Chapter 10

Olive Oils with Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI)

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Additional information is available at the end of the chapter

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Abstract

The consumers' demand for excellence in agricultural products has led to the introduction of certification labels. Among others, the European Commission enforces two types of certification labels: protected designation of origin (PDO) and protected geographical indication (PGI) (EEC, No. 2082/92). Olive oil, as a typical high-value agricultural product, is included in PDO/PGI labeling. The latter constitutes a great motivation for a considerable range of consumers, as it is considered to be associated with high-quality olive oil. However, a misunderstanding and/or unawareness of PDO/PGI and "organic" certification labels is often observed. Limited investigations in PDO/PGI olive oils demonstrated lower occurrence and lower levels of agrochemical residues compared to conventional olive oils. Future investigations are required in this field, in order to confirm that the better cultivation and industrial processes associated with PDO/PGI certification result in lower levels of agrochemicals in the final products. Analytical and Bioanalytical Chemistry will play a vital role in the traceability of PDO/PGI olive oils and the confirmation of their geographical origin and authenticity.

Keywords: olive oil, protected geographical indication (PGI), protected designation of origin (PDO), pesticide residues, agrochemicals, traceability of olive oil, authenticity

1. Introduction

The EU quality scheme is known as PDO, PGI, and TSG, and it identifies agricultural products and foodstuffs farmed and produced to exacting specifications. This scheme was established in 1992 in order to allow producers to use the added value of their products, to protect the names of their products, to provide consumers with clear information on the product origin or specialty character linked to the region, and enables them to make more

informed purchases [1]. The implementation of the above legislative initiative, particularly enables farmers in disadvantaged areas switch to forms of integrated countryside development and improve their income due to better prices. In addition, consumers can buy quality-guaranteed products, based on origin.

2. The certification labels PDO and PGI in olive oils

In 1992, with Regulation 2081/92 [2], the European Union adopted, for the first time, the regime for the protection of geographical indications and designations of origin for agricultural products and foodstuffs. In 2006, this regulation was replaced by 510/06 [3], without any changes in scope and feasibility. In 2012, the European Commission introduced a new regulation on quality systems for agricultural products, Regulation (EU) No. 1151/2012 [4]. This regulation replaced previous ones, and concerned schemes including PDO (Protected Designation of Origin), PGI (Protected Geographical Indication), and TSG (Traditional Specialty Guaranteed), while introducing the definition of "mountain products." This regulation entered into force in December 2012 and is supplemented by the Delegated Act (EU) No. 665/2014, approved in July 2014. Regulation 1308/2013 attempts to justify the peculiarities of PDO and PGI products. According to researcher Martín, it is necessary to consider their legal nature as genuine intellectual property rights [5].

These labels were introduced in order to encourage diverse agricultural production, to protect names from misuse and imitation, and to help consumers better understand the specific character of the products.

The Protected Designation of Origin (PDO) is the European recognition (Reg. 510/06) [3] for an agricultural product or food, whose entire production cycle—from raw material to final product (processing, preparation, and packaging)—is carried out in a specific territory. Thus, PDO olive oils are produced, processed and prepared in a specific region, using the traditional regional production method. The combination of natural factors—including environmental characteristics, location, and human influence—makes the product unique. All production rules should be strictly adhered to, in order to ensure high quality and reproducibility of the characteristics of the product. In the case of Spanish Olive Oils, the term "D.O.," standing for "Denominación de Origen" (Denomination of Origin) is also used, while for French Olive Oils the term "AOC," standing for "Appellation d'origine contrôlée" (Controlled Destination of Origin) also exists.

The geographical indication is associated with at least one stage of production, preparation, or processing. For example, olives may come from another region and produced in the specified geographical location. This implies that PGI labeling provides a more flexible connection between the olive oil and the specific region, focusing on quality, reputation, and on specific characteristics attributed to the geographical origin.

It should be noted that PDO/PGI products adhere to strict production specifications during the whole processing cycle from harvesting to bottling, including among others, the methods

of cultivation, varieties of olives, and processing approaches. PDO/PGI labeling encourages agricultural production, protects regional products from misuse and imitation, and prevents consumers from being misled by providing them with information about the specific character of the products.

