Environmental Assessment of an Integrated Biorefinery for Grape Marc Valorisation

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INTRODUCTION

Food waste encompasses all edible and inedible components discarded throughout the food supply chain (Girotto et al., 2015). Annually, global food waste exceeds USD 1 trillion, accounting for over one-third of the total food produced worldwide (United Nations Environment Programme, 2024). In addition, this waste also contributes to environmental pollution, causing 8-10% of GHG emissions (Environmental Protection Agency, 2024). Within the wine sector, grape cultivation is responsible for approximately 2% of annual agricultural GHG emissions and 0.3% of total global emissions (Trioli et al., 2015). The wine production process generates substantial organic waste, with up to 30% of the harvested grapes becoming by-products after juice extraction (Genisheva et al., 2023). In the framework of the circular economy, waste reduction, recycling, and resource recovery are essential strategies for enhancing sustainability (European Parliament, 2023). The valorisation of agro-industrial by-products into value-added products presents a promising approach to mitigating environmental impacts. Thus, this research focuses on the environmental assessment of a biorefinery designed for the valorisation of grape marc for the extraction of phenolic compounds and the production of biochar, applying the Life Cycle Assessment (LCA) methodology.

MATERIALS & METHODS

The environmental impacts of this system are quantified and analysed following an attributional approach using the LCA methodology, according to ISO guidelines 14040 and 14044 (ISO, 2006a, 2006b). This methodology can be divided into four different phases: goal and scope definition, inventory analysis, impact assessment and the interpretation of the results. A 'cradle-to-gate' approach was used, which is a common practice in biorefinery system design (Gaffey et al., 2024), covering all the processes involved from the production of all the necessary inputs in the system to the production of the target outputs. In this research, the processing stages are divided into two main subsystems: (i) Total Phenolic Compounds (TPC) extraction (SS1), where phenolic compounds are isolated, and (ii) biochar production (SS2), where the residual biomass is converted into biochar and syngas (see Figure 1).

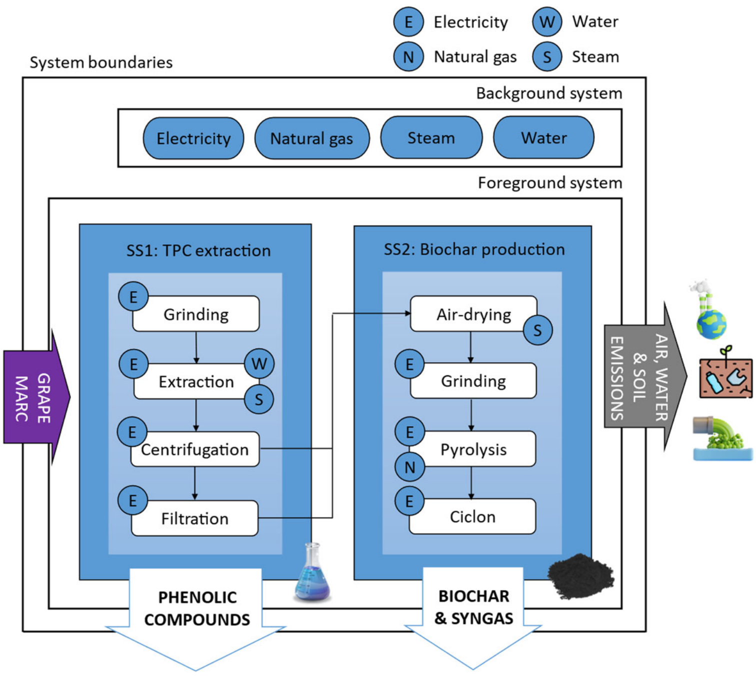

Figure 1: System boundaries of the biorefinery.

The environmental profile has been calculated considering the characterization factors of the ReCiPe v1.07 (H) impact method and considering the production of 1 kg of phenolic compounds as functional unit as it is the main product of the biorefinery. The impact categories selected were: Global Warming (GW), Stratospheric Ozone Depletion (SOD), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), Marine Eutrophication (ME), Mineral Resource Scarcity (MRS) and Fossil Resource Scarcity (FRS).

RESULTS & DISCUSSION

Preliminary results show that the main hotspot of the system is the generation of the high amount of steam needed in the biorefinery, followed by natural gas and electricity production. This is in line with many other reported studies analysing the environmental profile of different types of biorefineries, where its energy needs contribute significantly to the environmental profile (Santiago et al., 2022).

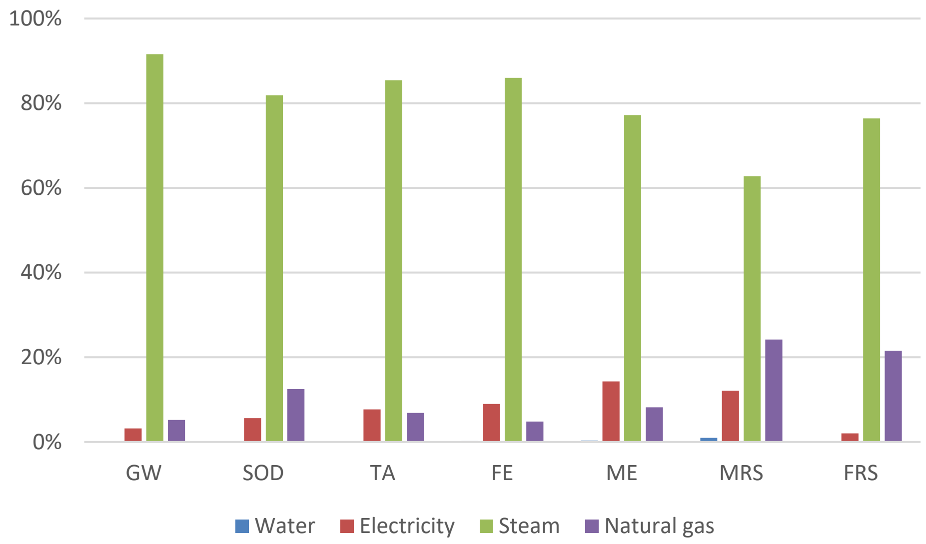

Figure 2: Main contributor per each one of the categories analysed.

CONCLUSIONS

This research evaluates the environmental sustainability of a biorefinery designed for the valorisation of grape marc to obtain phenolic compounds and biochar. The main hotspot of the system is the production of the steam required in the biorefinery, mainly in the purification of the phenolic compounds stream.

A possible area of improvement of these results for future studies could be test with sources or ways of producing the energy that is required in the plant or with different time-temperature processes during drying.

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