8

Table Olives as Sources of Bioactive Compounds

Dimitrios Boskou ■ *Aristotle University of Thessaloniki School of Chemistry, University Campus, Hellas*

Salvatore Camposeo and Maria Lisa Clodoveo ■ *Department of Agricultural and Environmental Science, University of Bari, Bari, Italy*

Introduction

Table olives are prepared from the fruit of olive tree (*Olea europaea* L.). Fresh olives are picked when green-ripe, turning color, or black-ripe, depending on the mode of processing to be used. Fresh olives are not edible because of the presence of oleuropein, a bitter glucoside. Processing of fresh olives reduces bitterness and makes them edible. Processing involves soaking in water, brine, or diluted alkali or drying by heating or salting. In general, larger-scale table olive processors may use lye treatments, which speeds up processing. Small- and very-small-scale producers favor more "natural methods." The residual bitter taste of processed table olives depends on the type and quantity of phenolic compounds present after the processing, and it is an important characteristic favored by consumers.

Table olives are a highly functional food with a balanced content of fats made up mainly of monounsaturated oleic acid. Eating olives also provides energy, fiber, vitamins, and minerals and contributes to the daily intake of nutritional antioxidants. The protein content is low (1.0–2.2%), but proteins are rich in essential amino acids. Olives constitute an essential element of the Mediterranean diet and are a featured ingredient in hundreds of dishes. They are important from a nutritional point of view for the general population in many Mediterranean countries, especially during the long periods of fasting. They are of vital importance for the Christian orthodox monks and nuns, who consume large quantities of olives. In Portugal, stoned, halved table olives, known as *alcaparra*, are largely consumed, and their production is an important agroeconomic factor for the local producers.

There are three main types of commercial table olives: Spanish-style green olives, Greek-style natural black olives, and California-style black ripe olives. In the Spanish and Californian procedures, olives are treated with a diluted aqueous NaOH solution that brings about several changes in biophenols, tocopherols, and triterpenic acids, but the composition of the triglycerides remains unaffected. After the treatment, the olives are rinsed to remove the alkali, and the fruit is then left to ferment in brine for several months. The production of naturally black olives in brine, according to the Greek traditional method and its variations, is a simple, natural process that does not use chemicals.

The major compounds present in olive fruits are anthocyanins (cyanidin and delphinidin glucosides), flavonols (mainly quercetin-3-rutinoside), flavones (luteolin and apigenin glucosides), phenolic acids (hydroxybenzoic, hydroxycinnamic, others), phenolic alcohols (tyrosol and hydroxytyrosol), secoiridoids (oleuropein, dimethyloleuropein, ligstroside, nuzhenide), and verbascoside, a hydroxycinnamic acid derivative. Table olives have a phenol composition that differs from that of olive oil and nonprocessed olives. This is due to the debittering process, which causes diffusion of phenols from the fruit to the water or brine and vice versa. When lye is used, sodium hydroxide and constituents with carboxylic and hydroxyl groups react, and the hydrophilic derivatives are washed away. Oleuropein and verbascoside are hydrolyzed to a great extent during the lye treatment. Acid hydrolysis of hydroxytyrosol, tyrosol, and luteolin glycosides takes place during the fermentation in brine when naturally black olives are prepared. Thus, the phenols reported to be present in commercial samples of table olives, depending on the method of debittering, are verbascoside, hydroxytyrosol, tyrosol, luteolin, luteolin, luteolin and apigenin 7-O-glycosides, and phenolic acids. Traditionally prepared table olives have been also reported that are rich sources of oleuropein. Other bioactive constituents in processed olives are maslinic and oleanolic acids, which are found in abundance in olive fruits. The natural process does not influence their concentration, but lower concentrations are determined in alkaline-treated olives. α-Tocopherol values reported for processed olives range between 10 and 90 mg/kg flesh. The lye step causes a reduction of α-tocopherol.

Debittering with existing technologies presents certain drawbacks such as time, discharges, and the prohibition of the product thus obtained in the trade of "ecological" olives. New procedures allow removing bitterness of the fruit through processes of oxidation of phenols. Such innovations may give answers to some problems in the table olives industry and may provide competitive advantages as long as olives and olive preparations are not evaluated as sources of natural antioxidants, because oxidation destroys the valuable phenols. In the last decades, olive products, particularly virgin olive oil and table olives, have continuously attracted interest because scientific research is providing more evidence to support the benefits of dietary choices on health. Table olives that are green, turning color, or black have not yet been fully appreciated as valuable functional foods equally important to virgin olive oil. Recent International Olive Council (IOC) reports underscore this.

Scientists are now examining methods based on targeting oleuropein hydrolysis with the use of enzymes for decomposition of oleuropein instead of traditional lye treatment. They are trying to overcome problems related to the presence of antimicrobial phenols, such as the dialdehydic form of decarboxymethyl elenolic, with an inhibitory activity of lactic acid bacteria. Storage of table oils and packaging are also important. Modification of atmosphere during storage and packaging to minimize changes in the phenolic compounds are new practices, indicating that these natural products are now seen as sources of valuable bioactive compounds and not as decorations for pizza, breads, and other products. The rich cultural practices and environment are also taken into consideration because tradition strongly influences the popularity of particular preparations. It appears that a promising and environmentally friendly approach for retaining the health compounds (initially present or formed during processing) is to combine tradition and technological innovation. This direction is clearly seen in the examples of innovation that follow:

- Table olives with a protected designation of origin (PDO) status, debittered by innovated traditional methods, low in salt, and packed under vacuum
- Fermented olives with the use of probiotic bacteria from olive's natural flora
- Traditional products based on improvement of cultivars with a sufficiently large phenol level to provide a functional value
- New table olive genotypes coming from cross-breeding programs

Popularity of Certain Preparations

There are many types of table olives available worldwide, and each growing country produces local and regional styles. Among Spanish consumers, green Sevillian-style olives are popular. In Greece, consumers prefer naturally black ripe olives in brine, salt-dried olives (thrumbes or date olives), and Greek donkey olives. In Italy, olives produced with traditional methods are popular (Castelvetrano-Sicilian-style green olives, Taggiasca-Ligurian-style black olives, Maiatica di Ferrandina-oven-dried black olives). In Portugal, olives are an integral part of the country culture, landscape cuisine, and traditions. Stoned alcaparras, fermented cracked green table olives, and black olives, such as "Galega" and "Negrinha de Freixo," are important. Olives de Nimes are produced in France. They are green ripe Picholine olives from Southern France processed in lye, similar to Spanish-style green olives. This type of olives is also produced in Morocco and Algeria from other varieties.

Antioxidant Activity and Biophenol Levels in Table Olives: Other Bioactives

Antioxidant Activity

There is a plethora of publications reporting the magnitude of antioxidant activity of table olives. Measurements are based mainly on the stable 2,2-diphenylpicrylhydrazyl DPPH radical assay. Extracts in methanol scavenge the radical, and the reduction of DPPH is monitored by the decrease of the absorbance at 515 nm. Results are usually expressed in Trolox equivalents or the quantity of phenols and the respective quantity of olive flesh needed to decrease the initial DPPH concentration by 50% (EC50). In addition, antioxidant assay by a beta-carotene and linoleate model system or the reducing ability of olive oil methanolic extracts by the ferric ion reducing antioxidant potential (FRAP) assay are determined. Trolox is used to construct a reference curve, and the results are expressed as mmol Trolox equivalents (mmol TE) per 100 g of sample.

These tests, applied also in olive oil, have certain drawbacks and are correlated differently to the total phenol content (Frankel, 2010; Gorinstein et al., 2003; Kaliora et al., 2013), but they are often used in monitoring changes of radical scavenging activity or total antioxidant status due to the progress of maturity or other factors. (Ben Othman, et al., 2008).

Total and Individual Phenol Levels

Total polyphenols are determined by the Folin-Ciocalteu's assay according to procedures developed for table olive samples (Blekas et al., 2002; Boskou, 2006; Sahan et al., 2013). Values are expressed as milligrams of caffeic or gallic acid per kilogram of flesh or equivalents of hydroxytyrosol in mg/kg dry weight. Reported levels for commercial table olives vary from 200–1700 mg/kg flesh and indicate that one of the best methods to preserve antioxidants is untreated olives in brine.

Due to hydrolysis of oleuropein, its derivatives, and other glycosides, which are the major constituents of the phenolic fraction in the fresh fruit, hydroxytyrosol, tyrosol, oleuropein aglycons, apigenin, and luteolin become the phenols present at high concentrations after processing for the preparation of table olives (Blekas et al., 2002; Boskou, 2006; Marsilio et al., 2001; Pistarino et al., 2013). Pereira et al. (2006) identified seven compounds in table olives from Portugal: hydroxytyrosol, tyrosol, 5-*O*-caffeoilquinic acid, verbascoside, luteolin 7-*O*-glucoside, rutin, and luteolin.

Blekas et al. (2002) undertook a study to evaluate table olives produced in Greece as sources of biophenols. Commercially available olives were analyzed for their total phenol content by using the Folin-Ciocalteu reagent and for individual phenols by reversed-phase chromatography–high pressure liquid chromatography RP-HPLC. Samples were Spanish-style green olives in brine, Greek-style naturally black olives in brine, Kalamata olives in brine, and dry salt debittered shrinked olives. Most of the types of olives analyzed were found to be good sources of phenols. Hydroxytyrosol, tyrosol, and luteolin were the prevailing phenols in almost all of the samples examined. High levels of hydroxytyrosol were determined mainly in Kalamata olives and Spanish-style green olives, cv. Chalkidiki (250–760 mg/kg).

High levels of hydroxytyrosol have also been reported for Greek table olives purchased from the local market in Athens (Boskou et al., 2006), especially in Tsakistes (small olive fruit, green color, in brine), Kalamon (big, black color, elongated form olive fruit, in brine), and Amfissas (big, black color olive fruit, in brine. Lower levels of total phenols and hydroxytyrosol have been reported by Marsilio et al. (2001) for California-style black olives due to oxidation catalyzed by iron salts used for fixation of color. Low values of total phenols were also reported for Castelvetrano-style green olives (Lanza, 2012).

Due to the variety and mode of debittering, some table olives may have high levels of oleuropein. Zoidou et al. (2010) identified Throuba Thassos, a traditional Greek table olive variety, as a rich source of oleuropein (concentration approximately 1.2 mg per fruit recorded over a 4-year period).

