Valorization of fruit waste for the production of bioactive compounds

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Nowadays, the fruit production and processing result in considerable waste production, with an adverse effect on both the environment and the economy of society (Nirmal et al., 2023). Fruits along with vegetables constitute the primary fraction of food waste globally, representing a significant portion of discarded food products. Based on FAO data (2019), the waste of fruits and vegetables accounted for 21% of the overall waste produced in 2016, with a significant portion attributed to the consumption stage (Figure 1). In the food balance for the year 2019, the global losses of fruit were estimated to approximately 22 million tons. This issue arises from a variety of factors throughout the agricultural, distribution, processing, post-harvest, and consumer stages of the food supply chain (Cassani & Gomez-Zavaglia, 2022; Oliveira et al., 2023). To address this issue, it is essential to minimize the generation of fruit waste and also to effectively utilize and develop strategies for managing these waste products. This approach has the potential to decrease carbon footprint and greenhouse gas emissions, thus, playing a role in attaining sustainable development goals (Campos et al., 2020; Nirmal et al., 2023).

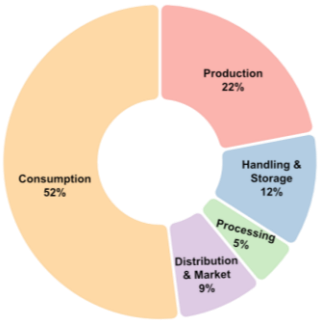

Figure 1. Percentage of fruit and vegetable loss across the European supply chain (FAO, 2011).

Fruit wastes and byproducts represent rich sources of valuable compounds, including phytochemicals, polysaccharides and dietary fibers. Moreover, they may contain various bioactive functional ingredients such as phenolics, carotenoids, flavonoids which offer various health benefits such as antioxidants and antimicrobial properties (Nirmal et al., 2023). The extraction and stabilization of these bioactive compounds can lead to the development of numerous functional foods, food additives, cosmetics, and nutritional products across diverse industries (Sha et al., 2023). Besides conventional techniques, there are numerous available emerging green technologies for the recovery of these compounds from fruit waste including ultrasound-assisted extraction, microwave-assisted extraction, pressurized liquid extraction (sub-critical water extraction), supercritical fluid extraction, pulsed electric field assisted extraction and enzyme-assisted extraction, each offering distinct advantages (Saini et al., 2019).

Ultrasound-assisted extraction utilizes mechanical waves (20 kHz to 100 MHz) to efficiently disrupt cell walls, while microwave-assisted extraction accelerates the process through microwave radiation (300 MHz to 300 GHz). Pressurized liquid extraction, involves maintaining solvents in a liquid state above their boiling point through elevated pressure, enhancing lipid solubility, diffusion rates, and matrix penetration. Supercritical fluid extraction leverages supercritical fluids for enhanced solvating power, and pulsed electric field assisted extraction promotes mass transfer disrupting cell membranes effectively while preserving compound integrity. Meanwhile, enzyme-assisted

extraction utilizes enzymes to destroy the cell wall, facilitating the release of bioactive compounds trapped in the fruit matrix. These techniques collectively enable efficient extraction, catering to diverse needs in harnessing valuable bioactive compounds from fruit waste (Nirmal et al., 2023; Saini et al., 2019).

Bioactive compounds are highly unstable and susceptible to rapid degradation under processing conditions like temperature and pH, making it crucial to protect them for various applications such as producing innovative functional foods. Following extraction from fruit waste, encapsulation may be a necessary step to protect and control the release of these compounds under specific conditions (Gajic et al., 2021). This process involves entrapping the compounds within carrier materials like cyclodextrin, maltodextrin, cellulose, gum Arabic, and whey protein. Encapsulation techniques such as spray drying, spray chilling/cooling, extrusion, emulsion-based methods, and freeze-drying are employed. Each technique is selected based on factors such as the nature of the compound, desired release profile, and the intended application of the encapsulated product (Marcillo-Parra et al., 2021).

Fruit wastes, abundant in valuable bioactive compounds, offer opportunities for new market development. These compounds possess diverse properties that can be further exploited for various applications. Utilizing encapsulation techniques for the extracted bioactive offers exciting opportunities, particularly in the realm of functional food additives.

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