Pulsed electric field-assisted green solvent extraction of valuable compounds from agro-food by-products

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The valorization of by-products derived from agro-food industry is a challenge, since it might contribute to lessening the waste disposal problem, as well as recovering a gamut of bioactive compounds with nutritional, functional and health beneficial properties, which may find several applications as natural additives or active ingredients for food, cosmetic, pharmaceutical and animal feed products (Carciochi, et al, 2017), thus highly contributing to a sustainable food chain from an environmental, social and economical point of view.
Among industrial agro-food residues, tomato processing by-products, namely peel, pulp and seeds, account for about 2–5% in weight of the total processed tomato fruits (Knoblich etv al., 2005). This by-product, which is currently used as animal feed, still retain significant amount of many bioactives, particularly carotenoids (lycopene), with high antioxidant power. Similarly, by-products (leaves, external bracts and stems) derived from harvesting and industrial processing of artichoke (Cynara scolymus), which account for up to 60 – 80% by weight of the total raw material (Lavecchia *et al*., 2018), represent a major disposal problem for agriculture and food processing companies, despite they still represent a cheap and rich source of valuable intracellular compounds (e.g. polyphenols, flavonoids) (Schutz *et al*., 2004) with high antioxidant properties.
Several researchers have investigated the application of conventional extraction techniques (e.g., percolation, maceration and Soxhlet extraction) for the recovery of high-added value compounds from plant based biomass. However, although these methods offer a simple approach, they typically suffer for several drawbacks mainly related to the presence of the envelop (membrane and wall) surrounding the plant cell, which acts as a barrier that greatly limits mass transfer phenomena of solvents and target intracellular compounds during extraction process. For these reasons, to recover a substantial amount of valuable compounds, the conventional extraction techniques may require intensive pre-treatments (drying, comminution) of the raw material, as well as the use of a large amount of polluting solvent, long extraction time and relatively high temperature, which may cause losses of thermolabile compounds, as well as lead to the co-extraction of undesirable components (Pataro et al., 2019).
These drawbacks are motivating scientists to explore more sustainable, efficient, rapid and cost-effective extraction techniques, based on a green extraction approach. In this frame, Pulsed electric field (PEF) treatment is an innovative non-thermal technology that has been proposed as an alternative to conventional (mechanical, thermal, chemical, and enzymatic) cell disruption methods. PEF processing involves the exposure of plant tissues placed in contact with two electrodes to repetitive short-duration pulses (1 μs – 1 ms) of moderate electric field (0.5-10 kV/cm) and relatively low energy input (1-20 kJ/kg), which induces the permeabilization of cell membranes by pores formation, known as electroporation or electropermeabilization (Raso et al., 2016). This has been proved to increase the efficiency of the conventional extraction processes of valuable compounds from a wide range of food processing by-products while reducing the energy costs, the solvent consumption, and shortening the treatment time (Donsì et al. 2010).
The aim of this work was to demonstrate the potential of PEF pre-treatment to intensify the extractability of valuable compounds from two different agro-food by-products using a green approach. In a first set of experiments, which was carried out in the frame of the European project AccelWater (Project ID: 958266), the effect of pre-treatment (E=0.25–5 kV/cm; W_T =1–20 kJ) on the recovery of lycopene (hydrophobic molecule) in either acetone or ethyl lactate from industrial tomato peels residues, was investigated. In a second set of experiments, the extractability of polyphenols (hydrophilic compounds) from artichoke by-products (stems) during aqueous extraction was studied. The achieved extracts were analysed in terms of lycopene concentration (for tomato peel), total phenolic content (for artichokes) and antioxidant power (FRAP), which were measured spectrophotometrically as previously described (Battipaglia *et al*.; 2009; Pataro et al., 2018), as well as in terms of chemical composition via HPLC analyses (Pataro et al., 2018).
Results showed that cell damages induced by PEF treatment carried out at 5 kV/cm and 5 kJ/kg was enough to significantly enhance the extraction yield of lycopene (18% on average) and the antioxidant power (18.1% on average) in either acetone and ethyl lactate extracts, as compared with untreated samples. However, acetone gave the highest lycopene yield (Table 1). Similarly, aqueous extracts from optimally PEF pre-treated (E=1-3 kV/cm; W_T=5 kJ/kg) artichoke by-products possessed significantly higher content of total polyphenols (+350% on average) and antioxidant power (+193% on average), as compared with the untreated samples (Table 1).

Moreover, HPLC analyses showed that all-trans lycopene was the main carotenoid extracted from tomato peels, while chlorogenic acid was the most abundant phenolic compound recovered in extracts from artichoke by-products.

In conclusion, the results of this work demonstrated the capability of PEF technology to promote the green extraction of high-added value compounds of different polarity from agro-food by-products with very low energy expenditures, thus contributing to decrease disposal issues and to expand market opportunities, leading to a greater diversity of products.

Table 1. Lycopene concentration in ethyl lactate extract and total phenolics in water extracts of PEF-treated tomato peels and artichoke stems, respectively.

By-products		Lycopene Concentration (mg/100g DW)	Total phenolics concentration (mg/100g DW)
Tomato peels	Control	1394.5	-
	PEF	1649.6	-
Artichokes stems	Control	-	42.6
	PEF	-	125.0

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