Introduction

The questions “What is virgin olive oil quality?” or “How can quality be objectively determined?” as stated elsewhere (Psomiadou et al., 2003), seem to be rather rhetorical and their meaning may differ depending on the person who poses the question. Authenticity of an olive oil is the first priority because of the high price of the product. In the case of monovarietal oils or oils of protected denomination of origin, misbranding issues become important.

The list of methodologies and purity criteria developed over the years is long and continuously updated. When genuineness is guaranteed, commercial quality of the product is mainly characterized by sensorial features (Angerosa, 2000) and free acidity content. The maximum level of initial free acidity is rather low for edible types of the product (0–2%, expressed as oleic acid). Oxidative status that affects nutritional and sensorial value of olive oil is not considered in depth in the existing legislation. In our view the overall quality of the oil from production to consumption is strongly related to oxidative stability and its impact on the evolution of flavor, taste, color, and the content of endogenous antioxidants and other minor constituents beneficial to health. Therefore, this chapter emphasizes the factors and conditions affecting oxidative stability of virgin olive oil and the changes observed in the macro- and micro-constituents of the product from production to consumption. Changes due to enzymatic activity during storage (oxidative and hydrolytic) are also discussed. Effects of cultivar and extraction practices to the initial virgin olive oil quality characteristics are not detailed since they are covered in Chapters 4, 5, 7, 10, and 11. Commercial quality criteria of the product as defined by international legislative bodies, given in Chapter 7, are discussed only when necessary.

Extended chapters on olive oil quality can be found in relevant publications edited by Boskou (1996), Kiritsakis (1998), and Harwood and Aparicio (2000). Recent reviews on oxidative stability and related subjects of virgin olive oil were published by Velasco and Dobarganes (2002), Servili and Montedoro (2002), and Kiritsakis et al.
(2002). Spanish, Italian, and Greek literature is rich in editions on the quality of oils from local cultivars.

**Virgin Olive Oil Shelf Life**

Although “olive oil is best when fresh and wine after aging,” according to the common belief, virgin olive oil is a stable oil and its shelf life is longer in comparison to that of other edible oils. The characteristic triacylglycerol composition and the presence of antioxidants (mainly polar phenols and \( \alpha \)-tocopherol) are established key factors for the resistance of the oil to autoxidation. A series of other constituents, namely, free fatty acids, pigments, unsaturated hydrocarbons, enzymes, and trace metals are expected to affect positively or negatively, though to a lesser extent, oxidative stability. According to regulations product shelf life cannot exceed an 18-month period. However, as no specific instructions for storage conditions are given to consumers, maltreatment of the oil, even by those who traditionally use it, is common.

Virgin olive oil “keepability” can be defined as the length of time under ambient temperature within which no off-flavors are developed and quality parameters such as peroxide value and specific absorbance values are retained within accepted limits for a stated commercial category.

Prediction of food shelf life is a desirable goal in the food industry. To estimate olive oil resistance to oxidation, the Rancimat or AOM test results were found meaningful (Psomiadou et al., 2003; Hrnčíř and Fritsche, 2005). Efforts for prediction based on kinetic and/or mathematical approaches seem promising as far as they concern “the possibility of the packaged product not to reach the end of its shelf life under certain conditions” (Monteleone et al., 1998; Pagliarini et al., 2000; Goutierrez and Fernandez, 2002; Psomiadou et al., 2003; Coutelieris and Kanavouras, 2006; Kanavouras and Coutelieris, 2006). Oxidative Stability Index (OSI) values are reported to correlate with results produced by fast-ultrasound assisted method for the determination of the oxidative stability of virgin olive oil (Canizares-Macias et al., 2004). With this new technique the determination time is reduced many folds.

Olive oil shelf life depends on the material of the container used (De Leonardis and Macciola, 1998). Stainless steel tanks, tinplate metal vessels, and glass containers protect the oil from oxygen and light. Polymers with special characteristics such as polyethyleneterephthalate coated with high barrier resin or with high barrier resin including “oxygen scavenger” has been recently suggested as a promising alternative to traditional glass, though mechanical compatibility remains to be tested (Cambacorta et al., 2004).

