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Characterization of pistachio oils and defatted flours regarding cultivar and geographic origin

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ABSTRACT

The present study analyses pistachio oil and defatted flour obtained from twenty cultivars originating in eight different countries. To identify the cultivar effect, all pistachio varieties were grown in the same plot to control environmental and agricultural management effects on kernel chemical traits. Regarding oil, three different groups were defined according to the physicochemical parameters of interest. Cultivars in group 1 showed a higher content of linoleic fatty acid (higher than 26.4%), while cultivars in group 3 type showed a stronger presence of oleic acid (higher than 67.8%), resulting in oils that were more stable to oxidation. Cultivars with intermediate characteristics were included in group 2. Defatted flours showed significant differences in nutritional quality parameters, such as protein content (34.6–46.1%) or concentration of essential minerals, such as Fe (17.3–45.1 mg/kg) or Mg (0.13–0.18 g/100 g). Beyond the cultivar effect, the geographical origin of the cultivar was identified for the first time as a source of variability in pistachio product traits. The content of Fe in pistachio flours and the content of stigmasterol in pistachio oils are proposed as useful parameters for discrimination of cultivars attending to the place where the cultivar was originated.

1. Introduction

The pistachio (*Pistacia vera* L.) is a native tree from the Middle East (Whitehouse, 1957) that has been largely spread around the Mediterranean basin and other areas with Mediterranean type climates, such as California and Australia. This expansion has resulted in the development of different cultivars adapted to the environmental conditions of their growing area or the preferences of the local markets. All these cultivars compose a huge genetic resource of plant material that should be studied in order to identify their characteristics and make the best use of it.

The consumption of pistachio by-products has interesting commercial opportunities due to their health benefits. Pistachio consumption has been shown to be associated with a significant increase in high-density lipoprotein (HDL) (Sheridan et al., 2007) with a reduction in low-density lipoprotein (LDL) (Sari et al., 2010). It also reduces the level of triglycerides in blood (Dreher, 2012; Sauder et al., 2015), the risk of coronary heart disease (Dreher, 2012; Braschi and Naismith, 2008) and shows high antioxidant and anti-inflammatory potential (Bulló et al., 2015). Moreover, pistachio consumption does not lead to weight gain and may even improve the risk factors associated with metabolic syndrome (Wang et al., 2012).

Pistachios beneficial effects have mainly been related with the presence of five components: unsaturated fatty acids, phytosterols, dietary fibre, proteins and magnesium (Dreher, 2012). Pistachios contain adequate amounts of all of the essential amino acids (Sathe et al., 2008) and are rich in fibre (Bulló et al., 2015). Within nutritional benefits of pistachio consumption, the study of the lipid fraction is crucial. In pistachio kernels, lipids account for 50 to 62 g/100 g (Catalán et al., 2017). Pistachio fatty acid profile is mainly compound by oleic (51–81%), linolenic (8–31%) and palmitic (7–15%) fatty acids (Dyszel and Pettit, 1990; Satil et al., 2003; Tsantili et al., 2010; Catalán et al., 2017). Among interesting minor components in nut oils, previous studies reported high contents of tocopherols and phytosterols, reported as decisive for nut oil quality (Roncero et al., 2016, Maestri et al., 2015; Stuetz et al., 2017). Specifically, pistachio oil shows the higher concentration of total phytosterols compared to any other nut oil, up to 271.9 mg per 100 g oil (Kornsteiner-Krenn et al., 2013; Arena et al., 2007), with high concentrations of β-sitosterol (up to 90%) and minor concentrations of campesterol and stigmasterol (Catalán et al., 2017). However, the tocopherol content in pistachios is lower than in other nuts as almonds, with average concentrations around 350 mg/kg oil

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(Ling et al., 2016a). However, tocopherols from pistachios have been demonstrated to be rapidly accessible in the stomach, thus maximising the possibility of absorption (Mandalari et al., 2013). In addition, pistachios are the only nut that contains significant amounts of lutein and zeaxanthin (USDA, 2013). The analysis of how these and other components vary depending on the cultivar and the origin of the cultivar would provide useful information.

The analysis of chemical traits to identify the origin of food products has been largely used for products such as wine (Etiévant et al., 1988; Aires-De-Sousa, 1996) and more recently in other products such as olive oil (Tapp et al., 2003; Saitta et al., 2010), coffee (Anderson and Smith, 2002) and beans (Di Bella et al., 2016). Several studies have found differences in pistachio seeds according to their origin country by analysing the fatty acids (Dyszel and Pettit, 1990), triglycerides (Dyszel and Pettit, 1990), ultimate elements (Anderson and Smith, 2005), phytosterols (Arena et al., 2007), major coloured compounds (Bellomo and Fallico, 2007) or, more recently, phenolic compounds (Saitta et al., 2014). However, the origin country effect comprises the differences that appear depending on several secondary variables (mainly cultivar, environment and land management), so the independent effect of each one of these variables should be singly studied.