Other Functional and Nutritional Bioactives

Phytosterols

The composition of sterols in olives is similar to that of extra virgin olive oil produced from the same cultivar. Phytosterols are functional ingredients because they reduce the absorption of cholesterol in mammals; therefore, a high dietary intake might have a positive impact on health. However, the concentration in olives is too low for significant effect. It is claimed that consumption of 1.5–2.0 g/day of phytosterols is needed for a hypocholesterolemic effect (commercial hypocholesterolemic spreads have 8% sterols or stanols). Thus, a serum-cholesterol-lowering effect attributed to sterols in table olives would be of limited significance.

Triterpenic Acids

Maslinic and oleanolic acids are located in the epicarp of the fruit at a concentration of approximately 0.1% (Guinda et al., 2010). The natural process of debittering does not influence their concentration in the final product (Alexandraki et al., 2014). Lower concentrations have been determined in alkaline-treated olives. Romero et al. (2010) reported values ranging from 460 to 1470 mg/kg fruit in commercial black and green olives. Natural black olives, which are not treated with NaOH, showed a higher concentration than 2000 mg/kg in the olive flesh.

Both acids are considered to be important bioactive compounds that can confer multiple beneficial health effects to the consumer. Interest in their pharmacological potential focuses on inflammation, cancer, cardiovascular pathology, and vasorelaxation (Herrera et al., 2006; Rodriguez-Rodriguez and Ruiz-Gutierrez, 2010; Valero-Muñoz et al., 2014).

Squalene

Squalene is believed to offer positive effects on human health because it may have a chemopreventive effect in some types of cancer and it is beneficial for patients with heart disease and diabetes (see also Chapter 1).

Fiber

Table olives are an excellent source of dietary fiber (approximately 3 g per 100 g of edible portion) consisting of pectin, hemmicelluloses, cellulose, and lignin. These compounds are bioactive because they reduce the absorption of cholesterol, reduce glucose in type 2 diabetes patients, increase satiety, protect stomach mucosa, and have a laxative effect. One-hundred grams provide approximately 13% of the recommended daily allowance (Lopez et al., 2014; Lanza, 2012).

Vitamins

According to Lopez et al. (2014), α-tocopherol content is approximately 3.5 mg/100 g in the edible flesh of green Spanish-type olives; this corresponds to 25% of the daily recommended allowance for this vitamin. Other vitamins of some importance are beta-carotene (provitamin A), pantothenic acid, and vitamin B1.

Probiotic Bacteria

Table olives could be used as a vehicle for incorporating probiotic bacteria and transporting bacterial cells into the human gastrointestinal tract (Peres et al., 2012). The incorporation of health-promoting bacteria into table olives would add new functional features to table olives.

Table Olive Processing

The International Olive Council defines table olives as the fruits of the olive tree (*Olea europaea* L.) that have undergone the pertinent processes: preservation by natural fermentation or by heat treatment, with or without the addition of preservatives, and packed with or without covering liquid.

Olives are picked at different stages of maturity (Figure 8.1), and they are then processed to eliminate the characteristic bitterness caused by their oleuropein glucoside, thus making them suitable for human consumption. There are several ways to prepare table olives.

Debittering Techniques

The presence of oleuropein in fresh olives precludes the consumption of raw fruits. The binding of phenolic hydroxytyrosol to the rest of the oleuropein molecule is essential for the bitter taste of the substance. The hydrolysis of this compound produces the hydroxytyrosol and the elenolic acid nonbitter molecules.

The concentration of this secoiridoid glucoside in fruits depends on many factors such as variety, irrigation, and degree of ripening. Indeed, the level of oleuropein in olives decreases significantly with maturation. Fruits intended for Spanish green and California black olive types are harvested with a green-yellow color on the surface and possess a strong bitter taste. Mature olives, which are used for natural black olives, are black in color and less bitter.

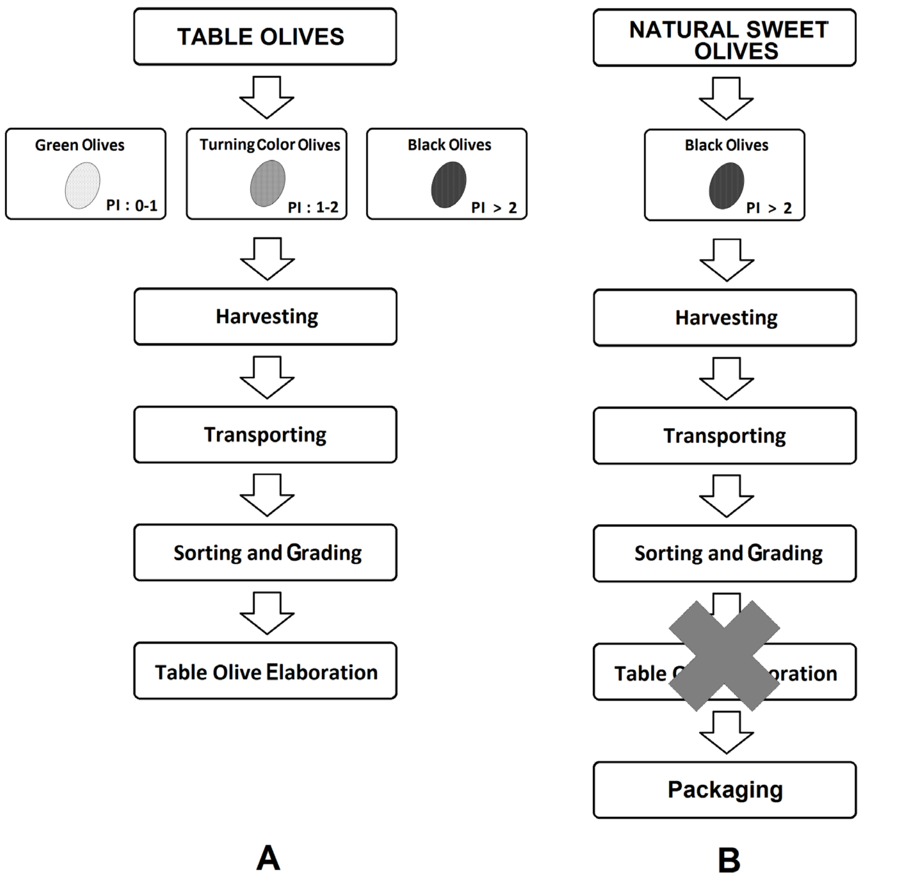


Figure 8.1 A: Table olive classification based on Pigmentation Index (Jaén Index—P.I.) and main pre-processing operation; B: Natural sweet olives.

Oleuropein can be removed by natural methods (dilution or microbial enzymes), alkali treatment, drying, or salt curing. Figure 8.2 shows the chemical and biochemical hydrolysis of oleuropein.

The biochemical method used to debitter olives is based on microbial degradation of oleuropein (Marsilio and Lanza, 1998) performed by yeasts and lactic acid bacteria naturally present in olives and the brine. A two-step process is postulated: the first step is the hydrolysis of the glycosidic linkage of the oleuropein by β-glucosidase with formation of oleuropein-aglycone, the first observable intermediate in the process; in the second step, the amount of aglycone formed is hydrolyzed to elenolic acid and

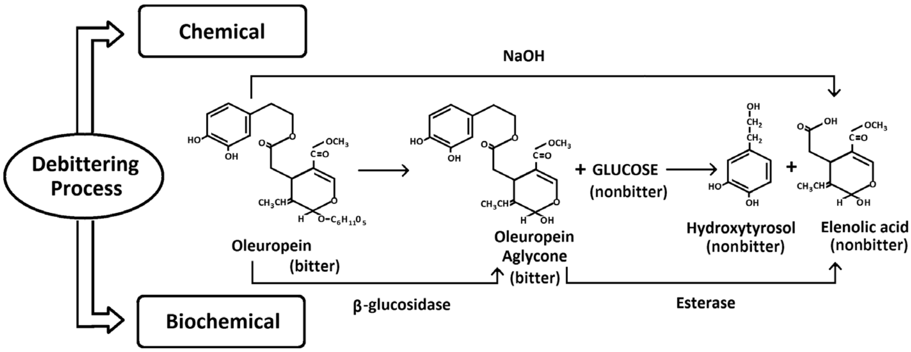


Figure 8.2 Chemical and biochemical hydrolysis of oleuropein.

hydroxytyrosol, probably by an esterase activity. The natural-style process can lead to uncontrolled and long fermentation as well as low-quality products with variable sensory characteristics. In order to standardize the quality of products by reducing the period of the debittering process and spoilage, it is possible to use selected starter cultures characterized by rapid and predominant growth; homofermentative metabolism; tolerance to salt, acid, and polyphenols; and few growth factor requirements.

Chemical hydrolysis of glycosides is performed by dipping the drupes in solutions of sodium hydroxide. The alkaline treatment does not allow the cleavage of the oleuropein moiety into its three moieties (hydroxytyrosol, glucose, and elenolic acid) but is able to cleave only the ester bond between hydroxytyrosol and elenolic acid glucoside (Brenes et al., 1995). Afterward, during the fermentation step, an acid hydrolysis of elenolic acid glucoside to glucose and elenolic acid occurs. The elenolic acid, which is comparatively unstable, tends to degrade due to the acid conditions in the surrounding solution (Brenes and de Castro, 1998). The glucose formed is used as substrate by the microorganisms present in the fermentation brines.

Elimination of bitterness by means of solubilization of the oleuropein into the processing medium is achieved when the water-curing method is applied. Cracking or cutting the olives speeds up the diffusion of the water-soluble oleuropein (Kailis and Harris, 2007). When olives are put directly in brine (natural-style olives), bitterness is lost because of the diffusion of oleuropein from the fruit to the surrounding brine and the acid hydrolysis that occurs (Gikas et al., 2006).

