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Selected Topics in Food Process Engineering

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Chapter 8
Solvent and Green Extraction Processes: Applications in the Food Industry

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1 Introduction

Consumers are increasingly aware of the impact of food on their health. Thus, foods with natural components are preferred over food with synthetic components. The demand for natural ingredients such as plant extracts is fast-growing globally. Plant extracts are known for their antioxidant and antibacterial activities due to the presence of bioactive metabolites. Plant extracts can be used in food as coloring agents, flavoring agents, preservative agents, functional ingredients, and edible oil. Thus, the recovery of bioactive metabolites for food matrices is a strategy widely used in the food and herbal medicinal sector and with a significant economic value (Jha & Sit, 2022). For example, according to the International Trade Centre (2022), plant extracts belong to a market estimated at USD 6.9 billion in 2020. Moreover, plant extracts can participate in the global functional food market, which is rapidly expanding and expect to grow up to 276.68 billion dollars at the end of 2024 with a compound annual growth rate of 9% (Lokhande & Pathak, 2021). Among the metabolites from plants, animals, microorganisms, and marine microorganisms with potential application in the food industry are carbohydrates, pigments, lipids, proteins, and amino acids. (Swamy & Akhtar, 2019). Moreover, the demand for

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bioactive compounds in different industries such as pharmaceuticals, food, nutraceuticals, cosmetics, and agricultural is growing, and the recovery of these compounds from plant and agro-industrial byproducts sources has been receiving significant attention. In that context, researchers are developing effective extraction processes under the approach of the Green Chemistry concept and its principles (Mohd Fuad et al., 2021).

The food industry needs to focus on greener and sustainable processes. For example, extraction is a crucial process before the purification of the bioactive compounds. In that context, the food industry is looking for greener extraction processes that use shorter extraction times and reduce the generation of toxic waste. Besides, there is great interest in adopting green extraction processes that require less energy and solvent in a sustainable approach. Thus, the use of green solvents that do not compromise the safety and quality of the extract is necessary (Makris, 2018). Green solvents are non-toxic, non-volatile, recyclable, biodegradable, and may not involve a high energy cost of synthesis (Torres-Valenzuela et al., 2020). Greener solvents such as supercritical fluids, ethanol, water, and natural deep eutectic solvents are increasingly used in the food industry.

Several conventional extraction processes such as maceration, Soxhlet, hydrodistillation, steam distillation, and percolation have been used to recover bioactive compounds from natural matrices. Although these extraction methods are energy and time-consuming, the use of GRAS (generally recognized as safe) solvents such as water or ethanol has improved the sustainability of these extraction processes. In the last decades, green novel extraction processes such as ultrasound-assisted extraction (UAE), supercritical fluid extraction (SFE), pressurized liquid extraction (PLE), ohmic heating extraction, and pulsed electric field extraction (PEF) have emerged. These novel extraction methods have been recognized for increasing extraction yield, reducing extraction times, and using environmentally friendly solvents (Putnik et al., 2019).

Diverse mechanisms and phenomena allow these extraction processes became a green alternative. For example, cavitation phenomena and implosion of cavitation bubbles enhance the extraction rates in UAE (Chemat et al., 2017). In SFE, a significant effect on solvent selectivity is caused by changes in pressure and temperature (Singh et al., 2021). In PLE, the elevated temperature enhances the solubility of the compounds while pressure keeps the solvent below its boiling point (Vazquez-Roig & Picó, 2015). In PEF, pores are formed into the cell membranes by an electric field. Then the membrane permeability is increased, enhancing the diffusion of the targeted compounds (Khadhraoui et al., 2021). In ohmic heating extraction (OHE), internal heat is generated by the application of electric fields on biological matrices (Bonifácio-Lopes et al., 2022). Moreover, these novel extraction processes allow the integration and intensification of the process. For example, ultrasound (Khadhraoui et al., 2021), pulsed electric fields (Aguilar-Machado et al., 2022; Ranjha et al., 2021), pressurized liquids (Viganó et al., 2022), and supercritical fluids (Al-Maqtari et al., 2021), have been used in the development of the integrated or intensified extraction processes. Figure 8.1 shows an overview of this chapter section, providing available information on conventional and novel