2016 method (v. 1.7) was employed in a hierarchical approach, covering endpoint level, and the results of Natural Resources, Human Health, and Ecosystem Quality were presented.

RESULTS AND CONCLUSIONS

The damage assessment results for the Human Health, Resources and Ecosystems categories were 1.65E-3 DALY, 1.33E2 USD2013 and 3.76E-6 species.year. In terms of normalization, the results for the Human Health category was 14x and 27x higher when compared to Resources and Ecosystems, respectively.

Figure 1 presents environmental damage by stages and process, with the biomass cultivation stage and the water and fertilizer processes (source of nitrogen and phosphorus) being omitted, as they resulted in negative contributions, that is, in the reduction of environmental damage. The solvent extraction step was the one that contributed the most damage (> 93%) in all categories studied. Evaluating the contributions by input, in the same way, the same result was observed for the solvent ethyl acetate, which justifies the emphasis on this stage. The manufacture of ethyl acetate requires the use of strong acids in significant quantities (Adesina et al., 2021), which results in a high environmental impact throughout its life cycle (Zaib et al., 2022). Electricity was the second input with the highest contribution to damage, varying from 3% to 7%. However, approximately half of these damages would be offset and mitigated due to the use of wastewater as a growing medium for microalgae, which avoids the consumption of fertilizers (to supplement nitrogen and phosphorus) and, especially, water. For better

results in this sense, drying methods with lower energy consumption would bring environmental benefits.

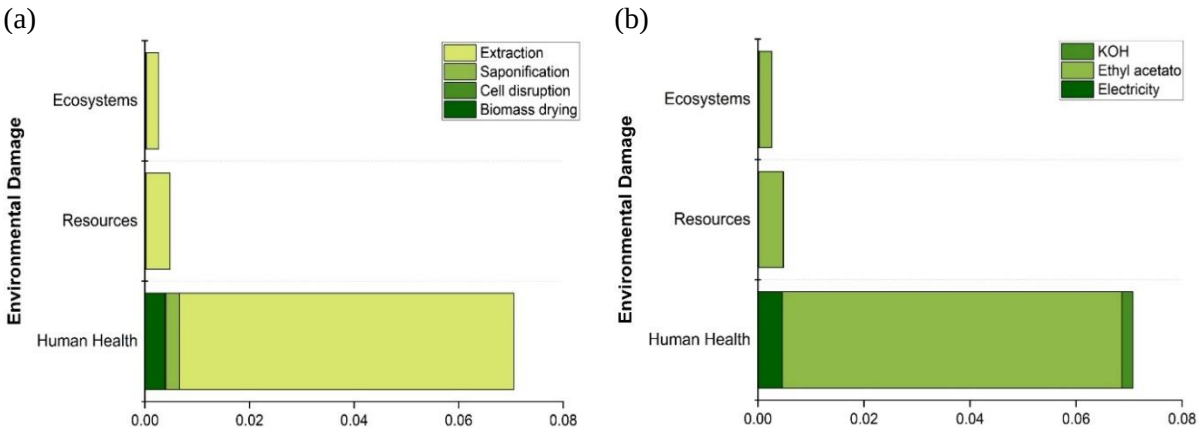

Figure 1. Normalization results of the environmental damage from the production of lutein from microalgae biomass cultivated in wastewater by (a) stages and (b) process.

The main challenge of the process of obtaining carotenoids from microalgae, as described, is related to the use of solvents, which results in a significant environmental impact, especially in the human health category. Therefore, it is essential to explore extraction technologies that preserve efficacy and cause less environmental impact.

ACKNOWLEDGEMENTS

This study was financed by the Minas Gerais Research Funding Foundation – FAPEMIG. Also, the authors gratefully acknowledge the financial support of the Postgraduate Program in Civil Engineering (PPGEC) from the Federal University of Viçosa, the National Council for Scientific and Technological Development (CNPq) [Grant Numbers: 301153/2013–2; 405787/2022–7; 406204/2022-5; 403521/2023-8] and Minas Gerais Research Support Foundation (FAPEMIG) [Grant Numbers APQ-00114/2021; PCE-00449-24; APQ-00756-23; APQ-03618-23; RED-00068-23].

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