The specifications for PDO/PGI olive oils are dictated by the corresponding Ministerial Decisions or the Executive Regulations of the European Commission. According to these regulations, the olive-crop of a specific variety that is used for the production of PDO/PGI olive oil, exclusively emanates from PDO/PGI regions. Moreover, the processing of the olive fruit takes place within the geographical area, in classic or centrifugal olive mills, which ensure olive-oil paste temperatures of less than 30°C or even lower, during all phases of processing. Finally, particular mention is made to farming techniques in the methods of fighting entomological offences and the short transport of the olive-crop to the olive press. It should be noted that another EU certification is the "Traditional Speciality Guaranteed" (TSG) scheme, which highlights the traditional character of the oil, either in the olive oil's composition or in its production (EC) No. 509/2006 [6].

Countries of the Mediterranean basin are responsible for 98% of globally produced olive oil; it is therefore plausible that these countries have registered the largest number of PDO/PGI olive oils. Indeed, until the 27th of March 2016, according to the EC's DOOR database (Database Of Origin & Registration), Italy had registered 43 PDO/PGI olive oils, while Spain, Greece, France, and Portugal had respectively registered 31, 30, 10, and 6, respectively [7]. From the aforementioned countries, geographical regions producing PDO/PGI olive oils are localized in Greece and France in specific locations, while they are almost uniformly spread in Portugal and Italy. In Greece, the majority (about 70%) of PDO/PGI olive oils are produced in the Peloponnese and Crete. In France, all PDO olive oils are produced in the South East region (Provence, Corsica, Nimes, Nyons, and Nice). Finally, in Spain, approximately half of PDO olive oils are produced in the southern region (EC, Agriculture and Rural Development) [7].

As mentioned above, PDO and PGI labeling of olive oil is connected only to its geographical origin, and not to holistic or ecologically balanced approaches of organic farming, which avoid synthetic chemicals and genetically modified organisms. Organic olive oil complies with EC Regulation 834/07 [8]. In a recent study concerning the Andalusian olive oil industry, the adoption of PDO certifications revealed no link with the implementation of better industrial practices but, rather, with better marketing practices [9].

3. PDO/PGI labeling as a promotion factor for olive oil

Factors that influence consumer behavior may be divided into three groups [10]: (a) properties of foods; (b) individual, related factors (e.g., biological, psychological, and demographic); and (c) environmental factors (i.e., economic, cultural factors, and marketing aspects. Trust and good knowledge of the product [16, 11, 12] are important factors for consumers [13], since they reduce complexity and uncertainty when it comes to making a purchasing decision [14]. The

impact of trust and its correlation to the willingness to pay, is higher among consumers of PDO/PGI products [14, 15]. Factors which seem to play an important role with respect to the consumer's perceived health risk of the olive oil product are the possible low credibility of the media through which it is promoted, the asymmetric information on the quality of the product and the consumer's concerns about the negative impact of agricultural products on health [16]. In the aspect of trust, a study revealed that Greek consumers tend to trust personal information provided by friends and relatives much more than written information on the product's label. This leads to the considerable quantities of unpacked olive oil which are being sold in Greece [17].

Other researchers [18] found that these "official cues" are more important for consumers who live in nonproducing olive oil countries. In countries which do produce olive oil, consumers tend to select olive oil based on origin and "sensory cues." Furthermore, elements related to the origin of olive oil, are gradually becoming more important in the consumer's decision process [19]. In this respect, there is a growing segment of consumers who prefer quality food with certification of origin (PDO/PGI). Sanz and Macias [20] confirmed the strategic role of Spanish PDO olive oils. These PDOs add greater value to local production systems and so enhance the final quality and market differentiation of a specific origin olive oil. Similar results were obtained by Scarpa et al. [21], who studied the PDO label in olive oil, along with two other products (table grapes and oranges). According to these authors, the role of PDOs was stronger for olive oil compared to the other two categories. Chaniotakis et al. [22] focused on the case of own-label olive oil (PDO, PGI, BIO, etc.). This study explores the factors affecting consumers' intentions to buy an own-label olive oil. These factors include the consumers' perceived benefits, economic situation, brand loyalty, and trust. The level of income has a negative impact on both consumer attitudes and purchase intention [22].

Panico et al. [23] investigated consumer preferences in extra virgin olive oil in Italy. Results showed that information on origin, both in terms of the adoption of PDO or PGI certification and labeling of the origin, production method and organoleptic characteristics, crucially affect consumer preferences. Market segmentation shows that there are consumers who are particularly sensitive to origin and organic certification, as well as labeling clarity [23]. Yangui et al. studied the effect of personality traits on consumer preferences in extra virgin olive oil [24]. The results demonstrate that Catalan consumers have unclear knowledge regarding organic attributes as correlating to other production system alternatives (conventional and PDO). The organic attribute is not perceived as a significant quality cue, and the price is not a relevant factor to interpret this result, as organic olive oils are cheaper than PDO olive oils on average. The Catalan consumers who are looking for quality, select PDO extra virgin olive oil. In another investigation performed in Andalusia (Spain) in a sample of 439 olive oil consumers, results demonstrated that origin labeling (PDO labeling), along with the price, affected the preferences of most consumers [25].

