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Electrotechnologies applied to valorization of by-products from food industry: Main findings, energy and economic cost of their industrialization

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ABSTRACT

There has been a growing interest to reuse food waste and by-products from different processing steps, not only to ensure the environmental sustainability but also to improve the economic performance of the processes. One way of recovery that has raised more interest is the extraction of valuable compounds, which can be used as ingredients in food and pharmaceutical industries due to their technological function, nutritional properties, or their beneficial effects on human or animal health.

In many cases, conventional solvent extraction cannot be economically feasible or involves the use of toxic solvents, hindering their subsequent management, or high temperatures, with consequent degradation of thermolabile compounds. Therefore, new pretreatment technologies that can partially or completely replace conventional methods, thus reducing the solvent consumption, temperature and/or the extraction time, can be a useful tool to get more efficient and sustainable processes. The use of electrotechnologies, especially pulsed electric fields and high voltage electrical discharges, may be a promising tool to achieve the above mentioned purposes, thus improving extraction processes in the upgrading of by-products. In this review, the main results published are summarized, emphasizing their potential applications and studying their energy and economic cost, a key aspect to assess its industrial viability.

Contents

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1. Introduction

One of the keys to ensure environmental, economic and social sustainability of industrial activities is to improve the management of waste and by-products generated. The food industry is one of the sectors that generates more waste along the entire chain, from primary production to waste generated in households, estimated figures above billion tons (Gustavsson et al., 2011), and therefore it constitutes one of the major stakeholders in the valorization of wastes and by-products (Koubaa et al., 2015; Roselló-Soto et al., 2015b).

According to the Food and Agriculture Organization (FAO), about a third part of the edible portions of food were discarded in 2011, meaning 1.3 billion tons of food waste (Gustavsson et al., 2011). Since the beginning of the industrial revolution until the twentieth century, most of these wastes have been treated as worthless waste, without taking into account their high environmental impact as well as their potential to be used as a source of high-added value compounds or as raw material in other industrial processes (Galanakis, 2012; Roselló-Soto et al., 2015a,b).

In the last decade, the growing awareness of society and, consequently, of the various government bodies, has led the institutions to establish policies for waste management to ensure the economic, social and environmental sustainability of the food chain. For example, the European Union established various measures to reduce the environmental impact of the generation and management of waste, supporting valorization processes (Anonymous, 2008; Luengo, 2015). As a result of these policies, over the last years, several strategies have been studied and developed to produce more efficient processes to enhance agricultural food waste as by-products, that is, as by-products that can be exploited in other industrial processes as ingredients or raw materials.

One way of adding value to food wastes and by-products that has aroused greater interest is the use of these materials as a source of compounds with high-added value, which can be used as natural ingredients in the pharmaceutical and/or food industry. These compounds can be interesting for their i) technological functions (e.g. dyes, preservatives, stabilizers, emulsifiers, etc.), ii) nutritional properties (e.g. proteins, vitamins, essential fatty acids, fiber, etc.) or because iii) they have some positive effect on human or animal health (e.g. nutraceuticals, bioactive compounds, antioxidants, etc.). Today, there is a lot of controversy and a lack of acceptance by the consumer of synthetic additives, so this form of recovery, in addition to its environmental interest, would also respond to consumer demand and, therefore, a competitive need for the food industry. The recovery of high-added value compounds that can be found in by-products involves their extraction by using systems that do not affect their functionality and later purification and stabilization to be used as ingredients (Fig. 1).

The extraction step represents the most critical stage and must be adapted according to the compound to recover and also according to the matrix that contains it. In addition, this extraction should be technologically and economically feasible to make it viable as an alternative valorization (Galanakis, 2013; Luengo, 2015).

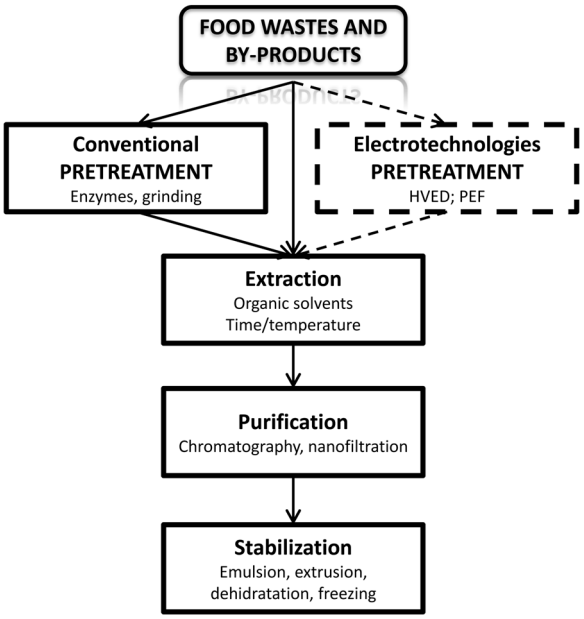

Fig. 1 – Schematic representation of the different constituent stages of the typical recovery process of nutrients and bioactive compounds from waste and by-products generated by the food industry. The scheme includes where the electrotechnologies have been proposed to be used. HVED: high voltage electrical discharges; PEF: pulsed electric fields.

The most commonly used techniques for extraction involve the use of solvents (liquid–liquid or solid–liquid extraction), which in some cases are toxic (e.g. methanol, hexane). Depending on the nature of the product, the extraction can be also assisted with mild (<40 °C) or high (>40 °C) temperatures to enhance process efficiency. However, in many cases the interesting compounds to be recovered are thermolabile, so it is not possible to increase the temperature above a threshold value, or the compounds are difficult to recover without damaging the structure of the by-product (the tissues behave as physical barriers which hinder the diffusion of substances), which contaminates the extract and consequently difficult its later purification (Barba et al., 2015a). In these cases, the final extraction yields are low and/or long extraction times are required. Furthermore, these processes involve the use of a very significant amount of organic solvents, which in many cases are toxic to human health and/or the environment (Barba et al., 2014; Deng et al., 2014).

In order to improve the amount of the recovered compound and/or to reduce extraction time, it is also common the use of a pretreatment to facilitate the subsequent extraction, such as reducing the particle size by mechanical procedures or using