A method based on the enzymic oxidation of the hydroxytyrosol moiety has been patented by García Borrego et al. (2009) to debitter olives by keeping the fruits under an overpressure of oxygen. In the olives darkened by oxidation, the reaction is catalyzed by polyphenol oxidases (Figure 8.3), which comprise a large group of enzymes that are al characterized by their ability to utilize molecular oxygen during the oxida-

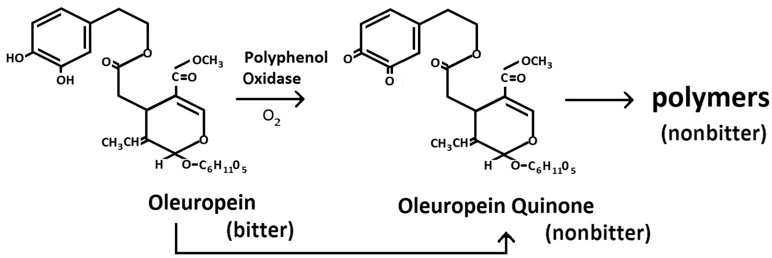


Figure 8.3 Polyphenol oxidase debittering of table olives.

tion of phenolic substrates. After the oleuropein oxidation, a rapid polymerization of o-quinones occurs, resulting in fruit browning (black, brown, or red color). The surface color obtained is not stable and fades progressively after oxidation and during the shelf life of the packed product. To prevent this deterioration, several iron salts can be added: ferrous gluconate, ferrous sulphate, and ferrous lactate.

Salt treatment is a dehydration technique that increases the shelf life of olives. The salt causes a water loss from the olives. Olives debittering is due to the diffusion of oleuropein into the generated brine and the subsequent enzymatic reactions catalyzed by polyphenol oxidases and esterases (Ramírez et al., 2013).

An alternative system to dehydrate the olives is the use of gentle heat treatment (40–50 °C). The loss of bitterness is due to the heat treatment that causes the loss of phenols as a result of both evaporation and decomposition (Hamama and Nawar, 1991). Attya et al. (2010) studied the effect of thermal oxidation of the catechol moiety of oleuropein and proposed the mechanism described in Figure 8.4.

It should be underlined that all these methods not only affect oleuropein levels but also the concentrations of other phenolics present in the finished olive products. Profiles of phenolic compounds in the end products, and consequently the nutritional value, are influenced by the olive cultivar, the pre- and postharvest factors, the debittering methods, and the processing style.

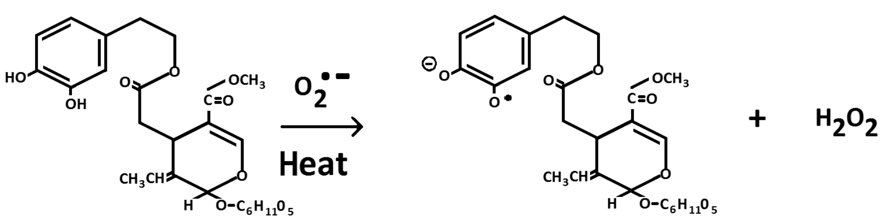


Figure 8.4 The oxidation of the catechol moiety of the oleuropein.

Table Olive Cultivars

In general, phenolic compounds vary considerably between cultivars in fruits with similar degrees of ripeness and inside the cultivar during the ripening. Genetic factors are predominant in the expression of phenolic compounds in olives; in fact, large differences exist between olive cultivars. Internationally important varieties for table olive production are listed in Table 8.A.

Table 8.A Some important varieties for table olive production, their origins in the world, fruit weight and processing types. (Part of the information reported into the table are provided by Kailis and Harris, 2007).

Variety	Countries	Fruit Weight	Processing Type	
Al-Doebli	Syria			
Arauco	Argentina			
Arbequina	Spain			
Arbosana	Spain, USA			
Ascolana tenera	Italy			
Azeradj	Algeria			
Barnea	Israel, Australia, New Zealand			
Bella di Cerignola	Italy			
California Mission	USA			
Carolea	Italy			
Carrasqueña	Portugal			
Cailletier/Niçoise Taggiasca	Nice–France, Liguira–Italy			
Conservolea	Greece			
Domat	Turkey			
Empeltre	Spain			
Galega Vulgar	Portugal			
Gemlik	Turkey			
Gordal	Spain			
Hojiblanca	Spain			Californian Style

Table 8.A *Continued*

Variety	Countries	Fruit Weight	Processing Type
Hondroelia/ Halkidiks	Greece		
Itrana	Italy		
Lucques	France		
Kalamata	Greece		
Manzanilla Cacereño	Spain		
Manzanilla de Sevilla	Spain, USA, Israel		
Memecik	Turkey		
Meski	Tunisia		
Nafplion	Greece		
Nocellara del Belice	Italy		
Oblica	Croatia		
Picholine Languedoc	France		
Picholine Marocaine	Morroco		
Redondal	Portugal		
Sigoise	Algeria		
Soury	Lebanon		
Tanche	France		
Termite di Bitetto	Italy		
Zutica	Croatia		

Medium Size: 2–4 grams
High Size: 4–6 grams
Very-High Size: greater than 6 grams
Green Table Olives
Turning Color Table Olives
Black Table Olives

Preprocessing Conditions

Only firm, unmarked olives are used for top-quality table olives. The main reason for the decreasing market values and quality of olives is damage occurring during picking, packing, transportation, and storing.

Harvesting Time

Texture and color of the processed olives are the most important factors that should determine the optimum time for harvesting. Fruits with high flesh-to-pit ratio are more desirable to the consumer. On the other hand, the fruit becomes increasingly soft as it matures. Therefore, in general, harvest time is the stage when the fruit has reached the maximum possible size with a texture that will not be unacceptably soft in the finished product.

Olives' ripening stage also strongly influences changes in their phenolic content and profile. During olive ripening, the concentration of total phenols progressively increases to a maximum level at the green-skin stage, decreasing sharply as ripening progresses (Bellicontro et al., 2012; Conde et al., 2008). With regard to the degree of ripeness and oleuropein and pigment levels, three phases are distinguishable: (1) a growth phase, when oleuropein accumulation occurs; (2) a green maturation phase that coincides with a reduction in the levels of chlorophyll and oleuropein; and (3) a black maturation phase that is characterized by the appearance of anthocyanins and flavonoids and during which the oleuropein levels continue to fall (Amiot et al., 1986; Damak et al., 2008). The disappearance of oleuropein in the fruit flesh is related to the formation of phenolic oligomers of oleuropein, probably due to the enzymic activity of the polyphenoloxidase (Amiot et al., 1989; Cardoso et al., 2005; Damak et al., 2008). The concentration of hydroxytyrosol follows a similar trend (Charoenprasert and Mitchell, 2012). In general, oleuropein concentration in olive pulp decreases during maturation (Charoenprasert and Mitchell, 2012; Damak et al., 2008). In contrast, the glucoside forms of flavonoids, luteolin-7-glucoside (Malik and Bradford, 2006), cyanidin-3-glucoside, cyanidin-3-rutinoside (Romero et al., 2002a, 2002b), and quercetin-3-rutinoside (Esti et al., 1998) are more abundant in the pulp of mature olive fruit. As maturation increases, levels of demethyloleuropein, hydroxytyrosol-4-β-D-glucoside, demethylligstroside, and oleoside-11-methyl ester increase (Bouaziz et al., 2005; Charoenprasert and Mitchell, 2012; Servili et al., 1999; Sivakumar et al., 2005)

Figure 8.1 indicates a range of pigmentation index corresponding to the right period to harvest for each table olive preparation and style. The three maturation states for raw olives are:

1. Green olives: yellow-green in color prior to pigmentation developing
2. Turning color olives: multicoloured (rose, wine-rose, or brown) or olives that have not reached complete ripeness

3. Black olives: fully ripe, or slightly before full ripeness (reddish black, violet-black, deep violet, greenish-black, or deep chestnut colored)

Pigmentation index (PI) is expressed as Jaén Index. This harvesting index assesses ripeness as a function of fruit color in both skin and pulp (Camposeo et al., 2013).

Olive Fruit Harvesting, Transport, and Storage Conditions

The ideal method for harvesting table olives is to pick the drupes from the trees by hand (Figure 8.5). Hand picking is the simplest, but most time consuming and expensive method. More often olives are harvested using bare or gloved hands and special rakes. For tall trees, long sticks or canes are used to beat the branches until all the olives have fallen into the nets below. It is also possible to use stairs or eleva-

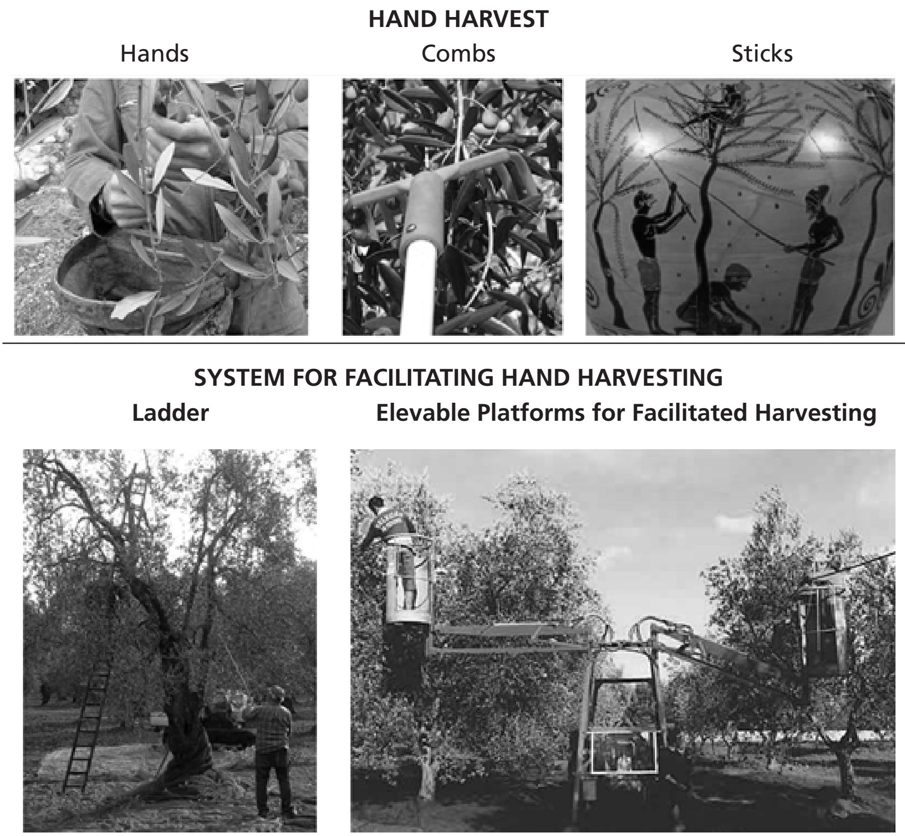


Figure 8.5 Hand harvesting systems and nets.

