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Optimization of pistachio oil extraction regarding processing parameters of screw and hydraulic presses

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ABSTRACT

Optimization of pistachio oil extraction with hydraulic and screw presses regarding yield, physicochemical and sensory analysis of obtained oils was developed. In addition, pistachio defatted flour was also analysed. In the hydraulic press extraction, no differences were found regarding yield and physicochemical characteristics in oils. However, sensory analysis suggested extraction using roasted pistachios (100 °C/30 min). In the screw press differences were found in yield and sensory attributes. Oil extraction with lower rotational speed (17 rpm) resulted in higher yields and the oil was more valued by consumers. Pistachio flour obtained with the two presses presented differences in moisture, fibre, nitrogen, protein and ash content. The lack of influence of extraction parameters in physicochemical characteristics of oil suggested to change the focus to yields and sensory evaluation of oils. Pistachio flour as a by-product had elevated protein content.

1. Introduction

The pistachio (*Pistacia vera*) is a tree native of the Middle East that has become a popular crop in arid areas of the Mediterranean basin and the United States due to its tolerance to hot and dry conditions. The annual growth rate of the harvested area has increased 2.15% per year and the production up to 5.70% yearly in a period of twenty years (1994–2014) (FAOSTAT, 2016). As a result, its global production has increased from less than 40,000 Mt in 1993 to exceed for the first time 100,000 Mt in 2012 (FAOSTAT, 2016).

Pistachio contains about 50% of oil (Tsantili et al., 2010) with some variations depending on the cultivar. It is a healthy oil according to the fatty acids profile with predominance of unsaturated fatty acids, mainly oleic acid, linoleic acid, and to a lesser extent linolenic acid (Arena, Campisi, Fallico, & Maccarone, 2007; Sena-Moreno et al., 2015; Tsantili et al., 2010). In addition, pistachios present high contents of phytosterols and phenolic compounds (Tomaino et al., 2010) with many health benefits according to their antioxidant properties (Gentile et al., 2007). Phytosterols have been proposed as blood cholesterol reducing agents and have been associated to a decrease in the risk of several types of cancer (Awad & Fink, 2000; Ostlund, 2004). Due to the higher content of unsaturated fatty acids and the presence of important quality micronutrients, it is important to control the extraction process to obtain high-quality pistachio oil.

Pistachio oil extraction can be done using different methods that result in different yields and pistachio oil qualities. Solvent extraction provides the highest yields but the obtained oils present lower quality due to the appearance of undesirable flavours and odours and the inactivation or disappearance of vitamins and other bioactive substances (Abdolshahi et al., 2015; Miraliakbari & Shahidi, 2009; Satil, Azcan, & Baser, 2003). In recent years, the use of supercritical fluids has emerged as an alternative to solvent extraction (Jokić, Vidović, & Aladić, 2014; Palazoglu & Balaban, 1998; Sheibani & Ghaziaskar, 2008). The use of pressurized CO_2 allows obtaining high quality oils due to the extraction at lower temperatures (Abbasi, Rezaei, & Rashidi, 2008; Chan & Ismail, 2009). However, oil quality and yield need to be balanced as the reduction of temperature, pressure, and CO_2 mass flow rate influence the extraction yield of oil (Jokić et al., 2012). High production costs are the main constraint of this method, limiting its use to high valued products.

Pressure systems allow obtaining high quality oils at an affordable price. Presses produce a pleasant product that may be directly consumed and that conserve all the health benefits associated to pistachios consumption (Álvarez-Orti, Quintanilla, Sena, Alvarruiz & Pardo, 2012). Presses enable the obtainment of high quality oils with yields that allow a viable production of pistachio

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oil.

Pistachio roasting is a primary step in pistachio oil extraction that could increase consumer preference (Kashani & Valadon, 1984) due to the appearance of Maillard reaction products responsible of pleasant odours and colours. Pistachio roasting also contributes to reduce the main health risk of pistachio consumption as it reduces the aflatoxin concentrations in the nut (Yazdanpanah, Mohammadi, Abouhassani, & Cheraghali, 2005). Previous roasting is only advisable when using the hydraulic press, as the use of the screw press itself provides pistachio oil with similar properties to those obtained with pistachio roasting (Sena-Moreno et al., 2015).

After pistachio oil extraction, a solid by-product remains. By grinding, it becomes pistachio defatted flour, a highly valuable product that can be used in human nutrition, or with other purposes such as animal nutrition or as a nutritional supplement in mushroom cultivation (Pardo-Giménez et al., 2016).

The main objective of this study was to compare and optimize pressure extraction conditions using a screw press and a hydraulic press, in order to obtain high quality oils from the physical-chemical and sensory points of view. In addition, the changes in the defatted flours originated in the process were evaluated.

2. Materials and methods

2.1. Sampling

Pistachios from Kerman cultivar (*Pistacia vera* L. var. *Kerman*) were provided by the Centro de Mejora Agraria El Chaparrillo (Ciudad Real, Spain). Pistachios were shelled in controlled conditions before immediate drying at room temperature for three days. Dried pistachios were vacuum packed and refrigerated until processing.