Storage of oils under nitrogen can extend shelf life as shown by Di Giovacchino and coworkers (2002). The importance of introduction of nitrogen to an olive oil production line has often been stressed (Garcia et al., 2001).
Storage in the Dark

Examination of the real keepability of virgin olive oil is now gaining popularity in contrast to studies based on accelerated oxidation that prevailed in the 1980’s. Trials carried out at room temperature (25-30°C or lower) for samples stored in open or closed vials indicated a wide range of shelf life periods that are related to the combined effect of minor and major constituents.

Changes in the Lipid Substrate

Recent revision of EC legislation (EC, 2003) concerning olive oil characteristics reduced further initial values for free acidity of edible types of virgin olive oil. If an oil sample does not meet the limits set for free acidity, then, it is examined for its conformity to other quality parameters. Free acidity increases with time in both filtered and unfiltered oils (Brenes et al., 2001). However, acidity is not expected to contribute to an increase in oil stability as was indicated from the results of Mateos and coworkers (2003). The authors using purified olive oil as a model system, devoid of minor constituents, examined the effect of increased amounts of oleic acid (0-1%) in the absence and presence of polar phenols. The effect was not statistically significant in the presence of polar phenols.

Changes in the content of positional isomers of diacylglycerols (DGs) in storage have been proposed as a quantitative measure to assess olive oil history (Frega et al., 1993). In particular, the ratio of 1,3-DGs/1,2-DGs or the ratio of 1,2-DGs to the total amount of DGs has been proposed for such an objective (Perez-Camino et al., 2001). Recently, Spyros et al. (2004), using 31PNMR showed that the isomerization depends strongly on the rate of the TG hydrolysis, the initial free acidity of the oil and storage conditions. The authors applied their model to several olive oil samples of known and unknown storage history and found a very good agreement for a storage period of up to 12 months. Longer periods of storage cannot be predicted from this index alone, since isomerization of DGs reaches equilibrium with time.

In almost every paper cited herein on olive oil stability, there are data regarding changes in the lipid substrate during autoxidation. These changes depend on an array of factors that are not always examined. Many of the trials involved storage of oil in open vials or in petri dishes at elevated temperatures. In this way autoxidation proceeds faster and changes in minor compounds evolve in a pace and manner possibly different from that occurring under reduced oxygen atmosphere. Generally, good quality virgin olive oil resists autoxidation longer than other oils rich in mono-unsaturated fatty acids (Koski et al., 2002). More recently, investigations focused on alterations of oil under conditions, mimicking storage in tanks, retail containers or domestic use. The main drawback of such trials is that monitoring periods cover only the initial stage of the oxidation process. Oxidative changes in the oil matrix are very slow when the container is filled with oil or nitrogen has been flushed through. Slow
rates of oxidative changes have also been observed in veiled virgin olive oils (Tsimidou et al., 2005). Virgin olive oils stored in sealed bottles for 12 to 24 months at ambient temperatures did not show any alterations in peroxide and $K_{232}$ values (Brenes et al. 2001; Psomiadou and Tsimidou, 2002a) or in the percent composition of polyunsaturated fatty acids (Rastrelli et al., 2002; Morelló et al., 2004). Oils oxidized faster when the containers were opened periodically (Psomiadou and Tsimidou, 2002a) or were half empty (Rastrelli et al., 2002). The pattern of oxidation depends on the fatty acid composition of selected samples and the level of anti/pro-oxidants present. Therefore, observations and conclusions depend heavily on the experimental design. A random scheme in the selection of samples (Gomez-Alonso et al., 2005) also restricts generalizations.

