An holistic approach for the valorization of pomegranate by-products using green methods

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Pomegranate (*Punica granatum* L.) is one of the most significant sources of polyphenols compared to other edible fruits. It is mainly consumed fresh or as a fresh juice and pomegranate-based drinks. During the processing of pomegranate fruits into juice, large amounts of by-products, such as peels and seeds, are generated. Peels and seeds constitute approximately 78 and 22% of pomegranate wastes, respectively, and they are typically used as feedstock or are disposed as wastes (Kaderides and Goula, 2019). Pomegranate peels constitute 24% of the total fresh fruit mass and contain higher amounts of antioxidants, such as phenolic acids (e.g. gallic acid, ellagic acid, caffeic acid), flavonoids [i.e. flavonols (e.g. catechin, gallocatechin, epicatechin), anthocyanins) and hydrolysable tannins [i.e. ellagitannins (e.g. punicalagin), gallotannins], than the edible parts (Çam and Hışıl, 2010). In the case of seeds, they are mainly composed of oil (12–24%), proteins (10–20%), and insoluble fibers (Talekar *et al* 2018). Pomegranate seed oil constitutes a great source of polyunsaturated fatty acids, especially punicic acid, with many health promoting benefits. Consequently, pomegranate by-products should be considered as a potential source of value-added components, which can be exploited and used as natural additives in food, cosmetic, and nutraceutical industries (Kaderides et al., 2021).

In this frame, a holistic approach for the management of pomegranate wastes towards the recovery of bioactive compounds, is proposed. In the case of pomegranate peels, free and bound phenolic compounds were extracted from defatted material with the aid of ultrasound-assisted extraction. (UAE). Free phenolics were extracted using an hydroethanolic solution whereas alkaline hydrolysis was used in order to liberate bound phenolic compounds. Response Surface Methodology (RSM) was employed to optimize the extraction parameters for the recovery of bound phenolics, namely, the duration of sonication (min), the solvent:solid ratio (v/w) and the NaOH concentration (mol/L). Total phenol content, radical scavenging activity as well as punicalagin content, determined by RP-HPLC-DAD, were monitored in order to verify the effectiveness of the process.

Moreover, in the case of pomegranate seeds, different methods were investigated for oil extraction. Specifically, results using ultrasound-assisted extraction were compared to conventional maceration extraction (CME) utilizing an organic solvent, namely n-hexane. Furthermore, the potential of enzymatic pretreatment to increase the pomegranate seed oil extraction yield, was investigated. This procedure was also optimized in terms of the pretreatment time (60-240 min), the type of enzyme (cellulose:pectinase) (0-100% cellulose), the enzyme concentration (2-4% w/w), and the ratio of solution/solid waste, which ranged between 2/1 and 6/1 mL/g. The effects of simultaneous enzymatic pretreatment and UAE were also investigated.

Findings of the present study seem promising for the holistic valorization of pomegranate industry by-products towards the recovery of valuable compounds as well as their future application as natural additives to functional products, minimizing, at the same time, the environmental hazard.

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