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An integrated process for utilization of pomegranate wastes — Seeds

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ABSTRACT

In this work, a new method for pomegranate seeds application was developed based on the ultrasound-assisted extraction of seed oil and its subsequent encapsulation by spray drying. Extraction temperature, solvent/solid ratio, amplitude level, and pulse duration/pulse interval ratio were the factors investigated with respect to extraction yield. Ultrasound was sound to increase extraction yield, but mainly to shorten the treatment time by over 12 times. Different materials were used as encapsulating agents. Ratio of core to wall material, inlet air temperature, drying air flow rate, and feed solids concentration were the factors investigated with respect to encapsulation efficiency. The resulting microcapsules were evaluated in terms of moisture content, bulk density, and rehydration ability. The optimum operating conditions were found to be: wall material, maltodextrin/Tween 80; ratio of core to wall material, 0.23; inlet air temperature, 150 °C; drying air flow rate, 22.8 m^3/h; feed solids concentration, 30% (w/w).

Industrial relevance: Pomegranate seeds, a by-product of pomegranate juice and concentrate industries, present a wide range of pharmaceutical and nutraceutical properties. Therefore, the seeds could have more beneficial applications in food industries instead of being used as animal feed or in commercial cosmetic products. In this work, a new method for pomegranate seeds application was developed based on the ultrasound-assisted extraction of seed oil and its subsequent encapsulation by spray drying.

1. Introduction

Food processing wastes have long been considered as a matter of treatment, minimization, and prevention due to the environmental effects induced by their disposal. Nowadays, food wastes account as a source of valuable nutraceuticals (Schieber, Stintzing, & Carle, 2001; Sonja, Canadanovic-Brunet, & Cetkovic, 2009). The renaissance of nutraceuticals from agricultural by-products is realized due to the existence of methodologies, which allow not only the recovery, but also their reutilization inside foods. Production is principally conducted in 5 steps: macroscopic pretreatment, macro- and micro-molecules separation, extraction, purification, and nutraceuticals formation (Galanakis, 2012). Thereby, classic processing technologies and specific methodologies have been developed to meet the goals of each recapture step (Galanakis, 2013).

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits that contain the highest concentration of total polyphenols in comparison with other fruits studied (Fazaeli, Yousefi, & Emam-Djomeh, 2013). Pomegranates are rich in aril, the percentage of which ranges from 50 to 70% of total fruit and comprises of 78% juice and 22% seeds (Mohagheghi, Rezaei, Labbafi, & Mousavi, 2011). According to Eikani, Golmohammad, and Homami (2012), pomegranate seeds show average contents of about 37–143 g/kg of fruit. Oil content of seeds varies from 12 to 20% of the seed on a dry weight basis (Al-Maiman & Ahmad, 2002). Pomegranate seed oil was reported to present biological properties (Eikani et al., 2012), such as antioxidant and eicosanoid enzyme inhibition properties (Qu, Pan, & Ma, 2010), immune function and lipid metabolism (Yamasaki et al., 2006), estrogene content (Tong, Kasuga, & Khoo, 2006), skin photoaging inhibition effect (Park et al., 2010), lipoperoxidation and activity of antioxidant enzymes (Melo, Carvalho, Silva, & ManciniFilho, 2010), toxicological evaluation (Meerts et al., 2009), and protective effect against gentamicin induced nephrotoxicity (Asadpour, Boroushaki, & Sadeghnia, 2010).

Therefore, due to the above-mentioned pharmaceutical and nutraceutical properties of pomegranate seed oil and also due to the large annual production of pomegranate seeds as a by-product of the juice and concentrate industries, the seeds could have more beneficial applications in food industries instead of being used as animal feed or in commercial cosmetic products. One way to utilize the seeds is to extract the oil and use it in various food products.

Pomegranate seed oil can be extracted with various solvents and extraction methods (Abbasi, Rezaei, Emamdjomeh, & Mousavi, 2008;

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Abbasi, Rezaei, & Rashidi, 2008; Eikani et al., 2012). Shortcomings of existing extraction technologies, like increase consumption of energy, high rejection of CO_2 and more consumption of harmful chemicals, have forced the food and chemical industries to find new separation "green" techniques which typically use less solvent and energy, such as ultrasound extraction (Chemat, Huma, & Khan, 2011). Extraction enhancement by ultrasound has been attributed to the propagation of ultrasound pressure waves and resulting cavitation forces, where bubbles can explosively collapse and generate localized pressure causing plant tissue rupture and improving the release of intracellular substances into the solvent (Knorr, Ade-Omowaye, & Heinz, 2002). According to Vilkhu, Mawson, Simins, and Bates (2008), the implosion of cavitation bubbles generates macro-turbulence, high-velocity interparticle collisions, and perturbation in micro-porous particles of the biomass, which accelerates the eddy diffusion and internal diffusion. Moreover, the cavitation near the liquid–solid interface sends a fast moving stream of liquid through the cavity at the surface, whereas cavitation on the product surface causes impingement by micro-jets that result in surface peeling, erosion, and particle breakdown.

Ultrasound has been recognized for potential application in the extraction of herbals and oils (carnosic acid, ginseng saponins, carvone, limonene, antraquinones, amaranth oil, gingerols, soybeans oil, almond oil, apricot oil), proteins (soy protein), and bioactive compounds from plant (polyphenols, anthocyanins, tartaric acid, aroma compounds, polysaccharides and functional compounds) or animal (chitin, lutein) materials (Vilkhu et al., 2008). Abbasi, Rezaei, and Rashidi (2008) and Goula (2013) extracted oil from pomegranate seeds applying ultrasonic irradiation. However, the effects of processing factors on the yield of ultrasound-assisted extraction have been studied only for substrates consisting of particles having a single dimension (Goula, 2013) or for indirect ultrasound extraction (Tian, Xu, Zheng, & Lo, 2013).

