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Evaluation of Jerusalem artichoke as a sustainable energy crop to bioethanol: energy and CO_2eq emissions modeling for an industrial scenario

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ABSTRACT

An alternative to the sugar/starch-based crops bioethanol is lignocellulosic biomass, but its utilization to biofuels is still not economically viable. In this context, an increasing interest has arising on the search for specific energy crops that do not require arable lands and are not water intensive, such as Jerusalem artichoke (JA). So, this work consisted on the cultivation of JA on those agricultural conditions and its further evaluation as a sustainable feedstock towards bioethanol. Two strategies of producing bioethanol were evaluated pointing out for the consolidated bioprocessing with the *Zygosaccharomyces bailii* Talf1 yeast as the best approach for further scale-up, based on energy data analysis and ethanol productivity. Different industrial scenarios were outlined and compared for overall CO_2eq emissions and energy consumption per liter of ethanol (L_{EtOH}), using adequate criteria on a cradle-to-gate approach. With no land-use change, no biogenic and no co-products credits, the comparison of the overall energy consumption and CO_2eq emissions (100% process) from JA ethanol (9 MJ/L_{EtOH}; 679 g CO_2/L_{EtOH}) with sugarcane/sugar beet ethanol (42/29 MJ/L_{EtOH}; 731/735 g CO_2/L_{EtOH}) and with gasoline refinery (15 MJ/$L_{EtOH\ eq}$; 1154 g CO_2/$L_{EtOH\ eq}$), highlights the JA as an alternative feedstock to be a focus of ethanol research for gasoline blends.

1. Introduction

Environmental issues, such as greenhouse gas (GHG) emissions, and the depletion of fossil fuel reserves are still driving research on renewable sources for energy and chemicals. Biomass can be converted into ethanol through either biochemical (hydrolysis and fermentation) or thermochemical conversion processes (gasification and catalytic synthesis) [1]. There is a multitude of feedstocks for biomass conversion to bioethanol. According to the Renewable Fuels Association, worldwide ethanol production is dominated by the U.S. (corn feedstock) and Brazil (sugarcane feedstock) that produce 85% of the world's ethanol (c.a. 92 billion liters). Europe is the third main producer (sugar beet feedstock). According to 2014 statistics of the European Renewable Ethanol Association (ePURE) [2] there are 8799 million liters (ML) of installed production capacity in Europe. Minimum installed capacity stands for Denmark with 5 ML and maximum goes to France with 2318 ML. The main feedstocks used for the production of renewable ethanol in the European Union are wheat (34%) and maize (42%), followed by sugar beet (17%) [3].

Despite its applications to hygiene and wine industry, bioethanol is also playing an important role as a substitute of the gasoline fuel in pure or blended form (e.g. E27 to E100 in Brazil, and E15 and E85 in U.S.) [4]. The importance of bioethanol as an industrial product has generated a great deal of research in increasing the ethanol fermentation yield [5–7], and, at the same time, in increasing its sustainability when compared to its fossil fuel competitor. The improvement of the bioconversion efficiency is an important issue and it is already being tackled [8–10]. Without this improvement biofuels could not be market competitive.

The benefits in gasoline substitution are measured in avoided GHG emissions, i.e. GHG emission reduction in percentage. In

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