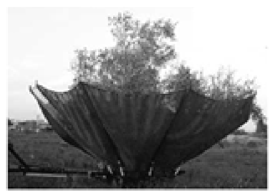
(continued)

MECHANIZED HARVESTING TOOLS

Pneumatic Harvester | Rotovibrational Harvester | Hand Held Shaker

The cost of these machines is relatively low. They have a work productivity double compared to the harvest done by hand reducing the number of workers. It is possible to use the machine independently of the type of the canopy and also when the ground is wet or very sloping or terracing.

HARVEST NETTING

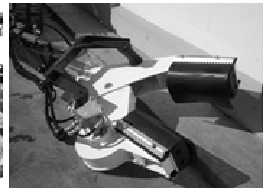


Nets are carefully spread under the trees, and the olives are stripped from the trees in a number of a ways, including by hands, with special rakes or with long sticks.

Figure 8.5 *Continued*

tors. However, expense and provision of the labor are the main difficulties in olive harvesting, and its costs are also influenced by competition between growers and producers of other commodities. Mechanical harvesting could be an economically feasible solution to long-term industry sustainability (Camposeo and Godini, 2010; Godini et al., 2011) (Figure 8.6). On the other hand, one of the main disadvantages of mechanical harvesting is the risk of fruit damage. The mechanical damage during harvesting consists of local tissue degradation combined with an output of intracellular water and the oxidation of phenolic compounds after impact (Segovia-Bravo et al., 2009). The oxidation process produces a darkening of the color first on the olive surface and, after some time, into the flesh to the endocarp. Considering the effect of harvesting method on table olive quality, in general, less bruising is encountered in hand-picked fruits. Other factors influencing deterioration are the transport conditions and the duration of storage. Olives should be transported

MECHANICAL HARVESTING MACHINES



The most widespread shakers found recently are basically made up of two eccentric masses rotating in opposite directions, or one single eccentric mass rotating around an axis. Both options make for effective combinations based on a wide stroke amplitude in one case, and a high frequency in the other. The second type of shaker is easier to construct and requires lighter supporting structures. These machines present a high efficiency of fruit removal (about 91%) and a high work productivity (about 90–295 kg/h*person), but they require a minimal planting distance of 5 meters. They are easily maneuverable with good performance when used for other crops such as walnuts, almonds, and cherries. The cost of these machines is relatively low.

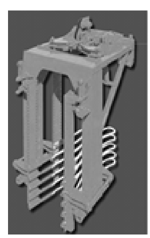
TRUNK SHAKER WITH REVERSED UMBRELLA

The coupling between the reversed umbrella and the vibrator is more often requested; the improvements make operation faster and safer, and important updates regulate the incline of receiving walls, maintaining them under tension and eliminating possible temporary tractions that may eventually cause breaks.

CONTINUOUS HARVESTING MACHINES

Coffee Shaker Fingers

Grape Harvester



A new generation of continuous harvesting machines has been adapted or developed and used in many olive-growing regions. Grape harvesters and coffee harvesters have been used in young tree with good to optimal results, but they are limited to trees not higher than 2.5 to 3.5 meters or wider than 2 meters.

Figure 8.6 Mechanical harvesting systems.

Figure 8.7 Transporting raw olives.

carefully to the processing facility and processing should start as soon as possible. To prevent postharvest deterioration, olives must be packed and transported in shallow ventilated crates that allow air circulation, but never in closed crates, bags, or sacks (Figure 8.7). The thickness of the olive layer inside the crates should be not too high, in order to avoid squashing the fruits on the bottom of the box due to the weight of the mass. In bruised olives, during the postharvest period, oleuropein decreases due to the browning reaction (Segovia-Bravo et al., 2011). The mechanism of the browning is first caused by the enzymic release of hydroxytyrosol from oleuropein and hydroxytyrosol glucoside because of the action of the β-glucosidase enzymes present in the olive fruit (Fernández-Bolaños et al., 1995; Segovia-Bravo et al., 2009). Simultaneously, an additional hydroxytyrosol release can occur due to chemical hydrolysis of oleuropein (Brenes et al., 1993, 1995). In a second step, hydroxytyrosol and verbascoside are oxidized by the polyphenoloxidase present in the fruits (Segovia-Bravo et al., 2007). The whole process leads to browning. A chemical oxidation of hydroxytyrosol may also occur at the same time (Brenes-Balbuena et al., 1992). Rejano et al. (2008) suggested dipping injured olives in a cold NaOH solution to prevent the formation of the brown spots. Thus, mechanically harvested olives could be transported from the groves to the factories in this solution; however, this can be expensive, particularly if refrigeration is required, and a new waste is generated. Immersion of olives after harvesting in an acidic medium or in solutions containing ascorbic acid or sodium metabisulfite has also been proposed to reduce olive bruising (Segovia-Bravo et al., 2011).

Figure 8.8 Sorting and grading of table olives.

Fruit browning during postharvest storage is favored by the presence of oxygen and high temperature. A suitable method to inhibit the browning of fruits is the employment of atmospheres modified with nitrogen, argon, or SO_2 (Sánchez et al., 2013). Nanos et al. (2002) found that green olives destined for Spanish-style processing had good quality after postharvest storage in a CO_2-controlled atmosphere. Olives can be also immersed in several chemical solutions (ascorbic acid, NaOH, SO_2) with the aim of reducing oxygen diffusion into the fruit.

Sorting and Grading

Sorting and *grading* are terms that are frequently used interchangeably in the food processing industry. However, sorting is a separation based on a single measurable property of raw material units, while grading is "the assessment of the overall quality of a food using a number of attributes" (Eissa and Hafiz, 2012). The aim of a sorting treatment is to remove diseased, damaged, and deformed fruits. Grading of fresh product may also be defined as "sorting according to quality." Table olives are graded into quality categories according to their size, color, shape, and the presence of defects. Sorting and grading can be undertaken by hand or by machine. Grading according to the presence of defects remains an expensive manual operation (Figure 8.8) due to the lack of small grading machinery to fit small farms. High technological grading machinery classify the fruits based on the different specific gravity of the olives at diverse maturation stages, or by means of visible and near-infrared inspection systems.

Sorted and graded olives are more desirable for processors than delivering the olives as they are in the orchard. Olives can be damaged during any vigorous grading procedures, so appropriate precautions must be taken to prevent this. Injuries such as bruising when the olives pass through mechanical sorters and graders can lead to the formation of brown spots, gas pockets, or blisters during processing.

Table Olive Processing Methods

Numerous table olive processing methods are available. These depend on olive variety, degree of ripeness, and cultural and traditional factors. Many olive varieties can be processed for the preparation of table olives; however, from a commercial point of view, those varieties are important for the specific processing method and satisfy consumer preference.

As previously mentioned (Figure 8.1), table olives can be classified according to the pigmentation index of the fresh olives and the final product (green olives, turning color olives, and black olives [IOOC/Codex Alimentarius]). An alternative classification is based on the processing types, as Figure 8.9 shows.

The processing method applied can influence the flavor and the texture of each olive style. The mildest method to produce table olives is water curing. Water-cured

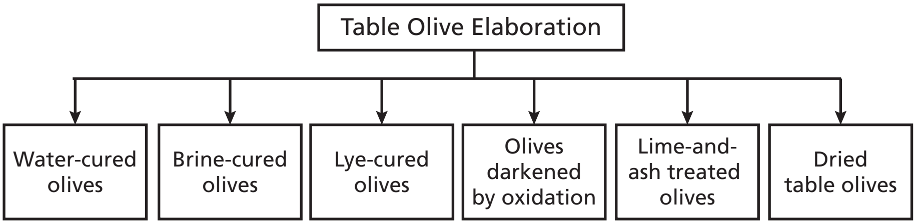


Figure 8.9 Table olive processing types.

olives maintain the flavor of olive fruit as much as other styles. A distinctive flavor and aroma characterize brined olives due to the lactic acid produced by the lactic bacteria during the fermentation process. Brined olives tend to be saltier than lye-cured olives.

Processing Olives with Water (Water-Cured Olives)

After cutting or cracking the fruits, olives are soaked in water. The water is changed daily over a week or more, depending on the olive style and the final bitterness. After curing, the olives are placed in a finish brine, where a fermentation can occur. The so-called naturally black-ripe Kalamata olives, Traditional Ligurian (Benedictine-style) olives, and Taggiasca olives are water-cured olives. After the water curing, red wine vinegar and olive oil are added to the naturally black ripe Kalamata olives, giving the traditional Kalamata-style olive. Hojiblanca, Leccino, and Barnea varieties can also be processed as Kalamata-style olives.

Megaritiki is another famous Greek olive cultivar that is widely cultivated in regions such as Attica and is characterized by a very low concentration of secoiridoid derivatives. Table olives from this variety belong to a group of cultivars that traditionally require little processing to debitter, indicating that oleuropein levels in the untreated fruit of this variety are lower compared to others. The fruits are crushed and immersed for a few days in water. The olives produced with this method are traditionally known as *klastades*. In the Lazio region of Italy, the most famous brine-cured olive style is called “black olives of Gaeta.”

In the northeast of Portugal, stoned halved olives known as *alcaparras* are largely produced by the local growers using domestic or small-scale facilities, commercialized in the local market, and seasoned with herbs, onion, garlic, vinegar, and olive oil. They are consumed mostly in the same winter season that they are grown, due to their reduced shelf life. Alcaparras are processed from green or yellow-green healthy olive fruits that are broken using a wood hammer to separate the pulp from the stone. The pulp is sliced into two approximately equal parts, perpendicularly to the major axis of the fruit, and placed in water, which is changed three or four times during a week. The alcaparra processing method presents some similarities with that used for

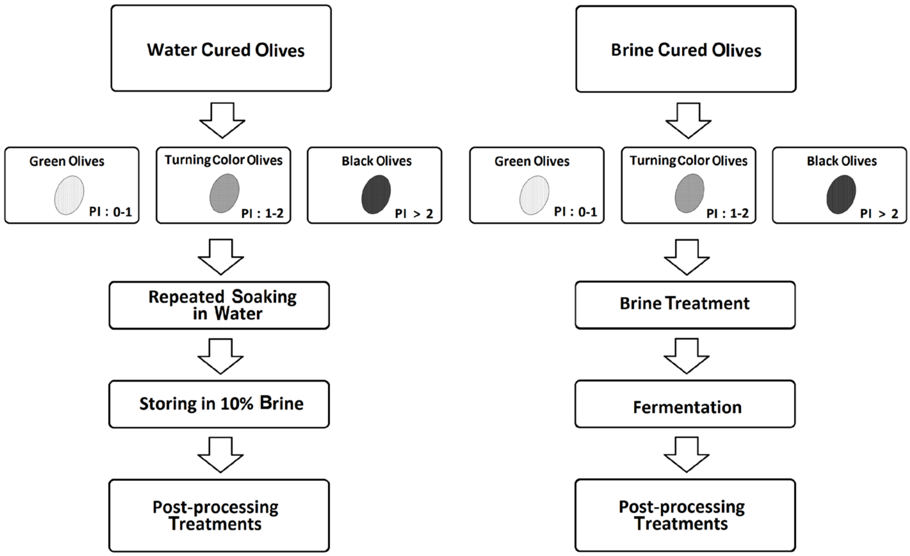


Figure 8.10 Flow diagrams of some of the table olive processing methods: water curing and brine curing olives.

