Innovative Food Science and Emerging Technologies 35 (2016) 139–148

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

Olive by-products for functional and food applications: Challenging opportunities to face environmental constraints

M. Antónia Nunes, Filipa B. Pimentel, Anabela S.G. Costa, Rita C. Alves *, M. Beatriz P.P. Oliveira

REQUIMTE/LAQV, Department of Chemical Sciences, Faculdade de Farmácia, Universidade do Porto, R. Jorge Viterbo Ferreira 228, 4050-313 Porto, Portugal

ARTICLE INFO

Article history:
Received 4 February 2016
Received in revised form 3 April 2016
Accepted 23 April 2016
Available online 25 April 2016

Keywords:
By-products
Olive
Bioactive compounds
Food industry

ABSTRACT

This comprehensive review points out the major developments on the recovery of bioactive compounds of olive by-products, intending innovative food applications and enhanced technological functions. Nutritional and sensorial factors influencing consumers' acceptance are also discussed. Besides being an economic burden for producers, olive oil by-products also represent a severe environmental problem. Simultaneously, these are rich in bioactive compounds, which are remarkable added-value ingredients for other industries. New applications have been focused in ameliorating the food nutritional profile, replacing or improving technological properties/functions of food additives, and extending food products shelf life. Eco-friendly food packaging is also a promissory application field. The improvement of nutritional functionality and sensory quality of enriched food is another challenging task. Despite the large chemical characterization of olive products and olive oil processing by-products, further research is still needed to fully understand the potential of this valuable raw material.

Industrial relevance: High added-value ingredients can be obtained by recovering bioactive compounds from olive by-products. Those can be used by food industry to improve food product nutritional profile and/or with a technological functionality. This review presents food applications developed with ingredients and bioactive compounds derived from olive processing by-products. It aims to be useful for food industries and other agro-industrial stakeholders in order to encourage and expand the utilization of olive by-products in the development of innovative food products.

Contents

* Corresponding author.
E-mail address: rita.c.alves@gmail.com (R.C. Alves).

http://dx.doi.org/10.1016/j.ifset.2016.04.016
1466-8564/

1. Introduction

Olea europaea L. is an evergreen tree that has been cultivated for more than 7000 years. It is found throughout the world, particularly in the Mediterranean countries (Cavalheiro et al., 2015). Olive oil production, an important agro-industrial activity for many of these countries, generates a large quantity of wastes (Mirabella, Castellani, and Sala, 2014; Naziri, Nenadis, Mantzouridou, and Tsimidou, 2014). Indeed, it is estimated that just the production of olive pomace (OP), one of the major olive oil processing by-products, reaches 2,881,500 tonnes/year worldwide (Ravindran and Jaiswal, 2016). The seasonable production of olive oil creates, in a short period of time, a high amount of wastes to be resolved as rapidly as possible. A substantial quantity of wastes can have harmful effects in the environment due to its high organic content and phytotoxicity (Bhatnagar et al., 2014). Moreover, the management of olive oil residues is an economic burden to producers (Esteve, Marina, and García, 2015).

The olive fruit can be structurally separated in three parts: the epicarp (skin), the mesocarp (pulp), and the woody endocarp (stone), which contains the seed (Bianchi, 2003; Naziri et al., 2014). Different techniques can be used to extract olive oil. The most common processes that are used are: traditional pressing mills (mainly employed by small producers), the three-phase system, and the two-phase system (Qdais and Alshraideh, 2016).

The three-phase extraction system (Fig. 1), which involves the use of large amounts of water (up to 50 L/100 kg olive paste), is still used in some olive oil producing countries. An annual worldwide production exceeding 30 million m^3 per year of olive mill waste waters (OMWW) is obtained with this process, representing a great environmental problem due to its organic load and polyphenol content (Asfi, Ouzounidou, Panajiotidis, Therios, and Moustakas, 2012; Kavvadias, Doula, Komnitsas, and Liakopoulou, 2010). This system has been increasingly replaced by the more eco-friendly two-phase system in which no water is added. In this case, only olive oil (product) and a humid semi-solid pomace (by-product) are obtained. Nevertheless, the resulting OP has a high moisture content which impairs a proper storage (Qdais and Alshraideh, 2016). In spite of that, olive oil producers are adopting this sustainable two-phase system since it simultaneously decreases the volume of waste water and allows the obtention of a liquid/solid by-product rich in residual olive oil and bioactive compounds (Lafka, Lazou, Sinanoglou, and Lazos, 2011).

The applied technology has a significant impact not only in the quality of olive oil, but also in the type and amount of the generated wastes (Naghmouchi, Mutjé, and Boufi, 2014). There is a rising interest in recovering the bioactive compounds of these by-products for cosmetic, pharmaceutical and food applications (Yener, 2015; Roselló-Soto et al., 2015). Indeed, a vast area of research focusing nutritional and technological food applications of olive oil by-products (and their bioactive compounds) is arising, anticipating "zero waste" awareness by the main food stakeholders: the olive oil processing, food and nutraceutical industries, and science and technology research institutions.

This review aims to update the most integrative options for olive by-product recovery, intending food applications.

2. Olive oil by-products

During olive oil processing, a variety of wastes and by-products are produced. The main ones with major nutritional and technological interests, under the scope of this review, are the olive pomace, the olive mill waste waters, the olive leaves, and the olive stone and seed.

2.1. Olive pomace

Virgin olive oil is extracted from olives using exclusively mechanical techniques, which consist in the crush of the fruit to allow the oil release, the malaxation of the olive paste to induce the oil drops coalescence, and the mechanical recovery of the oil by centrifugation or pressing. The main purpose of this process is to separate the oil drops contained in the fruit mesocarp cells (Clodoveo, 2012; Puértolas and Martínez de Marañón, 2015). Along with the mechanical extraction, a liquid/solid by-product, the OP, is discharged (approximately 35–40 kg of OP per 100 kg of olive). This main by-product of the olive oil production is a heterogeneous biomass with a significant moisture and oil content, which depends on the cultivation region and the employed extraction method (Akay, Kazan, Celiktas, and Yesil-Celiktas, 2015; Meziane, 2011). In a continuous two-phase

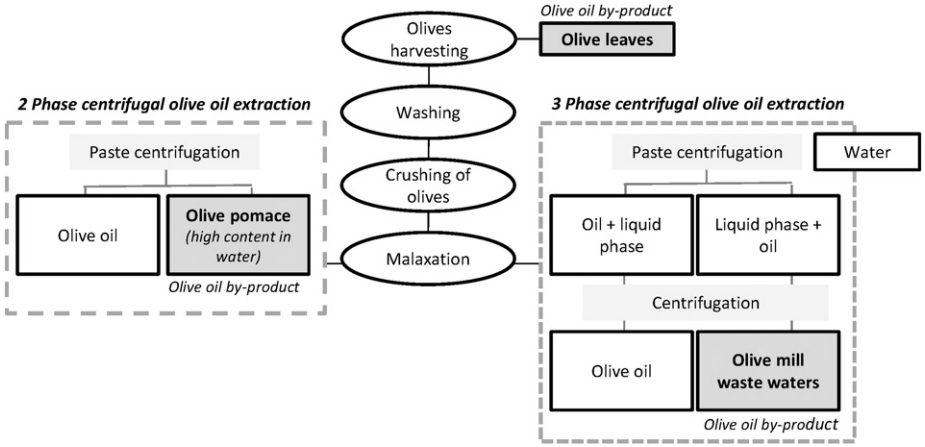

Fig. 1. Olive oil extraction process.