Opuntia ficus-indica: a biorefinery integrated process for the valorization of cladodes

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Cladodes of Opuntia Ficus-Indica are the major by-product of prickly pear production. It is found that one hectare of cultivated area generates about 6 – 8 tons of this pruning waste (Procacci et al., 2021).

In recent years, several studies demonstrate cladodes being a rich source of value-added compounds (Fawzy et al., 2021) such as dietary fibers, mono, and polysaccharides (Albergamo et al., 2022) and many investigations have been conducted to prove their possible uses. Despite that, for the best knowledge of the authors, no research has been done on the possibility of using cladodes in a cascade biorefinery processes.

The present work is focused on the development of a biorefinery integrated process for the valorization of O. ficus-indica cladodes. As illustrated in Figure 1, the process is composed of two sequential phases: a first step that uses ultrasounds to produce polyphenol functionalized polysaccharides and a second step that uses extraction residues as a substrate for the production of biogas in an Anaerobic Digestion (AD) procedure.

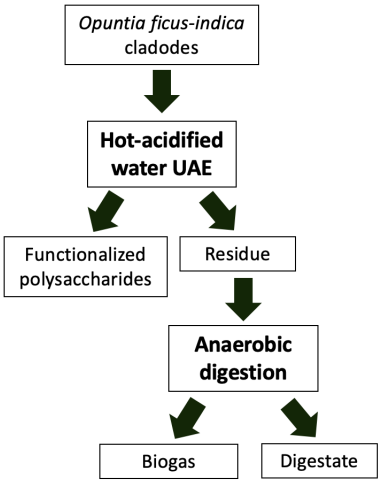

Figure 1: scheme of biorefinery process for cladodes of Opuntia ficus-indica

Ultrasound-Assisted Extraction (UAE) is employed to obtain functionalized polysaccharides. UAE is a clean and green technique, versatile, easy to use and relatively low budget compared to other extraction techniques (Tiwari, 2015). Ultrasounds generate cavitation bubbles able to enhance the contact between treated material and solvent, improving and accelerating the mass transfer of the target compounds (Adetunji et al., 2017; Moorthy et al., 2017).

A Design Of Experiment (DoE) is applied to investigate testing parameters of UAE and process variables are optimized using Response Surface Methodology (RSM). The optimal parameters (SL = 1:10 w/v, pH = 2.5, t = 20 min, and T = 65 °C) allows to obtain a yield of extraction equal to 12.07 ± 1.7 % dw (Zamboi et al., 2024).

Opuntia has also the adequate composition and nutrients for the developing of Anaerobic Digestion (Rojas et al., 2023). Nevertheless, research reports that cladodes used alone and without pretreatment have a poor yield in terms of biogas production because of its physicochemical characteristics and the presence of lignocellulosic material. Therefore they are often used in combination with other substrates such as cow manure (Espinosa-Solares et al., 2022) or pretreated. Between different procedures, acid pretreatment using HCl is reported as the most effective, since it allows to break lignin seal, increasing the accessibility of cellulose by bacteria working in AD. Acid pretreatment is reported to increase methane yield from approximately 420 NmL/gVS for non-treated substrates to 600 NmL/gVS for treated substrates (Calabrò et al., 2018).

Polysaccharides extraction generates residues that could be used to perform Anaerobic Digestion, since UAE is performed in hot and acidified water. Indeed, a pH 2.5 HCl solution is added to the sample in order to enhance the extraction yield. AD tests will be performed in batch reactors with 80 % working volume, mesophilic conditions (35 °C), using a substrate:inoculum ratio 1:1, Total Solids (TS) 6 %, C/N 20 – 30 %, t 21 – 30 days. AD results for the residue will be compared to results for cladodes and for co-digestion with other most common used substrates.

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