Monitoring of changes in the substrate is based on two parameters: the peroxide value and absorbance at 232 nm. Changes in absorbance at 270 nm are much lower, especially in the first stage of autoxidation. Grigoriadou and Tsimidou (2006) examined whether $K_{232}$ values and other UV absorbance characteristics could replace the determination of peroxide value (PV) in routine quality control of ready to be consumed or stored virgin olive oil. For this reason PV and extinction coefficients were determined for a large number of virgin olive oil samples ($n=40$). The samples were then stored at 45°C for several weeks. Changes in the lipid matrices were monitored by periodic measurements of the same quality indices. UV spectra and derivative spectra were obtained before and during storage. Regression data showed that the PV is correlated with the $K_{232}$ value not only at time zero but also during storage. Evidence derived from the first derivative spectrum was found very useful for the evaluation of the oxidative status of the oil. These findings may be used to simplify the decision tree suggested for “the verification of consistency of a virgin olive oil sample with commercial category declared” in the EEC Regulation No 1989 (2003), which takes into account acidity measurement, PV and absorbance values ($K_{270}$, ΔK, $K_{232}$).

UV absorbance seems very useful for the collection of information about the oxidation process during storage. Peroxide value determination can, therefore, be excluded from the routine control and the use of unwanted chemicals can be avoided.

**Volatile Compounds Content and Development of Sensory Defects.** The current olive oil legislation and trade standards refer to four groups of off-flavors: musty, mustiness-humidity, winey-vinegary, and rancid. The three first groups are related to olive quality whereas the last one, rancid, develops in storage. Lampante oils are those characterized by intense defects. Such an oil is subjected to refining for further industrial use. Morales and coworkers (2005) identified the major components responsible for the negative characteristics of oils for three major European varieties. The highest sensory significance, evaluated by odor activity values, corresponded to 1-octen-3-ol for mustiness-humidity; ethyl butanoate, propanoic, and butanoic acids for musty sensory defect; acetic acid, 3-methyl butanol, and ethyl acetate for winey-vinegary; and several
saturated and unsaturated aldehydes and acids for rancid defect. The presence of acids (acetic, butanoic, hexanoic, and heptanoic) indicates a high level of oxidative alteration in the oil. Rancid flavor comes from the contribution of 2-octenal, 2-heptanal, and 2-decenal with high odor thresholds. Saturated aldehydes–hexanal, nonanal, octanal, pentanal, and heptanal–influence the final aroma. Temperatures higher than the ambient favor increase in total volatile compounds content due to an increase in the content of hexanal and trans-2-hexenal in the presence of air. This increase leads to the development of rancid flavor (Di Giovacchino et al., 2002). Kanavouras and coworkers (2004) and Coutelieris and Kanavouras (2006) determined and used evolution of hexanal over time as the main indicator of the oxidative changes that take place in the oil matrix. Gómez-Alonso et al. (2004) observed that under accelerated oxidation of purified olive oil triacylglycerols at 40-60°C, the rancidity threshold coincided with the induction period for the kinetics of 2,4-decadienal formation.

**Changes and Effect of Polar Phenols**

The crucial role of polar phenolic compounds has been well established over the years (Tsimidou, 1998; Velasco and Dobarganes, 2002; Briante et al., 2003). High correlation coefficients have been repeatedly reported between total polar phenol content (or individual phenols) and peroxide values after storage for a given period or OSI values (Tsimidou et al., 1992; Pagliarini et al. 2000; Cinquanta et al., 2001; Blekas et al., 2002; Del Carlo et al., 2004). Ninfali et al. (2001) reported such a relationship with Orac Radical Absorbance Capacity values, i.e. the antioxidant potential of the oil. Gorinstein et al. (2003) and Pellegrini et al. (2003) extended this approach using more tests. Correlations for monovarietal oils vary with year of production. Similar relationships have been reported for o-diphenol content or for individual di-phenols over the years. Despite variations in methodology, all the evidence supports the great significance of polar phenols for the oil stability (Montedoro et al., 1992; Litridou et al., 1997; Tsimidou, 1999; Hrncirik and Fritsche, 2004; Gallina-Toschi et al., 2005).

