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Improving furfural sustainability: comparison of production technologies from an LCA perspective

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PURPOSE OF THE ABSTRACT

Furfural is one of the most relevant biomass-derived platform molecules worldwide. It is the basis for producing several bulk chemicals such as furfuryl alcohol or furan resins. Currently, the vast majority of furfural is imported from China, where it is produced from the hemicellulose fraction of corn cobs [1]. Although a lack of detailed environmental data exists, furfural technologies are associated with the production of great amounts of acid residues and large energy consumptions. The complete harnessing of the feedstock biomass can significantly improve both issues, by the integrated production of valuable outputs from the cellulose, hemicellulose, and lignin fractions. In this sense, Organosolv processes elicit great interest [2]. Coupling design and process scale-up with prospective life cycle assessment (LCA) are key for the identification of environmental hotspots in novel developments [3].

In this work, a prospective LCA is conducted to evaluate the production of furfural by a novel Organosolv process based on the fractionation of biomass (birchwood) using GVL/water mixtures [4]. This pathway is explored in detail along with benchmark technologies for furfural production aiming to assess the environmental performance of the Organosolv alternative. System boundaries are set to cover a cradle-to-gate scope, excluding use and end of life phases. From the sixteen environmental categories described in the Environmental Footprint 3.0 methodology, eight are selected (Fig. 1): Acidification (AC); Climatic change (CC); Ecotoxicity (ET); Terrestrial eutrophication (EPt); Ionizing radiation (IR); Land use (LU); Photochemical ozone formation (POF); Water use (WU). Inventory data are obtained by processes simulation and translated to environmental impacts in GaBi software (v10.0). GaBi Professional database is used for all the background processes, and the results are referred to the functional unit (1 ton of dry biomass treated).

Two main critical stages are identified (Fig. 1) in the Organosolv process, namely birchwood obtention and xylose-rich stream concentration prior to its dehydration into furfural. Birchwood dataset accounts for every process throughout forestry management and logging, milling, drying and final transport. These steps are the principal contributors to IR, LU and WU categories. LU is almost exclusively affected by birchwood cultivation phase (97.6%), mostly due to forest and arable land occupation. This high value can be reduced if woody or lignocellulosic residues are used as a feedstock, which is expected to be technically viable given the flexibility of the solvent mixture to fluctuations in the solid load and biomass composition. This would also redound in the reduction of the water requirements during biomass growth and processing (74.4% of the WU impact).

On the other hand, energy duties are covered with saturated steam generated via natural gas combustion. The categories principally affected by the heat requirements in the evaporation step are AC, CC, EPt, and POF. AC and EPt impacts are related to NOx emissions, while CO2 and CH4 releases are responsible for most of the CC effects. Last, POF is connected to chlorides generation, which is also the main cause for ET impacts both in the case of birchwood obtention and auxiliary steam generation. All impacts of the xylose concentration stage could be dramatically reduced if heat integration is performed on the analyzed system.

Finally, if allocation is considered between the three main outputs (cellulose, lignin and furfural) and the proposed

improvements are implemented, results indicate that the Organosolv process is competitive in terms of sustainability performance compared to benchmark technologies (Huaxia mod. Westpro, Biofine, Quaker-Oats).

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FIGURES

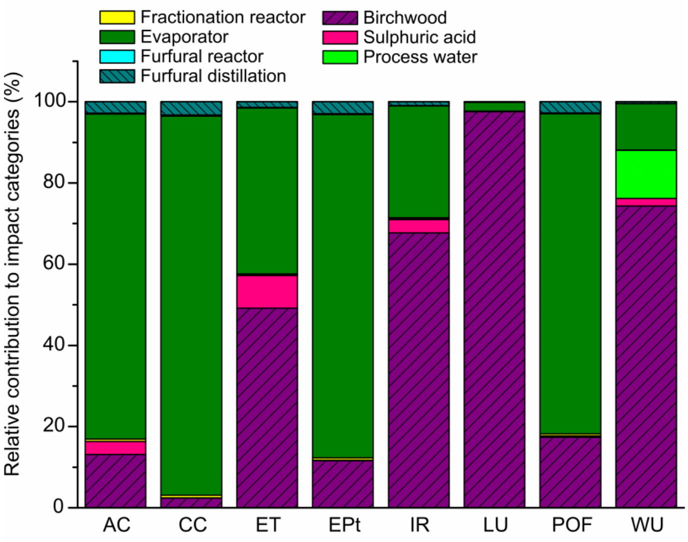

FIGURE 1

Figure 1

LCA results for Organosolv biomass fractionation process into furfural, cellulose and lignin. Percentage contribution of process stages to the evaluated impact categories.

FIGURE 2

KEYWORDS

LCA | Furfural | Biomass fractionation | Environmental impacts

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