Vlontzos and Duquenne [26] investigated the impact of subjective norms of consumer behavior in the Greek olive oil market. The study indicates that consumers are aware of, and accept paying premium prices for organic 66.4% olive oil, as well as for other 30.9% certification protocols (PDO, PGI, etc.).

Similar results were demonstrated in a study by Di Vita et al. [27], revealing that the three main factors affecting consumer preferences toward olive oil involve its area of origin, geographical designation (PDO and PGI), organic certification, and price. With regard to the price factor, consumers from traditionally nonolive oil producing countries, consider price to be an indicator of quality. Other studies indicate that Italian olive oil consumers are positively affected by PDO and BIO (Biological) labels [27, 28]. Other studies found that the PDO label was a more important factor than price [29–31]. Van der Lans et al. found [32]—also concerning olive oil—that price and color were more important than the PDO label.

Espejel et al. [33, 34], studied consumer buying intention for a PDO olive oil from Bajo, Aragon. The results show that the PDO label helps bring out feelings of satisfaction and loyalty.

Despite the fact that customers are strongly motivated to buy PDO/PGI products, many surveys [35–38] indicate that most consumers only have a vague knowledge of the definition and characteristics of PDO/PGI [29, 39, 40]. Percentages of correct understanding vary between 3% for both PDO and PGI in the Italian study by Aprile et al. [36], and 70% for PDO and 40% for PGI in the study by Likoudis et al. [40]. In this study, consumers indicated awareness of the fact that PDO/PGI certified products, including olive oil, were of better quality and safer compared with conventional ones. There is also further confusion regarding different grades of olive oil. For example, Greek consumers often falsely consider that olive oils sold in the market are all virgin [17].

4. Verification of the authenticity of PDO/PGI olive oils

Comprehensive control of PDO/PGI labeling is of vital importance for the protection of a high quality (or even high reputation) olive oil, from unfair competition with similar, but lower value, products. Thus, a verification of origin is the key parameter in establishing the authenticity of a PDO/PGI olive oil. The verification of the authenticity of a product is, however, a difficult challenge in analytical science and the valid strategy lies in the consideration of the product as a complex entity, rather than in measuring a simple property [41, 42]. It should be noted that olive oil composition may vary in soil characteristics, vegetal variety, growing conditions, climate, and/or fertilization. Systems of comparative indicators should be developed, and perhaps the most suitable word for such investigations is "discrimination" between original and fraudulent products rather than real "identification" of the geographical origin. This approach explains to a large extent the multivariate methods used very often in order to classify chemicals and physicochemical properties related to the geographical origin of olive oils [41].

Numerous approaches have been developed and proposed for the assessment of the traceability of olive oils. Classical chemical analysis, particularly determination of moisture content and peroxide index as well as quantification of volatile compounds, fatty acids, sterols, and triterpenic alcohols combined with an appropriate chemometric pattern recognition strategy [43] or neural networks [44] have been proven to be, among others, effective tools for the

recognition of the geographical origin of olive oils. However, this approach has major drawbacks such as the requirement of extensive high-skilled labor resources and the destruction of the sample, while it provides results in a lengthy turnaround time [45]. As alternatives, a wide range of instrumental methods of analysis, permitting rapid screening of olive oils under investigation have been proposed. The geographical identification of olive oils can be performed by studying their phenolic profile by means of liquid chromatography coupled to mass spectrometry and multivariate analysis tools [46]. A lower-cost photo-diode array detector can also be used for the simultaneous detection of the eluted phenolic compounds at different wavelengths and results should be submitted to chemometric techniques in order to create a chromatographic fingerprint [47]. Powerful chemometric tools include, among others, partial least squares discriminant analysis (PLS-DA) [47], linear and stepwise-linear discriminant analysis [48], and principal component analysis [49]. It should be noted that in some cases it is difficult to distinguish a high-quality, family-farmed olive oil, from a PDO extra-virgin olive oil. For instance, Antonini et al. [50] carried out a comparative investigation of several parameters including acidity, peroxide index, UV spectrum and levels of hydroxytyrosol, tyrosol, and dialdehydic forms of decarboxymethylelenolic acid linked to hydroxytyrosol and tyrosol. No statistically significant values between family-farmed and PDO olive oils were observed [50]. Another instrumental method of analysis with applications in the chemical and genetic characterization of PDO olive oils is nuclear magnetic resonance (NMR). Del Coco et al. revealed the possibility of tracing extra olive oils from the same PDO to different cultivars and, partially, to different subareas, by using ^{1}H NMR [51]. Camin et al. combined isotopic composition with ^{1}H NMR data, using multivariate statistical techniques to discriminate Italian olive oil from olive oil imported from Tunisia, with about 98.5% predictive success rate [49]. There are also several studies reporting the use of UV–visible [52, 53], near-infrared spectroscopy (NIS) [52–55] and artificial nose [56]. Due to its wide use in such investigations, the employment of NIR spectroscopy to predict the geographical origin of olive oil has been reviewed [57]. The combination of NIR and UV-visible spectroscopy, along with artificial nose, has also been reported [48].