Total polar phenols change during storage due to hydrolytic and oxidative processes. Total polar phenol content reduction was found to follow changes in the lipid substrate (Psomiadou and Tsimidou, 2002a). This reduction is limited (20-30%) under reduced oxygen availability. More recent is the interest in the contribution of individual phenols to stability. Information for the evolution of phenolic compounds in storage was very valuable (Cinquanta et al., 1997; Brenes et al., 2001; Lavelli, 2002; Tsimidou et al., 2005). Although sometimes conflicting results have been reported, it seems that tyrosol and hydroxytyrosol levels are continuously enriched due to hydrolysis of bound phenols. At the same time, hydroxytyrosol, an unstable compound, is oxidized rapidly in contrast to tyrosol. Loss in bound forms of hydroxytyrosol is greater than that of tyrosol derivatives (Gómez-Alonso et al., 2005). Lignan levels are less affected by storage conditions (Morelló et al., 2004). Type and levels of individual phenols...
phenolic compounds influence antioxidant capacity of virgin olive oil differently. The positive contribution of complex aglycone forms of hydroxytyrosol is stressed by many investigators. Changes in oil taste occur to a greater or a lesser extent since, for example, hydroxytyrosol aglycones are bitter and the free phenol, hydroxytyrosol, is not. Mateos et al. (2003) found that the concentration of \( \alpha \)-diphenols influences the performance of \( \alpha \)-tocopherol. This observation is not in accordance with previous reports on the behavior of \( \alpha \)-tocopherol or \( \alpha \)-diphenols (e.g. Yanishlieva and Marinova, 1992; Blekas et al., 1995). Studies on interactions of polar phenolic compounds with \( \alpha \)-tocopherol in model systems are expected to be meaningful if the substrate used is purified olive oil (devoid of pro/antioxidants), the test compounds are added at realistic levels and experiments are carried out at ambient temperature. Such experiments are so lengthy that in most cases induction period is not reached; even after 3 month storage (45°C, open vials) purified triolein to which a low amount of caffeic acid (10 ppm) had been added did not reach induction period.

### Changes and Effect of Tocopherols, Squalene, Pigments, and Other Minor Components

For years, the possible contribution of \( \alpha \)-tocopherol, squalene (the major minor constituent of the oil) and pigments (chlorophyll derivatives and carotenoids) to the stability of the oil remained poorly understood. Many investigators (Papadopoulos et al., 1993; Blekas et al., 1995; Baldioli et al., 1996; Manzi et al., 1998; Aparicio et al., 1999; Psomiadou and Tsimidou, 2002a; Deiana et al., 2002) focused on the role of \( \alpha \)-tocopherol in the storage period. The content in tocopherols depends on many factors, cultivar being an important one. The oxidation pattern seems to be greatly influenced by the initial level of tocopherols. Deiana and coworkers (2002) reported a high correlation between \( \alpha \)-tocopherol level and conjugated dienes in storage. Handling may cause a continuous loss if oxygen supply is renewed. This was shown by Psomiadou et al. (2000) in a trial with samples stored for 24 months which were opened periodically and samples that remained in closed vials for 24 months.

In olive oil models devoid of pro/antioxidants the effect of \( \alpha \)-tocopherols was found to be antioxidant in the range of 100-1000 mg/kg. The best effect was found for the lowest levels of addition (Blekas et al., 1995). Some authors argue that \( \alpha \)-tocopherol participates in the autoxidation process after a sufficient amount of hydroperoxides is accumulated. Others (Morelló et al., 2004) infer that \( \alpha \)-tocopherol is consumed from the beginning. In all cases, \( \alpha \)-tocopherol, though not so strongly in comparison to polar phenols, correlates with oil stability and it contributes significantly to the oil resistance to oxidation. It has also been found to interact with carotenoids and squalene but the results of such interactions are strongly dependent on experimental conditions (e.g. Rastrelli et al., 2002). Both pro-oxidant and antioxidant activities have been assigned to carotenoids depending on the substrate, concentration, and presence/level of individual tocopherols. However, the low amount of
β-carotene and lutein present in virgin olive oils limits their importance in autoxidation process, which is expected to cause further reduction of their initial levels.

