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Olive oil pilot-production assisted by pulsed electric field: Impact on extraction yield, chemical parameters and sensory properties

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ABSTRACT

The impact of the use of pulsed electric field (PEF) technology on Arroniz olive oil production in terms of extraction yield and chemical and sensory quality has been studied at pilot scale in an industrial oil mill. The application of a PEF treatment (2 kV/cm; 11.25 kJ/kg) to the olive paste significantly increased the extraction yield by 13.3%, with respect to a control. Furthermore, olive oil obtained by PEF showed total phenolic content, total phytosterols and total tocopherols significantly higher than control (11.5%, 9.9% and 15.0%, respectively). The use of PEF had no negative effects on general chemical and sensory characteristics of the olive oil, maintaining the highest quality according to EU legal standards (EVOO; extra virgin olive oil). Therefore, PEF could be an appropriate technology to improve olive oil yield and produce EVOO enriched in human-health-related compounds, such as polyphenols, phytosterols and tocopherols.

1. Introduction

Virgin olive oil (VOO), especially extra virgin olive oil (EVOO), constitutes one of the most appreciated and consumed vegetable oils worldwide because of its renowned organoleptic properties. Furthermore, due to the significant content in bioactive compounds, such as phenols, phytosterols or tocopherols, its regular consumption improves antioxidant status and blood lipid profile, reducing the incidence of some degenerative diseases such as atherosclerosis or cancer (Cicerale, Conlan, Sinclair, & Keast, 2009; Kritchevsky & Chen, 2005; Lozano-Sánchez, Segura-Carretero, & Fernández-Gutiérrez, 2010; Normén et al., 2001; Perona, Cabello-Moruno, & Ruiz-Gutiérrez, 2006).

In order to assure maximum quality, VOO and EVOO are only obtained using mechanical methods (Regulation EC 1513/2001). Industrial extraction of this kind of premium oil essentially involves (1) the crushing of fruit to break plant tissues and allow oil release, (2) the malaxation of the olive paste to induce the oil drops coalescence (typically < 27 °C, <1 h), and lastly (3) the mechanical recovery of the oil by centrifugation (continuous mode) or pressing (discontinuous mode). The olive oil obtained is usually filtered or decanted to remove any possible solid residues prior to bottling.

One of the most important industrial handicaps of VOO and EVOO production is the low efficiency of current extraction techniques. Typically only 80% of the oil present in the fruit is easily released (Aguilera, Beltrán, Sánchez-Villasclaras, Uceda, & Jiménez, 2010; Clodoveo & Hbaieb, 2013). The rest remains inside cells or is emulsified with water, linked to different factors such as olive variety or extraction conditions (Aguilera et al., 2010; Espínola, Moya, Fernández, & Castro, 2009; Moya et al., 2010).

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Furthermore, associated with these phenomena, an important amount of the bioactive compounds, such as polyphenols, phytosterols and tocopherols, still remains in the olive paste (Aliakbarian, Casazza, & Perego, 2011; Dermeche, Nadour, Larroche, Moulti-Mati, & Michaud, 2013). Nowadays, the most used solution in oil mills for improve extraction is increasing malaxation time or/and temperature. However, these practices have an important negative effect on the sensorial parameters, so their use is limited to olive oils of low quality (Anegrosa, Mostallino, Basti, & Vito, 2001). For that reason, an important research effort is being devoted to find innovative mild techniques to enhance VOO and EVOO production. The proposed techniques can be divided into in two groups: (1) the addition of chemicals or biochemicals to the olive paste, such as enzymes to degrade cell membranes or chemical coadjutants to avoid oil/water emulsions (e.g. calcium carbonate, natural talc), and (2) the treatment of the olive paste by physical technologies such as microwaves or ultrasound basically to break the cell envelopes (Chiacchierini, Mele, Restuccia, & Vinci, 2007; Clodoveo & Hbaieb, 2013; Espínola et al., 2009; Hadj-Taieb et al., 2012; Jiménez, Beltrán, & Uceda, 2007; Moya et al., 2010; Ranalli, Gomes, Delcuratolo, Contento, & Lucera, 2003).

The application of pulsed electric field (PEF) is an emerging physical technology that has been proposed for improving mass transfer processes in the food industry (Puértolas, Luengo, Álvarez, & Raso, 2012). The method is based on the formation of pores in cell membranes due to their exposure to low-moderate external electric fields of adequate strength (<10 kV/cm) and duration (microseconds). This electroporation mechanism increases the permeability of the vegetable cells, enhancing the diffusion of solutes through their membranes (Vorobiev & Lebovka, 2011). Published data relating to the use of PEF for assisting olive oil extraction are promising. Guderjan, Töpfl, Angersbach, and Knorr (2005) demonstrated firstly at laboratorial preliminary tests, the potential of PEF for increasing oil extraction yield from fresh olives (up to 7.4%). Although these authors did not study the PEF effect on olive oil bioactive compounds recovery, they published improvements on concentration of tocopherols, phytosterols and polyphenols in other vegetable oils, such as maize germ or rapeseed oils (Guderjan, Elez-Martínez, & Knorr, 2007; Guderjan et al., 2005). Recently, Abenoza et al. (2013) remarked upon the benefits of PEF on olive oil extraction yield and also studied its impact on product quality, using a laboratory-scale olive oil extraction system. However, in order to implement PEF technology in olive oil mills, it is necessary to hold pilot scale extraction studies to confirm the good results obtained in the laboratory.