the Kalamata type of olive, in the sense that olives are cut, debittered by contact with water, and thereafter conserved in brine (8%) to avoid fermentation. Nevertheless, the latter process uses pink to purple olives at a higher maturation stage, and therefore with a higher fat content. A flow diagram for this method of olive processing is shown in Figure 8.10

Processing Olives with Brine (Brine-Cured Olives)

In this process, olives are directly brined in 8–10% sodium chloride (Sanchez Gomez et al., 2006) in which they undergo complete or partial fermentation; they are preserved or not by the addition of acidifying agents such as lactic acid. The brine causes the release of the fruit cell juices, forming a culture medium suitable for fermentation that stimulates the microbial activity for fermentation and reduces the bitterness of the fruits. The fermentation of these olives takes a long time because the diffusion of soluble components through the epidermis, in fruits not treated with alkali, is slow. A diverse microbiota grows in these brines. When the olives are first placed in the brine, a robust fermentation by a heterogeneous group of microflora occurs. When the brine pH falls from 7 to 5, a mild fermentation occurs that is supported predominantly by yeasts and, to a lesser extent, by the lactic acid bacteria. Processing takes between 3 and 12 months, depending on the variety, maturation level of the fruit, temperature, salt, and pH levels of the brine.

Green-ripe olives take longer to process than naturally black-ripe olives. Brine cured olives are also called "natural olives." The most prevalent preparation is natural black olives, also known as Greek-style and Sicilian-style green olives. Other countries produce brine-cured olives that are sold mainly in the local market: Lugano (Italy); Nabali and Souri (Israel—dressed with lemons, garlic, peppers, and spices); Nafplion (Greece—also spelled Naphlion or Navplion, dark khaki-green, cracked, and crisp, with a fruity fresh and a tart bite taste); Nicoise (France, Provence region—color ranges from purple-brown to brown to black, more pit to meat, dressed with herbs de Provence); Ponentine (Italy—purple-black, packed in vinegar); Salona (Greece—brown or purplish-brown, soft texture); Termite di Bitetto (Italy—turning color olive, dressed with vinegar, olive oil, herbs, and spices). A flow diagram for this method of olive processing is shown in Figure 8.11.

Lye-Treated Olives

The main steps of lye-treated green-ripe olive processing includes an alkaline treatment (NaOH), a washing step to remove the excess alkali, a stage in brine in which the fruits undergo complete or partial fermentation, and preservation (or not) by the addition of acidifying agents. Lye treatment can be applied on green, turning color, and black olives. There are two main ways of processing green olives: one with fermentation (Spanish style or Seville style) and the other without fermentation (Picholine and Castelvetrano styles). In the Spanish or Sevillian style, the olives are treated in a diluted lye solution and remain in this solution until the lye has penetrated two-thirds of the way through the flesh. The lye is then repeatedly replaced by water. The subsequent step is a fermentation carried out in brine. The brine causes the release of the fruit cell juices, forming a culture medium suitable for fermentation. At first Gram-negative bacteria multiply, but after a week and a half they disappear. At pH levels of 6 and upward, lactobacilli develop massively until the Gram-negatives disappear and the brine attains a pH of 4.5. There is a predominance of *Lactobacillus plantarum,* which produces lactic acid from glucose almost by itself. When the fermentable matter is spent, acid formation ceases.

Yeasts appear together with the lactobacilli. Fermentative yeasts do not cause deterioration, but oxidant yeasts consume lactic acid and raise the pH level and may therefore jeopardize the process. When properly fermented, olives keep for a long time. Olives belonging to the Picholine variety, from Languedoc and Lucques in southern France, are placed in lye solution for 8 to 72 hours until the lye has penetrated three-quarters of the way through the flesh. Then they are immersed in a brine solution for 2 days. A second 7% brine solution is prepared, and acidity is corrected with citric acid (pH 4.5). After 8–10 days, the olives are ready to be eaten, and they retain their intense green color. Before shipment, the olives are washed repeatedly, sorted, and packed in suitable containers in brine. With

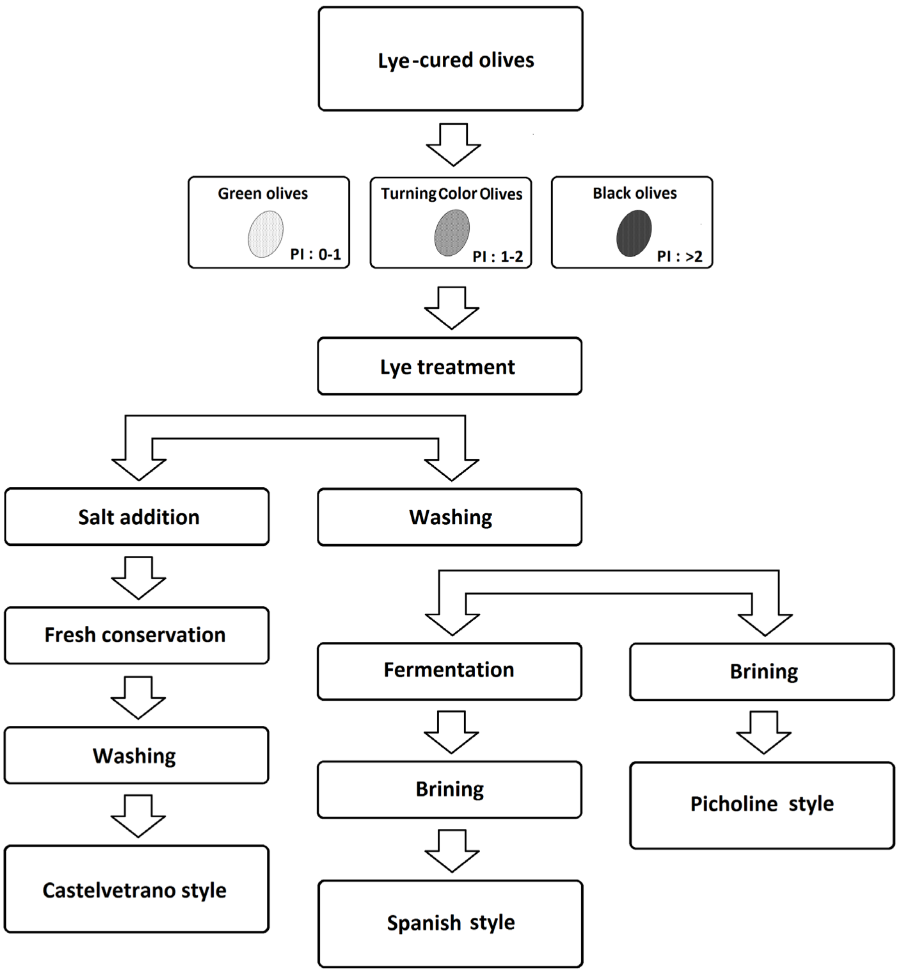


Figure 8.11 Flow diagrams of lye curing table olive processing method.

Castelvetrano table olives, a Sicilian variety called Nocellara de Belice is used. After washing the raw green olives, they are placed in a 2–3% lye solution. After 1 hour, coarse salt is added and agitated to mix and dissolve the salt. After 2 weeks, the lye–salt brine is drained and the olives are washed to remove excess lye. Castelvetrano olives have a shelf life of only a few months. The Halkidiki olive, often referred to as *Chalkidiki*, is grown exclusively in Greece in a region that is adjacent to Mount Athos in the region of central Macedonia. They are also known as “donkey olives” because of their large size, and they make excellent table olives. These golden green olives can be cured a few different ways. The most common is treating them with caustic soda for a period of 12–15 hours. Then the olives are washed until all traces of lye are gone. Once washed, olives are placed in tanks of sea-salt brine for fermentation. In a less common method, *donkey olives* are cured in a brine solution with both citric and ascorbic acid. The fermentation time usually takes around 3 months. A flow diagram for the most common lye methods of olive processing is shown in Figure 8.11.

Olives Darkened by Oxidation

In the method for processing Californian or Spanish-style black olives, fruits undergo successive lye treatments (from two to five times). During the intervals between lye treatments, the fruit is suspended in water or a weak brine solution in which air is bubbled. To prevent color deterioration, iron salts can be used to stabilize color. The browning development is also facilitated by the formation of ferrous complexes (uncolored) and the following oxidation to complexes of ferric iron (dark), leading to the formation of darker and more homogeneous polymers. Ionic interaction in the fruit between iron and other compounds, such as proteins, polysaccharides, or formation of iron tannate (also of black color), could be another factor important in the ripe color formation and fixation. A flow diagram for this method of olive processing is outlined in Figure 8.12.

Lime-and-Ash-Treated Olives

In some Italian regions, olives are prepared with an ancient and traditional method that includes debittering with a lime-and-ash mixture. CaO (lime) and olive wood ash are mixed and water is added to make a paste; then, the green olives are submerged in the mixture for some hours at room temperature. After alkaline treatment and washing, olives are placed in a solution of NaCl. This method, popular in all parts of Italy,is passing from generation to generation in different regions (Lazio, Calabria, Campania and Puglia) Due to historical tradition these olives have been recognized as “Traditional AgriFood Product” by the Italian Ministry of Agriculture “lime-and-ash olives” after reviewing all those items of preparation passed down from generation to generation; (Decree of the Italian Ministry of Agriculture 18 July 2000; XII Revision of 7 June 2012). The action of lime–ash is similar to the action of NaOH. A flow diagram for this method of olive processing is shown in Figure 8.12.