Few studies have analysed the differences attributed to the cultivar effect by using pistachio cultivars that have been grown in the same plot (Bellomo and Fallico, 2007; Tsantili et al., 2011; Rabadán et al., 2017a). When cultivars are grown in the same plot, the influence of ecological conditions (Silver et al., 1984) and management practises (Sánchez-Bel et al., 2008; Carbonell-Barrachina et al., 2015) are controlled, allowing the identification of the true cultivar effect. By analysing pistachios from different varieties grown in the same plot, it can be known which proportion of the differences related to the widely studied "origin effect" are the result of the cultivar effect.

The study of native pistachio cultivars of such countries as Tunisia (Chahed et al., 2008; Ghrab et al., 2010), Turkey (Seferoglu et al., 2006; Küçüköner and Yurt, 2003; Harmankaya et al., 2014; Saitta et al., 2014) or Iran (Kamangar and Farsam, 1977; Mahmoodabadi et al., 2012) has shown significant differences in chemical components, such as fatty acids, glycolipids, minerals or amino acids. The reported variability in pistachio cultivars within the same country has discouraged the study of common chemical traits in the native cultivars from each country. Studies developed on other nuts, such as hazelnut, show that the geographical origin of the cultivar has no influence in the fatty acids, tocopherols and sterols (Parcerisa et al., 1998). To our knowledge, no study concerning pistachio has specifically addressed this issue.

Most studies have evaluated the differences that appear in pistachio kernels depending on the origin country. By controlling the differences that can appear as a result of the environment and land management, this study analyses the differences that appear in pistachio oil and flour due to the cultivar and the geographical origin of the cultivar.

2. Materials and methods

2.1. Plant material

Pistachios were collected at an experimental orchard in the Centro de Mejora Agraria el Chaparrillo of Ciudad Real in the south of Spain. All varieties were grafted on *Pistacia terebinthus* L. and Peters and C. especial were used as pollinators. Within each genotype considered, kernels from three different trees were considered, and within each tree, kernels were collected from different parts of the tree. This sampling plan was designed to reduce the effect of the biological variability to a minimum.

The shell of the pistachios was removed in controlled conditions for immediate drying of the seeds. Pistachios were dried at room temperature until they reached a moisture content lower than 6%, avoiding the use of high temperatures that could affect kernel characteristics (Álvarez-Ortí et al., 2012; Sena-Moreno et al., 2015).

Twenty cultivars with different origins (Iran, Iraq, Syria, Israel, Cyprus, Greece, Italy and Tunisia) were evaluated. The differences in the oils and flours with respect to the geographical origin is made by grouping cultivars with the same origin. Our goal is to identify if the cultivars from one specific country have chemical differences that make oils and flours different from others with different origin. Even if they are grown on the same plot, the historical development of those cultivars in a specific environment (country) may lead to some common characteristics that made them different to others historically developed in a different country.

2.2. Oil extraction

Before oil extraction, pistachios were ground using a blender (GM200-RETSCH). Oil extraction was performed using a hydraulic press (MECAMAQ Model DEVF 80, Vila-Sana, Lleida, Spain) at pressures of 50, 100, 150 and 200 bar with increasing pressure each 5 min (20 min per sample). One kilogram of ground pistachios was placed each time on the hydraulic press. After pressing, the oil was centrifuged to remove remaining solids. Oil was stored in dark glass bottles at 5 °C to avoid degradation until analysis (Rabadán et al., 2017b).

The remaining pressing cake was ground using the blender so that pistachio flour passed a 1 mm mesh sieve.

2.3. Oil and flour analysis

2.3.1. Oil analysis

2.3.1.1. Oxidative stability. 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}.

2.3.1.2. Fatty acids. To determine fatty acid 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 N methanolic potassium hydroxide solution, and analysed by GC with a Hewlett-Packard (HP 6890) chromatograph equipped with an FID Detector. A fused silica column (50 m length × 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 rate through the column of 1 ml/min. 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).

2.3.1.3. Iodine values. Iodine values are a simple method to obtain information about the amount of unsaturation in oils. I_2V was calculated from fatty acid percentages by using the formula (Torres and Maestri, 2006):

$$I_2\,V = (\%\ \text{palmitoleic acid} * 1.001) + (\%\ \text{olei cacid} * 0.899) + (\%\ \text{linoleic acid} * 1.814)$$

2.3.1.4. Sterols. Sterols (%) were determined with a Hewlett-Packard (HP 6890) gas chromatograph with a capillary column (25 m length × 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; 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).

2.3.1.5. Tocopherols. The tocopherol content (mg/kg) in pistachio oil was analysed in accordance with the AOCS Method Ce 8–89. A solution of 0.1 g in 10 ml *n*-hexane was prepared and analysed on an Agilent