Psomiadou and Tsimidou (1999) assigned the weak antioxidant activity of squalene in olive oil to competitive oxidation phenomena. The authors reported on the confined role of squalene in the presence of primary antioxidants. Using HPLC methods, the same authors (2002a) monitored changes in α-tocopherols content (at 100 mg/kg oil level of addition) and squalene content (7000 mg/kg oil) and found that the decrease of the former is not in expense of the latter or vice versa. Therefore, it is not clear if tocopherols have a protective effect on squalene, as suggested by Manzi et al. (1998).

The importance of chlorophyll derivatives (mainly of pheophytin α) in the dark had really been overlooked because their role under light exposure attracted all the interest. Virgin olive oil is a natural lipid system that varies significantly in green pigment content (Mínguez-Mosquera et al., 1990; Gandul-Rojas and Mínguez-Mosquera, 1996; Psomiadou and Tsimidou, 2001). Psomiadou and Tsimidou (2002a), used the HPLC method they developed for the simultaneous elution of tocopherols and pigments (Psomiadou and Tsimidou, 1998), and found that the loss of pheophytin α in samples stored in sealed bottles for two years (ambient temperature) ranged from 50-90%. Changes in individual compounds were observed from the first stages of autoxidation. These were attributed to epimeric, pyro- and allomeric forms. Since then much discussion and work has been added as to whether the evolution of pheophytin derivatives (pyro and/or allomeric forms) can be used as indices of the oil history (production and storage conditions) (Gallardo-Guerrero et al. 2005; Anniva et al., 2006). Sterol contribution in the dark at low temperatures is negligible (Gutiérrez and Fernández, 2002) as expected.

In conclusion, it can be said that autoxidation of virgin olive oil during storage is an extremely slow process if technology delivers products with low initial peroxide/ \( K_{232} \) values and high levels of polar phenols/α-tocopherol content. Exclusion of air in bottled virgin olive oil is a prerequisite.

**Storage Under Light Exposure**

Virgin olive oil should not be exposed to light, as it contains endogenous photosensitizers at significant levels (5-40 mg pheophytin α). Pheophytin α has a higher photosensitizing effect in comparison with the respective chlorophyll (Endo et al., 1984). This effect is concentration-dependent and further enhanced by oxygen availability (Psomiadou and Tsimidou, 2002b). Changes in the lipid substrate are mainly monitored by the peroxide value measurement due to an oxidation mechanism that restricts formation of conjugated dienes. In open vessels autoxidation and photosensitized oxidation progress in parallel so that increase in \( K_{232} \) values is also expected.

Investigators have always suggested protection from light with the use of suitable containers. In spite of the suggestions, companies still prefer transparent contain-
### TABLE 6.1
**Experimental Conditions in Olive Oil Storage Studies (2000-present) Under Light Exposure**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Type of container/sample amount</th>
<th>Light exposure conditions</th>
<th>Storage period/temperature</th>
<th>Analytical characteristics determined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pagliarini et al., 2000</td>
<td>Dark glass bottles, 500 ml screw capped</td>
<td>Supermarket shelves, uncontrolled light</td>
<td>14-17 months/ uncontrolled temperature</td>
<td>PV, K&lt;sub&gt;232&lt;/sub&gt;, OSI, total carotenoids, tyrosol, hydroxytyrosol, (\alpha)-tocopherol</td>
</tr>
<tr>
<td>Psomiadou and Tsimidou, 2002b</td>
<td>transparent glass bottles, 10ml; 7% headspace</td>
<td>Fluorescence light 12100lx</td>
<td>Till Chl loss&gt;90%/ thermostated chamber, 25±1 °C</td>
<td>PV, K&lt;sub&gt;232&lt;/sub&gt;, OSI, individual chlorophylls and carotenoids TPPC**, (\alpha)-tocopherol, squalene</td>
</tr>
<tr>
<td>Okogeri and Tasioula-Margari, 2002</td>
<td>Transparent glass bottles, 100 ml, 3% headspace</td>
<td>Diffused light</td>
<td>12 months/ 6-18 °C</td>
<td>PV, K&lt;sub&gt;232&lt;/sub&gt;, TPPC, phenolic fractions, (\alpha)-tocopherol</td>
</tr>
<tr>
<td>Rastrelli et al., 2002</td>
<td>transparent glass bottles, 500ml; series a: half-empty, series b: 3% headspace</td>
<td>Diffused light</td>
<td>24 months/ room temperature</td>
<td>PV, (\alpha)-tocopherol, squalene, individual phenolic compounds, PUFA, sterols</td>
</tr>
<tr>
<td>Škevin et al., 2003</td>
<td>Open Petri dish/10g</td>
<td>UV Hanau lamp (365 nm)</td>
<td>8h/?</td>
<td>K&lt;sub&gt;232&lt;/sub&gt;, K&lt;sub&gt;270&lt;/sub&gt;, PV, ChlC, TPPC, TdiPC***</td>
</tr>
<tr>
<td>Kanavouras et al., 2004</td>
<td>Glass, PET and PVC bottles (500 ml), sealed with standard polypropylene threaded caps</td>
<td>Fluorescent light bulbs (4x 40 W),</td>
<td>12 months/15, 30, 40, °C, 60%RH</td>
<td>PV, K&lt;sub&gt;232&lt;/sub&gt;, volatiles</td>
</tr>
</tbody>
</table>