The main objective of the present study was to demonstrate at pilot scale in an industrial oil mill, the potential benefits of PEF technology in high quality olive oil production (VOO/EVOO), both to increase the extraction yield and to enhance the content of bioactive substances. In order to achieve this objective, a pilot production using a full continuous PEF-assisted extraction system was accomplished at a small olive oil producer. The effect of PEF treatment on olive oil extraction yield, general quality parameters, polyphenol content, tocopherol and phytosterol profiles, and sensory attributes was determined.

2. Materials and methods

2.1. Plant material

Olive fruits (*Olea europaea L.*) from Arroniz variety were harvested during 2012 season in a controlled non-irrigated orchard sited in Moreda de Álava (Basque Country, Spain). Arroniz fruits, one of the most popular olive cultivars in Navarra and Basque Country Spanish Regions, were harvested by hand (rakes) in December at the industrial optimum ripening state under the International Olive Council recommendations (2007) based on the black skin colour. Harvested fruits were transported the same day to the olive oil mill "Trujal Comperativo la Equidad" sited in Moreda de Álava (Spain) and subsequently, were washed, cleaned of leaves, weighed and, finally, processed.

2.2. Pilot PEF-assisted extraction system for olive oil production

Pilot PEF-assisted extraction system was arranged to accomplish olive oil production. This one comprised two units: (1) a commercial olive oil extraction plant (up to 800 kg/h; K30, Oleomio, Granada, Spain), including knives crusher, a batch malaxation container and a horizontal 2-phase centrifuge; and (2) a pilot PEF-system (KEA-smart, KEA-TEC, Waghäusel, Germany). This device is based on a 3-kW generator that produces monopolar exponential-decay electric pulses of 0.3 ms at a maximum peak voltage of 10 kV. KEA-smart is completed by parallel-plate in-line treatment chamber (tube) with a 3-cm gap between the electrodes.

2.3. Olive oil extraction conditions

Once olives had been mechanically crushed (3000 rpm; 3 mm sieve), the obtained paste was malaxated at 24 °C for 60 min in a stainless-steel horizontal container equipped with a helical mixing device (10 rpm) and a double jacket heating system. Following the malaxation step, olive paste was continuously pumped at 520 kg/h using a progressive cavity pump (included in the Oleomio system) firstly to the inline PEF treatment chamber and, subsequently, to the horizontal centrifuge (3200 rpm). In this step, olive oil was physically separated from the olive pomace and then was stored in stainless steel containers. After a natural decantation process to remove water waste and solid impurities (2 months, room temperature), final oils were bottled and, subsequently, analysed.

In order to obtain PEF-assisted olive oil production (PEF oil), pulsed electric fields of 2 kV/cm and 65 J were applied to the olive paste at a frequency of 25 Hz. At the flow rate used in the experiments (520 kg/h), this treatment corresponded to a specific energy of 11.25 kJ/kg. The olive paste temperature at the inlet and outlet of the PEF treatment chamber was controlled by KEA-smart system internal probes (thermocouples). The initial temperature of the mass was around 24 °C and the temperature rise due to the PEF treatment did not exceed 3 °C.

Control olive oil production (Control oil) was also obtained to make comparisons. In this case, olive paste was passed through the inline PEF treatment chamber, but without applying any electric field. Thus, any possible interference of the treatment chamber was avoided and same processing times between malaxation and centrifugation were used.

2.4. Determination of olive oil extraction yield

Olive oil extraction yield was calculated taking into account the flow rate of the olive paste (kg/h), the production time (h) and the final olive oil recovered after natural decantation (kg). The extraction yield was expressed in kg oil/100 kg of olive paste.

2.5. Chemical analysis of oil quality

General chemical parameters, free acidity (% of oleic acid), peroxide value (meq O_2/kg), K_{270} and $K_{232,}$ were determined according to the analytical methods described in the Regulation 2568/1991 of the European Union Commission and later modifications.

The total phenolic content was obtained by triple extraction of a solution of oil in hexane with methanol/water mixture (60:40). Folin–Ciocalteau reagent and sodium molybdate were added to a suitable aliquot of the combined extracts. Absorbance of the