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D-Lactic acid production from *Cistus ladanifer* residues: Co-fermentation of pentoses and hexoses by *Escherichia coli* JU15

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ABSTRACT

In this study, glucan-rich solids, and xylose-rich hydrolysates obtained from *Cistus ladanifer* distillery residues (CLR) were used for D-lactic acid (D-LA) production by the D-lactogenic *Escherichia coli* strain JU15. Firstly, hemicellulosic hydrolysates obtained by the autohydrolysis process were submitted to dilute sulfuric acid-catalysed post-hydrolysis. The influence of operational conditions on oligosaccharides hydrolysis was assessed by the combined severity parameter (CS) in the range of 1.1–2.3. The optimum post-hydrolysis conditions were found for CS of 1.6 (300 mM H_2SO_4, 15 min, 121 °C). Subsequent detoxification procedures on post hydrolysed liquors were carried out, where 9.1% (w/v) powdered activated charcoal enabled a full removal of furfural, 5-hydroxymethylfurfural (HMF), and phenolic compounds together with a reduction of acetic acid (37%), and formic acid (27%). Diverse fermentation modes using detoxified and non-detoxified hydrolysates, as well as using previously NaOH delignified glucan-rich solids alone (SHF or SSF) or together with pentoses liquors (SSCF) (5% loading) were performed. For all the tested conditions, both hemicellulose- and cellulose-derived sugars can be efficiently used as the carbon source to produce D-lactic acid by *E. coli* JU15 with a D-LA yield always surpassing 92 $g_{D\text{-}LA}$/100 g sugars.

1. Introduction

Lactic acid (LA) is an organic acid widely used in the food and cosmetic, pharmaceutical, and chemical industries. Its demand has increased considerably due to the promising applications of polylactic acid (PLA), a biodegradable and thermostable semi-crystalline polymer, used as a sustainable alternative to plastics obtained from petrochemicals (Abdel-Rahman et al., 2011; Martinez et al., 2017; Reddy et al., 2008). LA can be produced by chemical or fermentative routes, but the biotechnological production of chemicals from renewable materials (plant biomass, industrial waste, etc.) is an attractive way to obtain bio-based products (Zhao et al., 2019). Since the optical purity of LA is crucial to the physical properties of PLA (Okano et al., 2010), the fermentative route has advantages as it is possible to obtain optically pure D- or L-lactic acid when the appropriate microorganisms are selected (Abdel-Rahman et al., 2013).

Several bacterial strains, in particular from the *Lactobacillus* genus, have been described to have the ability to produce mixtures of L-lactic acid and D-lactic acid (D-LA). However, the single production of D-LA is only reported in a limited number of studies (Hama et al., 2015; Singhvi et al., 2017; Zhang and Vadlani, 2013). Furthermore, the majority of *Lactobacillus* strains cannot utilize pentose sugars as sole carbon and

Abbreviations: CLR, *Cistus ladanifer* distillery residue; CLRext, *Cistus ladanifer* distillery residue extracted in Soxhlet with ethanol and water; LA, Lactic acid; D-LA, D-lactic acid; CS, combined severity; SHF, Separate Hydrolysis and Fermentation; SSF, Simultaneous Saccharification and Fermentation; SSCF, Simultaneous Saccharification and Co-fermentation; HMF, 5-hydroxymethylfurfural.

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