2.2. Pistachio oil extraction

Oil was extracted with two different presses: hydraulic press (MECAMAQ Model DEVF 80, Vila-Sana, Lleida, Spain) and a screw press (Komet Oil Press CA59G – IBG Monforts Oekotec GmbH & Co. KG, Mönchengladbach, Germany). In the hydraulic press nine different extraction conditions were performed regarding different pressures applied and extraction times. Three different pressures (7.84 MPa, 11.77 MPa, 15.69 MPa) combined with three different extractions times (10min, 12min and 15min) were considered. In the screw press fifteen different extraction conditions were evaluated regarding different temperature and speed extractions. The influence of four different temperatures (50 °C, 75 °C, 100 °C, 150 °C) and three rotational speed conditions (17 rpm, 49 rpm and 96 rpm) were tested.

Oil extraction was performed using 200 g of pistachios for each processing condition. For the hydraulic press, the pistachios were ground and placed in the press using a filter. For the screw press, the pistachios were introduced directly into the press once the barrel was heated to ensure the correct extraction procedure. For each of the 24 extraction conditions tested, oil extraction was performed in triplicate.

After oil extraction, a centrifugation step was carried out in order to eliminate the remaining solid residues from the samples. Oil and defatted flour were stored under refrigeration conditions.

2.3. Pistachio roasting

An additional pistachio roasting step was considered for the extraction with the hydraulic press. To identify the better conditions of pistachio roasting, three temperatures (50 °C, 100 °C and 150 °C) and three roasting times (30 min, 60 min and 120 min) were considered. Roasting was performed in an oven, where pistachios were placed in a monolayer.

2.4. Physicochemical analysis of pistachio oil

Free acidity, given as % of oleic acid, was determined by titration of a solution of oil dissolved in ethanol/ether (1:1) with 0.1 mol/L potassium hydroxide ethanolic solution (EEC, 1991).

K_{270} and K_{232} extinction coefficients were calculated from absorbance of a 10 μl/ml solution of oil in cyclohexane at 270 and 232 nm, respectively, with a UV/VIS spectrophotometer Jasco V-530 (Jasco Analitica Spain, Madrid, Spain), and a path length of 1 cm (EEC, 1991).

Oxidative stability was evaluated by the rancimat method (Gutiérrez, 1989). Stability was expressed as the oxidation induction time (hours), measured with the Rancimat 743 apparatus (Metrohm Co., Basel, Switzerland). An oil sample of 3.5 g was used, warmed to 100 °C under an air flow of 10 l h^{-1}.

In order to determine fatty acids composition (%), the methyl-esters were prepared by vigorous shaking of a solution of oil in hexane (0.2 g in 3 ml) with 0.4 ml of 2 mol equi/L methanolic potassium hydroxide solution, and analysed by GC with a Hewlett-Packard (HP 6890) chromatograph equipped with a FID Detector. A fused silica column (50 m length x 0.25 mm i.d.), coated with SGL-1000 phase (0.25 μm thickness; Sugerlabor), was used. Helium was employed as a carrier gas with a flow through the column of 1 ml min^{-1}. The temperatures of the injector and detector were set at 250 °C with an oven temperature of 210 °C. An injection volume of 1 μL was used (Regulation EEC 2568/91, corresponding to AOCS method Ch 2–91).

The concentration of total polyphenols (ppm) was estimated using the Folin–Ciocalteau method (Gutfinger, 1981; Vázquez, Janer & Janer, 1973), the absorption of the solution was measured on a spectrophotometer Hewlett-Packard 8450 A UV/Vis.

Sterols (%) were determined with a Hewlett-Packard (HP 6890) gas chromatograph with a capillary column (25 m length x 0.25 mm i.d.) coated with SGL-5 (0.25 μm thickness; Sugerlabor). Working conditions were as follows: carrier gas, helium; flow through the column, 1.2 ml min^{-1}; injector temperature, 280 °C; detector temperature, 290 °C; oven temperature, 260 °C; injection volume 1 μl (Regulation EEC 2568/91, corresponding to AOCS method Ch 6–91). Apparent β-sitosterol was calculated as the sum of β-sitosterol, Δ5,23-stigmastadienol, chlerosterol, sitostanol, and Δ5,24-stigmastadienol.

Analytical tests were performed in triplicate.

2.5. Analysis of pistachio defatted flour

Main nutritional components of pistachio flour extracted with the hydraulic and the screw presses were determined. The method used to determine the water content consisted on measuring the loss of weight after oven drying at 105 °C for 72 h at least (Lau, 1982). Flour protein content was calculated by multiplying the total nitrogen content, obtained by the Kjeldahl method (FOSS, 2003), by a conversion factor of 4.38 (Miles & Chang, 1997). To determine ash content, flours were ashed at 540 °C for at least 6 h, to constant weight (Lau, 1982). Crude fat (ether extract) was estimated gravimetrically by filter bag technique after petroleum ether extraction of the dried sample in an extraction system Ankom XT10 (ANKOM, 2009). To determine the content of crude fiber, Weende technique adapted to the filter bag technique was applied. This method determines the organic residue remaining after digestion with solutions of sulfuric acid and sodium hydroxide, using an Ankom 220 Fiber Analyzer (ANKOM, 2008). Total carbohydrate content was calculated by subtracting the sum of the crude protein, total fat,