Dried Table Olives (Shriveled Olives)

Naturally processed, additive-free, and healthy products are back in vogue. In this sense, the easiest method for treating olive fruits without chemicals and with the low-

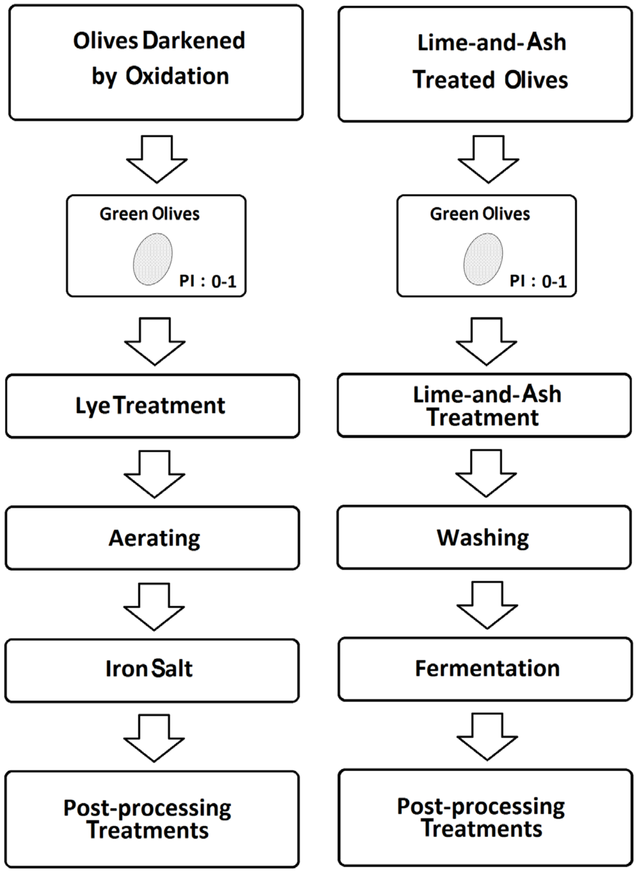


Figure 8.12 Flow diagrams of some of the table olive processing methods: olives darkened by oxidation, and lime and ash curing.

est production of waste consists of salt drying or heat drying. Resulting olives have a low water activity that renders them self-preserving.

Salt-Dried Olives

In Greece, but also in other Mediterranean countries such as Algeria and Morocco, the naturally black dry-salted olives are highly appreciated. Thassos is an olive variety used to produce naturally black dry-salted olives (Thassian Throuba Olive). Other varieties such as Kalamata, Manzanilla, or Leccino can also be used to produce salt-dried olives. Olives are harvested in December when fully mature and completely black in color. The traditional processing principle is to place the olives in concrete tanks as layers with coarse sodium chloride. Due to the high osmotic pressure exerted by the salt, olives lose water and other solutes, including much of the bitter agent oleuropein, and become gradually debittered and wrinkled (dry-salt processing). In some cases, after curing, salt-dried olives can be plunged briefly into boiling water to remove the excess salt, allowed to dry, then stored in extra virgin olive oil. Home processors can also add olive oil, herbs, and spices. Dry-salted olives have been reported to have a water activity of 0.75–0.85. The low water activity/high salt content of the product can ensure its microbiological safety during storage. Megaritiki olives are allowed to partially dry naturally on the tree and are then dried with coarse salt. Salt-dried olives can be vacuum packed to aid in their preservation. Some olives, such as Nyons, are dry cured first and then aged in brine. Nyons olives are made from Tanche olives grown in Nyons, France. The olives are pricked on all sides, dry-cured, then brined for 6 months. They end up wrinkly, dark black, and shiny, tasting mildly salty and bitter. Other countries produce salt-dried olives that are sold mainly in the local market: Gaeta (Italy—small, black, or mahogany-colored, often packed with herbs such as rosemary); dry-cured Moroccan (Morocco—black with a slightly bitter flavor); and dry-cured Californian (California—rubbed with olive oil). Figure 8.13 shows the main steps of the salt-drying process.

In Italy, black olives from Leccino and other minor cultivars are used to produce the “Strinate” olives. The fruits are stored in a jute bag after being combined with coarse salt. The bag is stored in a very cold place, mixing the olives twice daily to prevent formation of mold and to promote a better distribution of salt. After 20–40 days, the shriveled fruits are placed in glass containers with the addition of herbs, pieces of orange, lemon, garlic, paprika, and oregano. The popular so-called Moroccan oil-cured olives are cured in salt to remove extra water and then are soaked for one to a few months in olive oil. Oil curing is one of the most ancient forms of presenting olives.

Heat-Dried Olives

One traditional oven dehydration method is applied to treat ripe black olives, usually the Majatica cv., cultivated around Ferrandina in the Basilicata region (Italy). The Ferrandina-style process includes three operations: blanching, salting, and oven drying (40–50 °C) of mature black olives. The olives, collected at the appropriated ripening stage, are quickly immersed into boiling water for 5–10 minutes, partially debittered by salt treatment, and finally heat dried. The blanching procedure can be substituted by the immersion of chopped olives in water for 2–3 weeks, salted, and oven dryed. This variant of the process is called the *Sybaris method.* A more ancient technique is still employed in the Oinotria area, in the Calabria region (belonging to the ancient Magna Grecia, Italy), in the homemade traditional process. This is one of

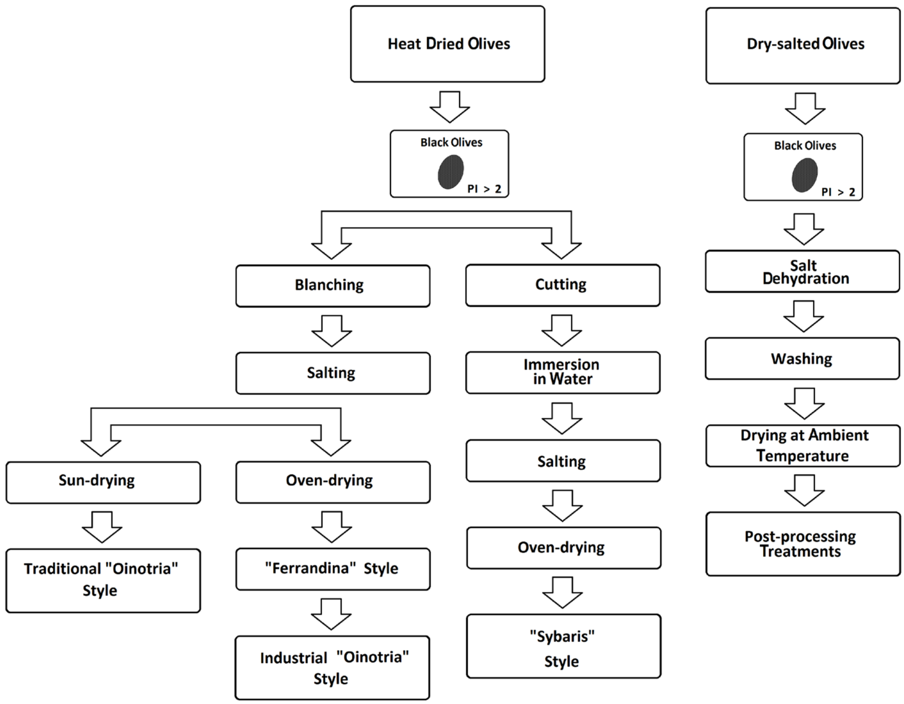


Figure 8.13 Flow diagrams of some of the table olive processing methods. Heat drying process and dry-salting process.

the oldest methods of full ripe table olive production. The legend says that Oinotria people adopted table olive consumption in 2000 BC, long before Greek immigration, according to the myth of Italo, the king of Oinotria gentry, who invented the *syssitia*, the conventional gathering. In the last step of traditional Oinotria method, olives are sun dried. Today, in the industrial process, the olives are oven dried. Figure 8.13 shows the main steps of the heat-drying process.

Influence of Processing on Olive Phenol

Unprocessed olives are well-known sources of phenolic antioxidants with important biological properties. Processing methods to prepare table olives may cause a reduction of valuable phenols and may deprive the food of precious biological functions. As stated before, debittering is essential for making table olives edible. Whatever the method used, a significant loss in polyphenols occurs during the various processing steps (Figure 8.14). It is fundamental to elucidate how the processing technologies

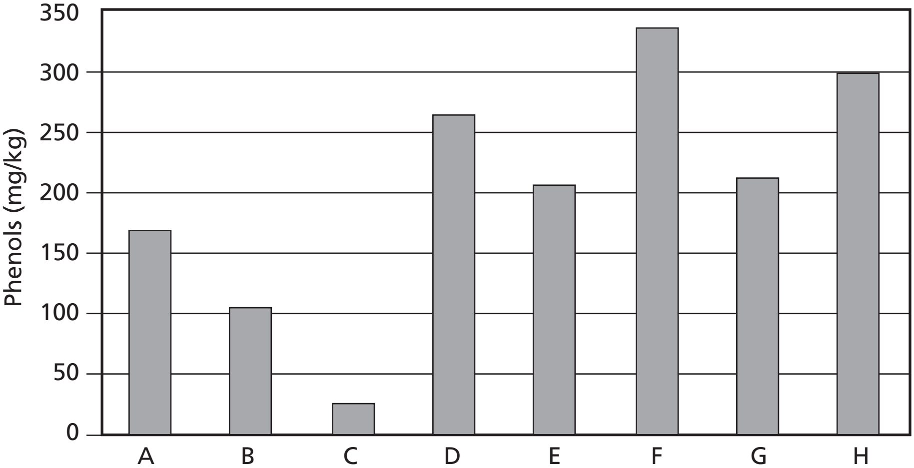


Figure 8.14 Influence of processing on olive phenol content. A: Servillan green olives—Intosso; B: Servillan green olives - Bella di Cerignola; C: Castelvetrano green olives—Nocellara del Belice; D: Ferradina black olives—Majatica; E Natural black olives—Taggiasca; F: Natural black olives – Peranzana; G: Natural black olives—Itrana; H: Natural black olives—Cellina. (Chart prepared from numerical values reported by Lanza, 2012).

used can affect health properties of table olives. Fadda et al. (2014) and Sahan et al. (2013) studied the effect of processing techniques on antioxidant capacity and phenolic compounds of table olives. They found that total phenol content and antioxidant capacity of fresh olives were higher than those of processed olives. Significant differences in antioxidant capacity were observed between treatments. The average antioxidant capacity (AC) of processed olives was in the following order: untreated black olives in brine > Californian-style black olives > untreated black olives in dry salt > Spanish-style green olives. The highest levels of AC were found in black olives in brine (744 µmol Trolox/g), and the lowest were found in Spanish-style green olives (735 µmol Trolox/g).