Pomegranate seed oil, like most edible oils, is chemically unstable and susceptible to oxidative deterioration, especially when exposed to oxygen, light, moisture, and temperature. That oxidative degradation may result in a loss of nutritional quality and a development of undesired flavors, affecting shelf stability and sensory properties of the oil (Calvo, Hernandez, Lozano, & Gonzalez-Gomez, 2010). In the food processing field, microencapsulation techniques have been widely used to protect food ingredients (i.e. flavors, essential oils, lipids, oleoresins, and colorants) against deterioration, volatile losses or interaction with other ingredients. Microencapsulation is the process by which the sensitive ingredients are packed within a coating or wall material. The wall material protects the sensitive ingredient (core) against adverse reaction, prevents the loss of volatile ingredient, and controls release of the ingredient (Loksuwan, 2007).

Microencapsulation can be accomplished by different techniques. However, spray drying remains the dominant method for microencapsulation, due to low cost and readily available equipment (Reineccius, 2004; Shu, Yu, Zhao, & Liu, 2006). Different encapsulating materials are used to enclose different core materials. Every encapsulation material has different encapsulating properties and release characteristics of the core materials. Hence, the selection of encapsulation materials for each core product is an important step in the successful encapsulation process (Kim, Morr, & Schenz, 1996). In a previous work (Goula & Adamopoulos, 2012), pomegranate seed oil, obtained by the conventional extraction method of normal stirring, was encapsulated by spray drying with dehumidified air using skimmed milk powder as wall material. However, there is lack of publication regarding encapsulation of pomegranate seed oil using other encapsulating agents.

Thus, the objective of this work is to optimize a new method for pomegranate seed application in food industries based on the ultrasound-assisted extraction of seed oil and its subsequent encapsulation by spray drying using different wall materials. The effects of various parameters on extraction yield and kinetics, on encapsulation efficiency/yield and on the main physical properties of the microcapsules (moisture content, bulk density, solubility) were studied.

2. Materials and methods

2.1. Materials

Fresh, good quality pomegranates (Wonderful variety) procured from the local market were used. Pomegranate seeds were separated from the juice and washed carefully to remove sugars and other adhering materials. The seeds were dried at 60 °C for 48 h and kept at −30 °C until use. The seeds were ground in a laboratory mill (Type A10, Janke and Kunkel, IKA Labortechnik, Germany) immediately prior to extraction. The particle size distribution of the milled seeds shows a bimodal distribution (Fig. 1), due to the two main anatomical parts (germ, seed coat) of the seeds. The small size (~0.32 mm) may be associated with seed coats, whereas the size of about 0.58 mm could be attributed to aggregated germ particles.

2.2. Process for pomegranate seeds utilization

Fig. 2 presents the proposed integrated process for pomegranate seed application in food industries.

2.3. Ultrasound extraction

A 130 W, 20 kHz VCX-130 Sonics and Materials (Danbury, CT, USA) sonicator equipped with a Ti–Al–V probe (13 mm) was used for ultrasound-assisted extraction in pulsed mode. A sample of pomegranate seeds was mixed with 100 mL hexane to produce different hexane/seed ratios. During the extraction process, the sample container was held in a thermostat-controlled water bath.

The extracts were collected at 2, 5, 10, 20, 30, and 40 min. The resulting extracts were evaporated using a rotary evaporator (Rotovapor R114, Waterbath B480, Büchi, Flawil, Switzerland) and then were dried until a constant weight was reached. The extracted oil was weighed and recorded as kinetic extraction data at that time. The results were the mean of two replications. Extraction yield, Y, (wt.%) was defined as the percent ratio of the total weight of oil extracted to the sample weight.

The variation of extraction yield during the extraction process was studied with various (i) extraction temperatures (T) (20 °C, 65 °C), (ii) hexane/seed ratios (LS) (8/1, 20/1), (iii) amplitude levels (A) (30%, 60%), and (iv) pulse duration/pulse interval ratios (DI) (3/4, 2/1). The Plackett–Burman design was used to screen for significant factors. Twelve experimental runs were carried out and each independent variable was tested at high and low levels.

The solid–liquid extraction process can be considered as the reverse of an adsorption operation, therefore the second-order law was applied

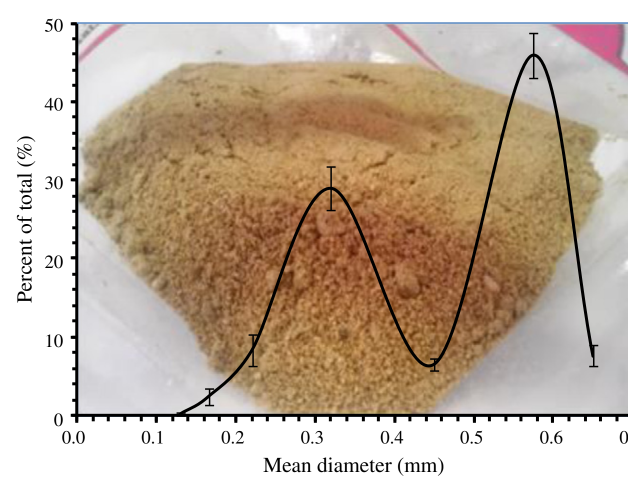

Fig. 1. Particle size distribution of milled pomegranate seeds.