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Integrated processes can turn industrial food waste into valuable food by-products and/or ingredients: The cases of olive mill and pomegranate wastes

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ABSTRACT

Heavy food industry wastes present a constant threat to the environment and a serious operational problem for the respective food industries. While numerous research works are focused on the management of food wastes a lot of work has been done on several such wastes, process efficiency (i.e. extent of waste valorization) along with financial viability still remain serious drawbacks. This work deals with two difficult food wastes, the olive mill wastewater (OMW) and the pomegranate wastes (i.e. peels and seeds). It presents integrated approaches for complete utilization of these wastes in recovering valuable by-products and/or ingredients, while succeeding total depollution (zero waste). Specially designed fermentation, spray drying and encapsulation technologies were properly applied to OMW to produce a number of valuable by-products, such as olive paste spread or olive powder (to be included in food formulations) and encapsulated polyphenols. Clean water is the only remaining "waste stream" that can be reutilized in the olive mill plant, thus reaching total exploitation of the original OMW. In the case of pomegranate waste, an integrated approach is suggested for complete utilization of pomegranate seeds and peels based on ultrasound-assisted extraction of oil and phenolics from seeds and peels, respectively; optimized extraction is followed by isolated ingredient encapsulation using a suitable spray drying technique.

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1. Introduction

Waste disposal is one of the major problems facing most food processing plants. Agricultural uses, as the traditional way of waste utilization, are no longer a feasible alternative, due to major changes in pollution law and agricultural practices. Furthermore, new developments in process engineering and the resulting byproducts make the valorization of waste increasingly interesting (Oreopoulou and Russ, 2007). According to Schieber et al. (2001) and Sonja et al. (2009), food processing wastes have long been considered as a matter of treatment, minimization, and prevention due to the negative environmental impact of their disposal. Nowadays, several food wastes are considered to be a source of valuable nutraceuticals. The isolation of nutraceuticals from agricultural by-products is realized due to the existence of methodologies, which allow not only the recovery, but also their utilization in food formulations (Galanakis, 2012).

The subject of the present work is to present integrated approaches for complete utilization of olive mill and pomegranate wastes in recovering valuable by-products and/or ingredients, while succeeding total depollution.

1.1. The case of OMW

OMW is an extremely offensive food waste stream, due to several negative effects, such as (Akdemir and Ozer, 2008):

(1) high phytotoxicity,
(2) strong discoloration and pollution of natural waters,
(3) threatening the aquatic life,
(4) problems with offensive odors.

The management of OMW is a very important issue in Mediterranean countries where more that 2.4 million tons of olives are produced per year (95% of the total world production), 90% of which is for olive oil production (Paraskeva et al., 2007). The olive producers operate on a seasonal basis and the production units are small and as a rule they do not process the liquid effluents from the

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production process. The most common practice followed today is the disposal of OMW in nearby aquatic receivers like streams, rivers, lakes and even the sea (Paraskeva et al., 2007). As a result severe environmental problems are caused.

Several methods have been proposed for treating OMW, such as:

(1) physical and physicochemical processes (Borsani and Ferrando, 1996; Cegarra et al., 1996; Caputo et al., 2003; Beltran de Heredia and Garcia, 2005; Taralas and Kontominas, 2005; Russo, 2007; Achak et al., 2009),
(2) biological treatments (Marques, 2001; Fountoulakis et al., 2002; Mantzavinos and Kalogerakis, 2005), and
(3) coupled physicochemical and biological treatments (Rozzi and Malpei, 1996).

While the efficiency of these processes, their complexity and processing costs involved may vary significantly, the high depollution cost is usually the main drawback for their industrial application (Paraskeva et al., 2007). According to Russo (2007), physicochemical processes need a complementary biological treatment for the complete degradation of the organic substance, whereas in the biological processes microbial growth is particularly difficult due to the antibacterial action of polyphenols. In addition, although the efficiency of the coupled treatments may be satisfactory, the discharge of a great amount of produced sludge is still a great problem.

The above treatment methods belong to a one-dimension waste treatment approach, which is depollution. They also share the same obstacle that is the high financial burden of depollution, especially considering the small size of most olive mills. A practical way to overcome this obstacle is to develop waste treatment schemes that combine depollution with recovery of valuable byproducts or ingredients. In such processes the income from byproducts could pay for the cost of waste treatment (depollution).

