Environmental, economic and circularity assessment of the hydrothermal liquefaction of black liquor under a biorefinery approach

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Abstract:

Introduction:

The transition from the traditional linear production to a circular model constitutes a promising pathway towards environmental sustainability (Hofstetter et al., 2021; Naidoo et al., 2021). A circular economy approach aims to reduce the exploitation of fossil resources, promote the comprehensive use of available resources and increase efficiency in the manufacturing sector. In this context, lignocellulosic biomass is considered a key element; its versatility to obtain different products, makes it a bio-based resource with great potential (AL-Kaabi et al., 2018; Granacher et al., 2021). Among the sectors with the greatest use of lignocellulosic biomass, pulp and paper mills stand out (David et al., 2021; Demuner et al., 2021). In this regard, the implementation of an integrated pulp-mill is considered as a promising alternative to valorize the hemicellulosic and lignin content from forestry resources, where these production flows could be used for the production of high value-added products and energy (Mäki et al., 2021). This work aims to evaluate the environmental sustainability of kraft pulp black liquor management towards the production of value-added products.

Materials and methods:

The search for circular strategies requires the development of exhaustive studies of the processes, with the objective of identifying which aspects can be improved for a beneficial influence on the environment. It is at this point that the use of life cycle analysis (LCA) methodology is essential, through which environmental impact profiles are obtained and sensitivity analyses are developed (Farzad et al., 2020). However, environmental studies are not enough to assess the degree of sustainability of a process, a cost analysis is also required, through the life cycle cost (LCC) methodology, which aims to calculate the economic viability of the process (Hosseinzadeh-Bandbafha et al., 2020). In addition, the degree of circularity (DOC), an indispensable concept in the framework of the Sustainable Development Goals, is also assessed by applying sustainability metrics and indexes (Ávila-Gutiérrez et al., 2019). In this report, the three assessment strategies have been applied to a new integrated kraft pulp mill biorefinery process aiming the valorization of the black liquor (BL) towards electricity (within a cogeneration section) and a biocrude (through a hydrothermal liquefaction process), subsequently processed to obtain a biofuel for the shipping and aviation sectors. Process modeling has been developed with simulation tools to obtain all the required values from mass and energy balance, economic requirements and stream recirculation.

Results and discussion:

The biorefinery scheme assessed contributes positively to the environment for two reasons: the amount of electricity produced by the cogeneration unit is sufficient to supply the process, thus avoiding the consumption of fossil resources, and the biocrude obtained is of high quality to be used to produce biofuels for shipping and aviation. The main critical points identified in the environmental profile are the background process to produce the kraft liquor, heat requirements, the use of certain chemicals and on-site emissions. Regarding the LCC study, the NPV and payback values show that the integrated biorefinery is an economically viable process. Regarding circularity, three types of indicators have been used:

performance indicators (representing the process efficiency), process flow indicators (focusing on inputs and outputs, energy requirements and emissions produced) and environmental indicators (mainly attributed to the characterization factors of the LCA study). Most of them show the suitability of the integrated biorefinery project to be framed within the circular economy concept: valorization of waste streams to obtain value-added products, reduction of fossil resource consumption, recovery and recirculation of energy to the process, reduction of environmental burdens and proven economic profitability.

Conclusions:

Once assessed, the LCA shows how the integrated biorefinery of kraft liquor for the co-production of electricity and biocrude contributes positively to the environmental pillar, the LCC concludes that the process is economically viable, and the DOC demonstrates the benefit of this process on the circular economy approach.

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Conference topic: Biorefineries / Waste valorization / Biotechnology / Circular economy