Monetizing Burdock into value-added products: A multi-objective optimization and systems integration approach towards circular economy

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Abstract

Arctium lappa is a traditional Chinese medicinal herb and an edible perennial plant of the *Asteraceae* family. Popularly known as burdock, this plant is native to Europe and Asia and was rapidly spread across North America by the early European settlers.

The different parts of the plant possess antioxidant, antibacterial and anti-inflammatory biological activities and are commonly used to treat various illnesses, such as throat infections, intoxications, skin infections and to relieve rheumatic pain and fever. Recently, it was confirmed that *A. lappa* is capable of improving mucus protection in the stomach and intestines, besides preventing mucous injuries caused by alcohol. Some burdock components have been reported to possess pharmacological activities like antioxidant, anti-inflammatory, antiproliferative and antiviral (Rodriguez *et al*., 2018).

At present burdock *is underused* and there are just a few studies in the literature devoted to the obtainment, characterization and application of its valuable extracts. Burdock root extractions with scCO2 and compressed propane, characterization and biological activities of the extracts, influence of process conditions (pressure and temperature) and solvent effects on the chemical composition, total phenolic content and antioxidant activity was reported by Rodriguez et al. (2018). In order to examine a multitude of alternative techniques to the same feedstock (burdock leaves), de Souza et al. (2019) studied the capabilities of pressurized liquid extraction (PLE) with hydroalcoholic solutions with different mass fractions of water, and compared those to the results obtained by: i) a sequential six step SCE with ethanol as a co-solvent and ii) a SCE procedure where distilled water was added to the ethanol as an auxiliary solvent, referred to as scCO2+EtOHH2O procedure. Major compounds found in the burdock root extracts were diisooctyl phthalate (DIOP) and 2,3-Dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one (DDMP), glycerol, methyl oleate, butanoic acid and pentadecanal. Analogous experiments were performed on the areal parts (leaves) of the plant by de Souza et al. (2018). A number of important phenolic compounds like lupeol acetate, amyrin acetate,

diisooctyl phthalate and phytol were identified in the extracts obtained and it was concluded that SCE with ethanol as a co-solvent has a potential as a viable technique.

Burdock thus, can be a potential feedstock for a wide variety of chemicals. However, as an option for extraction of all of these components from a single plant, the economic viability and environmental impacts for cultivation and conversion need to be studied for the plant species. It is known to originate from the northern parts of Europe and Asia, but also can be found around the world; because of its easy and rapid acclimatization, the plant is classified as an invasive weed in the majority of countries outside its native range. The promise to replace fossil sources with burdock as a feedstock allows a step towards circular economy, and establish an alternative supply chain which can be studied through Life Cycle Assessment. The feasibility of a biorefinery including decisions on scale, processes, products, water use, and waste management using the entire plant needs to be studied through Techno-Economic Assessment. Finally, the environmental impacts need to be quantified for the processes that convert burdock to products, including transportation of the species to the biorefinery.

A multiobjective framework is studied in this project, where potential tradeoffs are considered. The ultimate goal of this work is to study whether burdock can be considered a potential feedstock and to determine the viability using LCA and TEA analyses. Using process integration, the traditional approaches can be modified if it is infeasible, or improved if feasible.

Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 778168

Keywords: *arctium lappa; pharmacological activity; biorefineries; life cycle assessment; LCA*

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