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*ChlC: total chlorophyll content; **TPPC: total polar phenol content; ***TdiPC: total o-diphenol content*
ers following general trends in marketing. The latter are expected to change soon as consumers’ preference for virgin oil grows. Consumers are aware of the nutritional benefits of the oil and appreciate that these properties are preserved better in the dark under reduced oxygen availability. Studies on photo-oxidation of virgin olive oil (Gutiérrez-Rosales et al., 1992; De Leonardis and Macciola, 1998; Rahmani and Csallany, 1998; Psomiadou and Tsimidou, 1998) or on olive oil models (Kiritsakis and Dugan, 1985; Fakourelis et al., 1987; Rahmani and Saad, 1989) were rather limited until 2000. Monitoring of oxidation was mainly based on changes of the lipid substrate. Since 2000, there have been studies on photosensitized oxidation and other factors which either included in the stability experiments light exposure or mimicked conditions at the consumer sale points. Experimental conditions used in such studies vary; and as shown in the table changes in the content of photosensitizers and quenchers are not always taken into consideration (Table 6.1).

Loss of \( \alpha \)-tocopherol is greater than that of polar phenols in closed transparent bottles. Efficiency of \( \alpha \)-tocopherol under light exposure has been attributed to quenching of singlet oxygen by a charge transfer mechanism. Pirisi et al. (1998) have reported on the photolysis kinetics of \( \alpha \)-tocopherol under sunlight and artificial light \((\lambda >290 \text{ nm})\) in virgin olive oils and triolein. Psomiadou and Tsimidou (2002b) presented for the first time data on the protective role of squalene towards \( \alpha \)-tocopherol. This was demonstrated by HPLC monitoring of the two compounds. Two possible explanations were given by the authors: 1) regeneration of tocopherols by squalene and 2) formation of stable cyclic hydroperoxides by squalene, which has been reported to trap two molecules of oxygen (Psomiadou and Tsimidou, 1999).

Carotenoids quench singlet oxygen and excited states of photosensitizers. The physical quenching mechanism is explained by their low singlet energy state and also by a light filtering effect due to extended conjugation. This activity explains why their loss was found to be negligible under storage in closed vessels compared to losses observed when oils were oxidized in open vessels (Psomiadou and Tsimidou, 2002b).

Virgin olive oil storage conditions should exclude light. Attention should be paid to outlet positions in the supermarkets and also in domestic use.