Water Curing

Water-cured olives are characterized by higher levels of polyphenol than the brine- and lye-cured ones, as revealed by the retention of a more bitter taste (Boskou et al., 2006). In fact, the dissolution of phenols is driven only by the concentration gradient between the olive tissue and the surrounding water. The rate of this movement is a function of the difference in concentrations, the temperature, and the permeability of the cell membranes. Frequent water changes accelerate the debittering process.

Brine Curing

Brine-cured olives, compared with the water-cured ones, are less bitter. Different factors influence the effect of brine curing on the phenol content of the final product: the maturity stage of the fruits, the NaCl concentration, the duration of the treatment, and the temperature of the solution. In brine curing, the osmotic pressure of the salt present in the soaking medium constitutes another driving force for phenol diffusion. The water inside the fruits' cells tends to move toward the soaking solution because of the higher concentration of the solute, and it dissolves the phenols in the curing solution faster. At the same time, sodium chloride penetrates the olive tissue, determining the salty taste of the product. The salt concentration used by industrial and small processors varies from 4% to 15%. Due to the processing variability, the final commercial brine-cured olives are different in color, form, and other sensorial aspects. During brine treatment, a fermentation process can occur. Fermented brine-cured olives contain fewer phenols than the unfermented ones because microbiota present in the brine are able to hydrolyze oleuropein and the resulting products diffuse into the acidified brine solution rapidly. Fadda et al. (2014) investigated the evolution of the antioxidant activity of the polyphenolic extract during the processing of naturally fermented green olives brined at two different NaCl brine concentrations (4% and 7%). %). They observed a loss in antioxidant activity (close to 40%) during brining; this is correlated to polyphenol loss. Olives brined with 7% of NaCl showed a higher radical scavenging activity, with respect to the 4% brined samples, probably due to the higher polyphenol content of the extract.

Lye Curing

The lye-curing process is the strongest debittering method. The caustic soda increases the permeability of the fruit skin, increasing the rate of the oleuropein hydrolysis and diffusion. The lye causes the hydrolytic cleavage of the ester bond on oleuropein between hydroxytyrosol and oleoside-11-methyl ester (elenolic acid glucoside). Verbascoside is also hydrolyzed via the same mechanisms, producing hydroxytyrosol and caffeic acid. Hydrolysis of ligstroside produces tyrosol and the oleoside-11-methyl ester. During lye treatment, rutin and luteolin-7-glucoside levels decrease due to the hydrolysis of the glycosides. These neo-formed compounds can diffuse into the rinsing water. The lye curing can be also followed by a fermentation stage thanks to the glucose that becomes a substrate for fermenting microorganisms. Blekas et al. (2002) examined Spanish-style green olive samples and found the presence of only hydroxytyrosol, tyrosol, and luteolin in the fruit flesh, probably because glycosides are either partially hydrolyzed during lactic acid fermentation or pass completely into the brine. Kailis and Harris (2007) observed that during the brine treatment of the lye-treated olives, the hydrolysis byproducts of oleuropein, such as hydroxytyrosol and elenolic acid, pass into the brine. Indicative levels of phenols remaining in the flesh of Conservolea and Chalchidikis after processing by this method range from around 150–550 mg/kg and 400–1200 mg/kg, respectively. Residual hydroxytyrosol levels in flesh are around 150–500 mg/kg.

Fermentation

Fermentation is a phase common both to the brine and lye curing, and its effects on phenol content depend mainly on the ripening stage of the raw fruits and the different debittering methods previously applied. During fermentation, the phenol concentration is subjected to different and contrasting effects: The reduction of pH due to the production of organic acids can facilitate the diffusion of hydroxytyrosol, tyrosol, and oleoside-11-methyl ester into the surrounding medium, until an equilibrium is reached; on the other hand, microorganisms that consume the oxygen can prevent further oxidation of hydroxytyrosol. The main chemical changes that occur during fermentation are related to the levels of oleoside-11-methyl ester, which is rapidly converted to elenolic acid. Elenolic acid is unstable and degrades in the acidic conditions of the brine solution. Fermentation of Greek-style naturally black (brine-cured) olives results in a higher retention of total phenolics than Spanish- (lye-cured) or California-style (oxidized bubbling air) processing methods. Marsilio et al. (2005) studied the phenol concentration in the final product comparing the Greek- and the Spanish-style processing methods. They found that, starting from a total phenolic content in fresh olives equal to 5138 mg/kg of wet weight, levels had fallen to 2513 mg/kg in the Greek-style olives and to 448 mg/kg in the Spanish-style olives after 5 months of fermentation.

Romero et al. (2004) investigated the polyphenol changes during fermentation of naturally black olives. They found a great difference between the phenol composition of fresh and processed fruits. Acid hydrolysis of hydroxytyrosol, tyrosol, and luteolin glycosides takes place during the fermentation in brine when naturally black olives are prepared. Thus, the prevailing phenols in table olives are hydroxytyrosol, tyrosol, luteolin, and phenolic acids (Blekas et al., 2002; Boskou et al., 2006). As a consequence of the presence of acetic acid in the fermentation medium, acetylation reactions were also observed, and marked concentrations of hydroxytyrosol acetate and tyrosol acetate were detected.

Oxidation Process

If the alkali solution is coupled with the air or oxygen treatment (California-style black olives), the availability of phenols decreases due to the oxidative and polymerization reactions. Campestre et al. (2000) found that the flesh concentration of hydroxytyrosol decreased during the lye treatment in black oxidized table olives and during the rinsing step due to diffusion phenomena. Brenes et al. (1993) observed that the higher temperature increased the phenol diffusion rate into the surrounding medium. Blekas et al. (2002) analyzed phenol composition of table olive samples from the retail market. They observed that the browning process, favored by bubbled air and iron salt additions, caused the diminution of orthodiphenols in the flesh of California-type black olives. Ferrous gluconate treatment causes a sharp decrease in hydroxytyrosol due to oxidation, whereas the tyrosol level remains unchanged. California-style black ripe olives contain much lower concentrations of total phenolic compounds than either Spanish- or Greek-style table olives (Romero et al., 2004), and they have considerably lower or zero levels of hydroxytyrosol than the other processed table olives.

Dehydration Process

The dehydration process (using salt or heat treatments), despite the debittering action, causes an enrichment of phenol compounds in the olive flesh, which is explained by the reduction of water content. The dried olives, in fact, are characterized by a slightly more bitter taste than the other common curing styles.

Salt Drying

The levels of phenols in salt-dried olives depend on the variety, maturation state, and the quantity of water lost after processing. Researchers in Greece have found that residual phenol levels in Thassos are between 600 mg/kg and 800 mg/kg, but hydroxytyrosol levels are much lower than other olive styles, presumably because there is no fermentation step or acid conditions during processing. Zoidou et al. (2010), examining nine commercial types of table olives for their content of oleuropein and hydroxytyrosol, found that Throuba Thassos olives, which are processed by dry salt in a traditional Greek way, are the best source of oleuropein and hydroxytyrosol among traditional Greek table olives. The authors highlighted that the addition of edible olives in the human diet is necessary and, in combination with olive oil, they can provide important quantities of natural antioxidants, but this is highly dependent on the type of olives consumed.

Heat Drying

Ferrandina-style blanched olives are characterized by a high polyphenol content. Piercing gives faster drying kinetics, but with greater loss of polyphenols. Dried olives (dry matter nearly 80%) often are not characterized by a sufficient low a_w values; however, the high polyphenol content may be a sufficient barrier to microbial growth. Piscopo et al. (2014) studied the effect of the drying process conducted at two different air temperatures, 50 °C and 70 °C, on the qualitative parameters in dried olives. Carrying out physical and chemical analyses and an investigation of newly formed antioxidants on samples before and after treatments, they found a decreased content of total phenolic compounds after drying, with the biggest reduction at the lower temperature (50 °C). On the other hand, a higher drying temperature (70 °C) increased the total antioxidant capacity of olives, and this is probably related to the new formation of melanoidins—molecules formed at the last stage of the Maillard reaction that possess certain functional properties such as antioxidant, antimicrobial, and antihypertensive activities. A further fractionation confirmed the contribution of melanoidins to the overall reducing property of the extracts of dried olives. They concluded that dried olives could be rationally considered for "ready-to-eat" use or as ingredients in food formulations, with an added value derived from their increased functional property.

Stoning, Stuffing, and Seasoning

Consumers often prefer destoned olives. The effect of destoning is detrimental for the phenol content of table olives. Destoned olives are characterized by a higher surface through which polyphenols can diffuse into the surrounding liquid. Romero et al. (2004) (Figure 8.15) demonstrated that the destoning of olives reduced the hydroxytyrosol in olive juice; flotation, the new washing step that is used to separate the pitted product from the nonpitted and the small fragments of pulp, gives rise to new dilutions of polyphenols in the washing liquids.

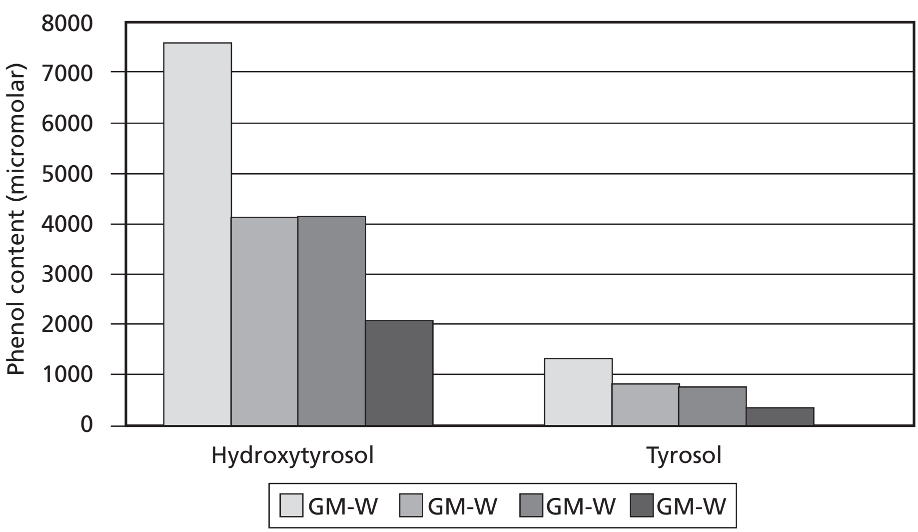


Figure 8.15 Effect of stoning on olive phenol content: GM-W: Spanish green olives—Manzanilla whole; GM-D: Spanish green olives—Manzanilla de-stoned; GH-W: Spanish green olives—Hijiblanca whole; GH-D: Spanish green olives—Hijiblanca de-stoned (Chart prepared from numerical values reported by Romero et al., 2004).