Another possibility of the geographical characterization of olive oils is related to their metal content, such as Cu, Cr, Fe, and Ni. Distribution of trace elements in virgin olive oils varies according to their geographical origin and, therefore, a "metal content fingerprint" can be provided by appropriate statistical treatment of the levels of metals, allowing for a geographical characterization of different virgin olive oils [58–60]. The determination of metals can be carried out, using appropriate pre-treatment of an olive oil sample—mainly digestion—and detection by spectrometric techniques, such as electrothermal atomic spectrometry (ET-AAS) [60], inductively coupled plasma-optical emission spectrometry (ICP-OES) [59], and inductively coupled plasma-mass spectrometry (ICP-MS) [61]. It should be taken into account that variability of each trace element in olive oils from the same geographical area can be considerable. In such cases, the appropriate chemometric approach can lead to their accurate characterization [60].

Isotopic ratio analysis of certain elements can also be used as a geographical traceability marker. Indeed, the isotopic fractionation of C, H, and O is linked to factors such as soil,

climate, latitude, and rain and, therefore, it is associated with the geographical area of olive trees [62]. Faberi et al. developed a PDO/PGI olive oil authentication, based on the isotope ratio of C in bulk oils and in their fatty acid methyl esters [63]. Another isotopic ratio for possible olive oil authentication purposes, refers to $^{87}Sr/^{86}Sr$, which has been successfully employed as an identification parameter for foodstuffs, such as rice [64], wines [65], and coffee [66]. This ratio would be a promising tool in the case of olive oils [67]. However, such isotopic analysis is only possible via ICP-MS, whose cost is a serious drawback for this approach. Finally, biological and immunochemical techniques can also be employed for the investigation of the geographical origination of olive oil [68]. More information can be found in other chapters in this book.

5. Agrochemicals in PDO/PGI olive oils

Despite the large arsenal of investigations on the levels of agrochemicals in olive oil samples, a systematic comparative study between olive oils with and without PDO/PGI labeling is missing. Among other agrochemicals, pesticide residues are of particular interest, because they are applied to large amounts to olive groves for the control of diseases and pests, such as *Dacus oleae, Saissetia oleae*, and *Prays oleae* in olive trees. They are also utilized in order to increase the number and/or size of olives and subsequent yields. Due to their lipophilic nature, pesticides possess considerable affinity with the lipid matrix of olive oil [69–71]. Thus, a wide range of pesticides can be accumulated in olive oil [72]. In order to serve the purpose of consumer health protection, the European Union has established maximum residue limits, MRLs, of pesticides in olives [73]. Along with Codex Alimentarius [74] of the Food and Agriculture Organization, the European Commission has extended legislation, establishing MRLs for several pesticides in olive oil [75]. With the purpose of comparing the levels of pesticide residues in PDO/PGI olive oils with conventional ones, Likudis et al. analyzed 70 commercially available PDO/PGI Greek olive oil samples for 51 target pesticides [76]. In 30 samples (46% of the analyzed samples), no detectable pesticide residues were found. In the positive samples, penconazole (n = 20), α-endosulfan (n = 18), β-endosulfan (n = 16), and flufenoxuron (n = 12) possessed the highest detection rates. Seven other pesticides, namely azinphos-methyl, chlorpyrifos, endosulfan sulfate, fenthion, parathion, parathion-methyl, and quinalphos were detected in fewer samples. The number of different pesticide residues detected in the positive samples ranged from 1 to 4 [76]. The presence of these pesticide residues is in agreement with previous studies concerning olive oil samples in Greece without PDO/PGI labeling [77, 78]. However, detection rates and concentration levels of pesticide residues in PDO/PGI olive oil samples reported by Likudis et al. [76] were significantly lower compared to previous investigations in conventional and organic cultivations [77, 78]. The case of fenthion, detected in 74% of the conventional olive oil samples investigated by Amvrazi and Albanis in a concentration range between 4.6 and 767 μg kg^{-1} [78] is indicative. The same pesticide was detected only in 4% of the investigated PDO/PGI olive oils with a concentration range in the positive samples between 16.9 and 23.9 μg kg^{-1} [76]. It should be noted that some pesticide residues gave statistically significant correlation, such as α- and β-endosulfan [76, 78]. Possible explanations are their