**Alterations Due to Enzymatic Activity**

The sequences of enzymatic actions that are expected to contribute to deterioration of olive oil have been outlined by Morales and Przybylski (2000). Lipase, lipoxygenase, and phenoloxidase and hydroperoxide lyase/isomerase or dehydrogenase activities have been observed during olive ripening, storage and the extraction process, mainly in the malaxation stage (Sciancalepore and Longone, 1984; Sciancalepore, 1985; Goupy et al., 1991; Angerosa et al., 1998; Morales et al., 1999; Salas and Sanchez, 1999). In this view undesirable enzymatic activity can be confined if GMP principles for virgin olive oil production are followed. Simultaneous grinding of stones and pulp has as a result the transfer of enzymes to **orujo** oil, which contribute to its deteriora-
tion in storage. (Boskou, 1996; Kiritsakis, 1998). Since desirable volatiles, responsible for the green odors are also accumulated in the same way (Olias et al., 1993; Morales et al., 1996; Aparicio and Morales, 1998; Angerosa et al., 2000; Ridolfi et al., 2002) enzymatic activity cannot be precluded in oil production line. Georgalaki and coworkers (1998) reported inconclusive information on the potential presence of proteins and oxidative enzyme (lipoxygenase and phenoloxidase) activities in virgin olive oils. The interest in olive lipoxygenase and other enzymatic activities and olive oil sensory quality is increasing (Williams et al., 2000; Briante et al., 2002).

**Microbiological Quality**

Microbiological studies on olive oil are limited and it is not clear whether or not microorganisms are involved in the improvement of the sensory attributes of the oil during the decanting process. Ciafardini and Zullo (2002a) carried out a trial during the sentimentation period, when the solid particles and microdrops of vegetation water present in the newly produced olive oil separate from the oily phase. They identified yeasts as the most prominent microbial population in the oil. The authors suggested filtration as a means to ensure top-quality extra virgin olive oil despite the serious reduction in polar phenols. The same authors (2002b) claim that microbiological glycosidases in stored olive oil could also be responsible for the loss in bitterness in addition to other hydrolytic enzymes. Hazard Analysis Critical Control Point preventive system adoption in the food business is expected to confer microbiological safety on olive oil production (Pardo et al., 2002).

**Olive Oil Quality Indices**

Many efforts are found in the literature for the establishment of indices of “authentication,” “cultivar characterization or differentiation,” “age,” or “history of oil characterization,” etc. All these efforts have tremendous limitations that should be considered before limits are proposed in legislation. Tunisian virgin olive oil exports suffered from limits set for the trilinolein content that did not consider natural variability. When such indices are designed to explain “history” of oils regarding storage conditions, the case becomes more complex. Data should be verified many times before adopted in official control. Quality control within the industry is free to apply any index that appears to protect its interests most.

In the early 1990s, the International Olive Oil Council proposed a quality index to numerically express the quality of virgin olive oil. The Global Index of Quality (I.G.Q.), a scale from 0-100, was given by a linear model based on sensory evaluation score, free acidity, specific absorbance value K\text{270}, and peroxide value. The legislative limits that have been recently revised (EC, 1991; 2003) made this model invalid because of changes in the limits set for each analytical parameter. However, the coefficient of correlation for the respective quality criteria were 0.50, 0.25, 0.125 and
0.125. Tsimidou et al. (1997) criticized this approach and stressed that commercial classification of olive oils does not always coincide with the actual stability of the oil and that sensory quality does not guarantee resistance to oxidation. Based on a multidimensional statistical analysis the authors proposed that a more complex factor expressing stability should be inserted to the equation. Such a factor could be the outcome of the co-evaluation of all parameters related with stability. Alternatively, total quality estimation could be expressed by two different indices, one for the sensory and the other for the oxidative stability of the oils. In this view, Psomiadou et al. (2003) proposed that \( \alpha \)-tocopherol content, total polar phenol content and total chlorophyll content, routinely determined, can also be considered for shelf life prediction and expiration dating.

### Consumer Preference

As shown by Monteleone and coworkers (1997), the relative importance of the sensory characteristics as a driver of overall liking for Italian extra virgin olive oil was taste/flavor>odor>appearance. Differences were not driven by sex. Males were more responsive to odor liking as a driver of overall liking than were females. Older consumers (more than 37 years) were more attracted by appearance than younger consumers.

