Industrial Crops & Products 187 (2022) 115157

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

An integrated olive stone biorefinery based on a two-step fractionation strategy

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ARTICLE INFO

Keywords:
Bioethanol
Biomass pretreatment
Ethanol-water organosolv
Furfural
Lignin-derived products
Olive oil industrial waste

ABSTRACT

Olive stones (OS) constitute a waste lignocellulosic material produced by the olive oil industry in great amounts, that currently is only used as a low-value energy source for industrial or domestic boilers. Having in view its full valorization, this work proposes and validates an integrated strategy aiming to obtain three different streams of sugars / lignin-derived compounds. Dilute acid hydrolysis was used to obtain a xylose-rich hydroysate that was chemically converted into furfural with a 48.7 % yield. The resulting acid-pretreated solid biomass that consisted mainly of lignin and cellulose, was subjected to a catalyzed ethanol-based organosolv delignification. Temperature, time, and sulphuric acid concentration were optimized in order to recover added-value lignin products and digestible cellulose.

At the optimal conditions (190 °C and 30 min), a 50 % delignification was reached, together with the highest enzymatic hydrolysis yields (190 g glucose/kg of OS). Phenolic compounds content in organosolv liquors reached 41.6 mg GAE/g OS. This extract presented an antioxidant capacity up to 10.9 mg TE/g OS. The pretreated solid fraction was used as a substrate for ethanol production by a pre-saccharification and simultaneous saccharification and fermentation process, enabling to obtain an ethanol concentration of 47 g/L, with a fermentation yield of 61.4 % of the theoretical maximum. Globally, from 100 kg of OS processed according to this experimental scheme, 6.9 kg of furfural, 6.2 kg of ethanol, 7.4 kg of lignin, and 4.2 kg of phenolics compounds can be obtained as main products, thus constituting a way of valorization of renewable material in a multiproduct biorefinery strategy.

1. Introduction

Lignocellulosic biomass (LCB) has a high potential for the production of fuels and value-added chemicals, in a biorefinery concept (Scopel and Rezende, 2021). The production of bioethanol and petroleum-derived products from residual LCB is a sustainable way to reduce dependence on fossil fuels, due to their abundance, renewability, and non-competition with food (Ferreira and Taherzadeh, 2020). One example of such lignocellulosic biomass are the olive stones.

Olive stones (OS) are a LCB generated in the olive oil production process, where other olive-derived residual biomass is produced, making this agroindustrial sector an interesting source of raw materials in a biorefinery context (Ruiz et al., 2017). To obtain olive oil, the whole olive is subjected to milling as a first step, then a malaxing process, and finally the separation of the oil from the rest of the mixture (olive pomace). The olive pomace is further conducted to an extraction facility to obtain olive pomace oil by solvent extraction and a final solid residue called exhausted olive pomace (EOP).

In recent years, the separation of the OS from the milled olives or from the final olive pomace has become frequent practice, due to its use as fuel in small industrial and domestic boilers (Manzanares et al., 2017), but still, this is a niche market. In order to illustrate the volume of available olive stones, and considering only Spain, as the main olive-producing country in the world, an estimation of 750,000 tonnes of OS is considered, based on the fact that it produces about 7.5 million tonnes of olive fruit in 2021 (https://www.fao.org/faostat/en/), and assuming that OS accounts for approximately 10 % by weight of the olive fruit (Romero-García et al., 2014). Moreover, OS has the advantage

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https://doi.org/10.1016/j.indcrop.2022.115157
Received 3 February 2022; Received in revised form 15 May 2022; Accepted 27 May 2022
Available online 20 July 2022