1.2. The case of pomegranate wastes

As far as pomegranate wastes are concerned, pomegranate (*Punica granatum* L.) is one of the oldest known edible fruit that contains the highest concentration of total polyphenols in comparison with other fruits studied (Fazaeli et al., 2013). During the industrial processing of pomegranate, large volumes of industrial wastes (i.e. peels and seeds) are produced, disposal of which has become an environmental problem. It has been reported that the peel and seed fractions of some fruits have higher bioactivities than the pulp fractions (Tomas-Barberan and Espin, 2001; Guo et al., 2003; Balasundram et al., 2006).

Pomegranate peel is the main waste fraction of pomegranate fruits, which had been widely studied because it contains numerous biologically active compounds including natural antioxidants such as phenolic acids and flavonoids (Singh et al., 2002; Li et al., 2006). Phenolic compounds have attracted more and more attention for their antioxidant behavior and beneficial health-promoting effects in chronic and degenerative diseases (Rice-Evans et al., 1996; Lodovici et al., 2001; Kim and Lee, 2004). Recent studies (Li et al., 2006; Tzulker et al., 2007) have demonstrated higher antioxidant capacity of the peel as compared with the aril juice. Thus, pomegranate peel attracts attention due to its apparent wound-healing properties (Chidambara et al., 2004), immunomodulatory activity (Gracious et al., 2001), antibacterial activity (Navarro et al., 1996) and antiatherosclerotic and antioxidative capacities (Tzulker et al., 2007).

As far as pomegranate seeds are concerned, oil content of seeds varies from 12% to 20% of the seed on a dry weight basis (Al-Maiman and Ahmad, 2002). Pomegranate seed oil was reported to present biological properties (Eikani et al., 2012), such as antioxidant and eicosanoid enzyme inhibition properties (Qu et al., 2010), immune function and lipid metabolism (Yamasaki et al., 2006), estrogene content (Tong et al., 2006), skin photoaging inhibition effect (Park et al., 2010), lipoperoxidation and activity of antioxidant enzymes (Melo et al., 2010), toxicological evaluation (Meerts et al., 2009) and protective effect against gentamicin induced nephrotoxicity (Asadpour et al., 2010).

Therefore, due to the above-mentioned pharmaceutical and nutraceutical properties of pomegranate peels and seeds and also due to their large annual production as by-products of the juice and concentrate industries, the pomegranate peels and seeds could have more beneficial applications in food industries instead of being used as animal feed or in commercial cosmetic products.

2. Proposed integrated processes

2.1. Process for OMW utilization

Fig. 1 presents the proposed integrated process for OMW utilization along with the main mass balances. As it can be seen, 850 kg of OMW derived from about 1000 kg of olives can lead to about 110 kg of dry olive powder, or 500 kg of olive paste spread and 90 kg of encapsulated polyphenols. The OMW powder can be used in a wide variety of applications, such as in the preparation of pharmaceutical products; i.e. cholesterol lowering agents and anti-cancer medicine; food products or food additives; cosmetic products, such as creams, balms, shampoos, hair conditioners. The only remaining "waste stream" is clean water that can be reutilized in the olive mill plant; thus the proposed scheme ends up with "zero" waste.

The OMW used for the development of the proposed approach was obtained from the three-phase olive oil mill "Emm. Averis & SIA O.E." located in Galatista of Chalkidiki in Greece. Its main chemical characteristics are presented in Table 1.

2.1.1. Screening of OMW

A woven vibrating screen with a nominal mesh size of 0.1 mm was used. The OMW for separation was poured onto the horizontal screen and the solids (OMWS) slide to the edge of the screen, while the liquid (OMWL) passes through the screen. The screen removed about 99% of total solids and the OMWS fraction had a solids content of 20.8 ± 1.5%.

2.1.2. Fermentation of OMWS

An equivalent volume of 6% brine was added to the OMWS and after foaming disappeared and the pH stabilized to around 4.4 in about 14 days, the fermentation was complete. The excess brine was then washed off. The obtained paste was used to make an "olive paste spread" product after mixing with olive oil, vinegar, peppers and herbs in different proportions.

2.1.3. Drying of OMWS

In a previous work, a new method of OMW drying was developed based on the use of relatively low air temperatures (Goula and Adamopoulos, 2013). A pilot-scale spray dryer (Buchi, B-191, Buchi Laboratoriums-Technik, Flawil, Switzerland) with cocurrent regime and a two-fluid nozzle atomizer was used for the spray-drying process. The modification made on the original design consisted of connection of the spray dryer inlet air intake nipple with an air drying unit by a flexible plastic air duct.

The controlled parameters were the humidity of drying air (0 g/kg dry air for dehumidified air and 1.5 g/kg dry air for atmospheric air), the type of the used drying aid (skim milk powder, 10 DE and 24 DE maltodextrin), the ratio (OMWS solids)/(drying aid solids)

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