International commerce takes into account odor/taste preference as it is exemplified by the requirements of international competitions. The Mario Solinas Quality Award is an international competition for extra virgin olive oil that was first launched in the 2000-2001 crop year. The award is devoted to the memory of the Italian pioneer scientist on sensory evaluation of olive oil. The sponsor, IOOC, classifies the oils into three groups according to the fruity attribute given by the panel that issues the sensory analysis certificate (Table 6.2).

This classification reflects consumer perception and appreciation of the fruity attribute of virgin olive oil. This view is different from current requirements of legislation. Legislative provisions are (a) no defects for extra virgin olive oil and a score ≤ 2.5 for virgin olive grades, and (b) fruity attribute score just above zero for both commercial grades. From the outcome of the last 4 year competitions it seems that Italian oils prevail in medium fruitiness whereas Greek and Spanish oil had more intense flavor. More evidence on positive and negative sensory attributes of olive oil can be found

### Table 6.2

<table>
<thead>
<tr>
<th>Mario Solinas Award Requirements for Fruity Attribute</th>
<th>Median of the fruity attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intense fruitiness</td>
<td>≥5</td>
</tr>
<tr>
<td>Medium fruitiness</td>
<td>2.5≤m&lt;5</td>
</tr>
<tr>
<td>Slight fruitiness</td>
<td>&lt;2.5</td>
</tr>
</tbody>
</table>
in published papers (Morales et al., 2000; Morales, and Tsimidou, 2000). Although color is an important quality attribute at present it has not attracted the interest of legislative bodies. Traditional consumers’ preference for greenish or yellowish hues of oils depends strongly on area of origin (Rahmani and Csallany, 1991; Ranalli, 1992). The scientific community has been working on the development of objective evaluation of olive oil color for many years (Minguez-Mosquera et al., 1991).

**Instead of an Epilogue**

Olive oil quality is a multifaceted issue that starts in the olive grove and is expected to end after digestion. Recent findings, including the discovery of an anti-inflammatory compound, oleocanthal, in newly pressed high quality extra virgin olive oils proved that olive oil quality has effects that remain even after digestion. Nature was generous with the olive tree and its products. Gods and people of the Mediterranean region adored it. Spanish, Italian, and Greek scientists struggled hard in the last century to establish it as an exceptional lipid source. The international scientific community became friendly during the last 15 years and this attitude added much to knowledge about its merits. Industry makes a lot of profit from scientific evidence and support. The ultimate consumer expects to receive the best quality product at a reasonable price throughout the year. The latter is a goal for the next few years.


1. Aging represents a great concern in developed countries because of the number of people involved and the pathologies related to it, like atherosclerosis, morbus Parkinson, Alzheimer’s disease, vascular dementia, cognitive decline, diabetes, and cancer.
2. Epidemiological studies suggest that a Mediterranean diet (which is rich in virgin olive oil) decreases the risk of cardiovascular disease.
3. The Mediterranean diet, rich in virgin olive oil, improves the major risk factors for cardiovascular disease, such as the lipoprotein profile, blood pressure, glucose metabolism, and antithrombotic profile. Endothelial function, inflammation, and oxidative stress are also positively modulated. Some of these effects are at-
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tributed to minor components of virgin olive oil. Therefore, the definition of the Mediterranean diet should include virgin olive oil.

4. Different observational studies conducted in humans show that the intake of monounsaturated fat may protect against age-related cognitive decline and Alzheimer’s disease.

5. Microconstituents from virgin olive oil are bioavailable in humans and show antioxidant properties and capacity to improve endothelial function. The anti-thrombotic properties of virgin olive oil can also help to modify hemostasis.

6. In countries where the populations follow a typical Mediterranean diet, such as Spain, Greece, and Italy, where virgin olive oil is the principal source of fat, cancer incidence rates are lower than in northern European countries.

7. The protective effect of virgin olive oil can be most important in the first decades of life. This suggests that the dietetic benefit of virgin olive oil intake should begin before puberty, and continue throughout life.

8. The Mediterranean diet, based on virgin olive oil, is compatible with a healthier aging and increased longevity.

9. However, despite the significant advances of the recent years, the final proof about the specific mechanisms and contributing role of the different components of virgin olive oil to its beneficial effects requires further investigation.

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