simultaneous use or the presence of intercropping activities (olive trees with apple or orange trees, vineyards, etc.

Except for the pesticide residues, heavy metals are also of specific importance. In general, crude oils manufactured without refining, such as extra virgin olive oils, may contain concentrations of trace elements [60]. Among heavy metals, As and Pb are of primary importance due to their high toxicity. Less toxic metals, such as Cu and Fe are also undesirable due to their adverse effects on the oxidative stability of olive oils. The presence of metals in olive oils is attributed to the environmental contamination of soils and air, the use of pesticides and fertilizers, as well as contamination from metallic surfaces during extraction from olive fruits [60, 61]. For this purpose, the International Olive Council (IOC) and the European Union have established criteria for the presence of metal residues. According to IOC, the maximum levels of As, Cu, Fe, and Pb in virgin olive oil are 0.1, 0.1, 3, and 0.1 $\mu g\ g^{-1}$, respectively [79]. The maximum level of 0.1 $\mu g\ g^{-1}$ for Pb has also been established by the European Commission in Regulation (EC) No. 1881/2006 [80]. Studies concerning the presence of heavy metals in virgin olive oils have given rather controversial results. However, relevant studies showed that metals extracted from virgin olive oil, only amount to a very small portion compared to their initial concentration in the olive fruits [61, 81]. Over 90% of the metal content present in the olive fruits remained in the olive pomace and, subsequently, they are transferred in great extent to the olive pomace oil [61]. However, such a trend was evident only for Cu in a relevant study reported by Bakkali et al. [82]. This study also revealed high Pb concentrations in extra virgin oils, very close to the maximum level of 0.1 $\mu g\ g^{-1}$. Unfortunately, today, there is a shortage of research on trace metal content in PDO/PGI olive oils. Future systematic studies and PDO/PGI certifications will need to explore the effect of good manufacturing practice on quality, also including levels of heavy metals.

6. Conclusions

PDO/PGI labeling of olive oil constitutes a great motivation for a wide range of consumers, even though a misunderstanding and/or lack of knowledge concerning their meaning is observed. To a significant extent, PDO/PGI labels seem to act as a link to better marketing policies rather than better industrial practices. In some studies, PDO/PGI labeling seems to have no impact concerning their personal characteristics and opinions. Consumer attitude toward certifications needs to be further investigated. The consumer is generally willing to pay a premium in order to buy high-quality olive oil, but there is a rather substantial lack of knowledge about how this quality is expressed and what PDO/PGI and "organic" certification labels stand for. As a result of consumer misunderstanding about certification labels and the confusion surrounding the different qualities of olive oil, significant amounts of unpacked olive oil—of questionable quality—are being sold. In this respect, information should be provided by local authorities and made available to the olive oil consumer. Despite the strict production rules of PGO/PGI foodstuffs, these labels do not necessarily imply that PDO/PGI olive oils are free of pesticide residues. What is required is a "green" and ecologically balanced approach, as expressed by organic farming, which is not the case for PDO/PGI labeling. More

research may indeed confirm that the better cultivation and industrial processes associated with PDO/PGI certifications, result in lower levels of agrochemicals in the final products. The relevant investigations should not only focus on pesticide residues, but be extended to include metals (As, Pb, Cu, Fe), which also affect olive oil quality. Analytical and Bioanalytical Chemistry will continue to be vital in terms of determining the traceability of PDO/PGI olive oils and in confirming their geographical origin and authenticity. Although instrument advances have led to great success in the identification and quantification of chemical compounds with validated methods, an internationally accepted methodology for the identification of the geographical origin of olive oil samples is still missing. New analytical approaches for in situ, rapid screening of olive oil samples are also required.

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