The evaluation of alcaparras stoned table olives reveals that they may constitute a good source of healthy compounds or phenol intake in the diet, with three main flavonoidic compounds identified in aqueous extracts, namely, luteolin 7-O-glucoside, apigenin 7-O-glucoside, and luteolin. The high phenolic content of these traditional stoned table olives, due to maturity at picking and the soft processing conditions, protects the products against autoxidation and microbial development (Sousa et al., 2011). The alcaparras olives are harvested at a medium ripening stage (when the skin is pink or purple) and are characterized by a lower fat content and a higher phenol content compared to the Kalamata olives harvested at a later maturation stage (Ünal and Nergiz, 2003).

Table olives can be stuffed or seasoned with many ingredients. The demand for this type of olive is increasing due to progressive consumer awareness of traditional and natural products. They can be produced following different recipes and using diverse natural ingredients (peppers, lemon, thyme, pimiento, garlic, cheese, etc.). Other traditional recipes employ vinegar as a seasoning ingredient. Vinegar has numerous flavor components that give the table olives desirable flavors and aromas, it acts as a preservative and as a solvent for herbs and spices, and it provides additional polyphenols. Seasonings can be a source of enzymes, which are able to solubilize into the brine and then act on the olives with uncontrollable effects (López et al., 2005).

Thermal Stabilization of Table Olives: Pasteurization

Not all types of table olives need pasteurization, but its application is common for many types of olive products in order to reduce the numbers of pathogenic and spoilage organisms in the olives and brine. The effect of thermal treatments on the color and texture of pickled green olives has been assessed by Sánchez et al. (1991), who concluded that such organoleptic attributes did not change appreciably as a result of the pasteurization treatments necessary to guarantee the product's stability. Pasteurization is unnecessary for bulk olive production with fermentation as long as brine salt, pH, and acid levels are controlled (Kalis and Harris, 2007). If higher temperatures are used, deterioration in color, texture, flavor, and nutritional value occur (Sanchez et al., 1997). The heat treatment in olive pasteurization may not only result in some losses of thermally labile nutrients and bioactive phenols, but also in the inactivation of oxidative and other degradative enzymes (e.g., endogenous and microbial polyphenol oxidase), preventing further and greater losses by enzyme-catalyzed degradation during storage.

Packaging Treatment to Ensure the Keeping Properties of the Packed Product

The stability of polyphenols is influenced by acidity of brine medium; oxygen; light; solvents; the presence of enzymes (endogenous or microbial), proteins, and metallic ions; and by the association with other food constituents, such as the seasoning ingredients (Castañeda-Ovando et al., 2009).

Packaging Medium Acidity

Olives packed in brine without any acidification presented a darker brine color than olives packed with added lactic and citric acids. Browning of brines can be attributed to the chemical oxidation of orthodiphenols present in brines, particularly hydroxytyrosol deriving from the hydrolysis of oleuropein. The oxidation rate of orthodiphenols depends to a great extent on the pH of the surrounding solution (García et al., 1992). For this reason, olives packed in acidified brines are characterized by low brine darkening and, as a consequence, a higher phenol content and nutritional value. The amount of phenols leached into the brine and subsequently oxidized, resulting in brine darkening, is usually much higher than that leached into the medium of lye-treated olives (Montaño et al., 1988).

Salt Concentration in the Packaging Medium

In the past, the packed olives were stabilized only by their physicochemical characteristics, high values of free acidity and NaCl and low pH. The presence of salt inhibits the spoilage of undesirable microflora and assures product stability during the commercial life of the product. The progressive preference of consumers for low NaCl levels has modified the stabilization methods. Producing table olives soaked in a storage medium with low NaCl concentrations requires the use of pasteurization. In the United States, a salt-free storage of black ripe olives combining acidulated water (lactic and acetic acid) in anaerobic conditions is used. This method was developed to alleviate the problem of brine disposal (Sánchez et al., 2006). Spanish green table olives can also be produced using salt mixtures (NaCl, KCl, and $CaCl_2$) to obtain a reduced sodium content in the final products (Rodríguez-Gómez et al., 2012).

Packaging Atmosphere and Additive Use

Fernández et al. (1997) suggested carbon dioxide (CO_2) for extending the shelf life of perishable foods because it increases the lag phase and the generation time of spoilage organisms. The use of CO_2 during the storage process of Manzanilla-Aloreña olives may displace oxygen and, thus, prevent browning reactions (derived from polyphenol oxidation) and retard microbial growth (Arroyo-López et al., 2008). Ozone treatment during the storage process of cracked olives could help to control the microbial population (Arroyo-López et al., 2006). During Spanish-style green olive fermentation, the use of Mg^{2+} in the storage solution may then delay the green color degradation. Sulphite can inhibit the polyphenoloxidase action (Sayavedra-Soto and Montgomery, 1986), and ascorbic acid has shown antibrowning activity in bruised olive fruits. Polymeric packaging materials can influence the oxygen permeability and consequently the oxidative phenomena, altering the sensory and the nutritional value of the product.

Packaging Medium Temperature

Oxygen permeability of the plastic packaging increases as temperature increases. The packaging brine color of pasteurized olives is usually darker than that of nonpasteurized ones, due to the chemical oxidation of phenols. Long storage tests on packaged olives have demonstrated that during storage of packaged olives, a rapid decrease of polyphenols in the fruits occurs due to the diffusion phenomena toward the brine. This undesirable effect is enhanced if the storage temperature increases up to 50 °C. Dry-salted olives are usually packed without brine in polyethylene bags, tins, or glass jars. A common solution to prevent the risk of yeast and fungi spoilage is packaging under modified atmospheres. Experiments conducted on dry-salted olives packed in HDPE plastic bags demonstrate that carbon dioxide was most effective in minimizing yeast counts and suppressing fungal growth.

Light Exposition during Olive Storage

The oxidative reactions are accelerated by the presence of the light. Sánchez et al. (1997) studied the effect of different storage conditions (in light or in darkness). They observed that the brine color of samples stored in light was paler than that of olives stored in darkness. In order to reduce transparency of the storage medium, light-barrier packaging materials can be used.

Olives Consumed without Any Processing

Olives Debittered by the Activity of Fungi

In Greece, mainly in Crete, the Thassos (a clone of Thrubolea cultivar) is used to prepare the "Thruba-style olives," a similar type of dry-salted olives. When completely mature, the superficial color becomes brown and the fruits are debittered directly on the tree without any further treatment (Panagou, 2006). Fruit debittering is due to the presence of the fungus *Phoma oleae* that grows in the flesh and hydrolyzes oleuropein. Enzymatic hydrolysis of oleuropein, particularly by β-glucosidase, is well established in the literature for both bacteria and fungi (Ciafardini and Zullo, 2002; Ciafardini et al., 1994). A similar type of olive is encountered in the Sicilian region (Italy); the "Passuluna" olives are natural over-ripe olives left on the tree until December-January, harvested, washed with hot water, and left to air-dry. These olives are debittered as the result of attack of the fungus *Camarosporium dalmaticum*, introduced in the drupe from dipteran *Prolasioptera berlesiana*, parasite of *Bactrocera oleae* eggs (Lanza, 2012).

Natural Sweet Olives

In Turkey there is a natural sweet olive cultivar known by the name of "Hurma." These olives go through a natural debittering on the tree during ripening. At the end of this process, the olive loses its bitter taste while still on the tree and has a dark brownish color flash and a wrinkled outer layer. The Hurma olive does not need to go through further processing. Therefore, consumers that have health problems such as hypertension prefer this olive type over table olives that have a higher salt content.

In Apulia (southern Italy), there are some cultivars are whose fruits are sweetened naturally on the tree without any process—so-called sweet olives. These fruits can be used for both oil extraction or debittering at green/turning ripening time, but overall they are used as fried olives after they are harvested at the black-skin stage (Godini et al., 2002). The interest for Apulian sweet olives, which were limited to private use until few years ago, is now starting to spread to restaurants, where these olives now represent a typical course. The cultivars known for the Apulian sweet olive production are Dolce di Cassano, Mele, Nolca, Pasola, and Termite di Bitetto. Except the last cultivar, for which there are specialized orchards, all other cultivars occur as isolated aged trees within olive orchards. These ancient cultivars seem to possess clones and/or ecotypes (Muzzalupo et al., 2009). Moreover, the literature reports several accessions related to these cultivars, as Dolce, Dolce di Andria, Dolce Mele, Nolca, Oliva dolce, Pasola di Andria, but a probable homonymy of these accessions has to be botanically investigated

At the moment, genetic and biochemical aspects of the natural sweetening of the olives of these cultivars are unknown. A quick oleuropein hydrolysis could hypothesized very early in the fruit ripening period. Most of the important agronomic, phenological, and ecophysiological parameters are uncertain or unknown as well, but they are essential for intensive cultivation.

The human consumption of these natural sweet olives without any chemical, enzymic, or other debittering leads to serious considerations regarding the environmentally favorable impact and the functional aspects. Indeed, no industrial process means: (1) no production of waste waters (saline/alkaline solutions) to dispose/recover, and (2) no loss of the native fruit phenolic pool, to which important organoleptic, nutritional, and functional properties of the table olives are due. Consequently, natural sweet olives could represent useful, abundant, low-cost, ecofriendly sources of bioactive compounds. Therefore, an insight into the sensory characteristics of olives from these genotypes and agronomic research could have an important impact on the table olive sector.

Innovative Proposals to Retain a Higher Level of Biophenols

β-Glucosidases of Microbial Origin as an Alternative Processing Method to Lye and/or Brine Treatment

In order to substitutie chemical methods based on NaOH treatment, Briante et al. (2000), Ciafardini and Zullo (2002), and Tuna and Akpinar-Bayizit (2009) investigated enzymatic hydrolysis of oleuropein catalyzed by β-glucosidase activity in olive processing. According to these authors, β-glucosidase prevents the loss of fermentable material during the washing step of lye treatment, enhances the initial growth of lactic acid bacteria, and results in a favored end-product with high sensory quality. Potential use of enzymes instead of traditional lye treatment can result in products that are highly accepted by consumers, as well as environmental protection because of the impact of waste water from currently applied practices.

Combining Tradition and Innovation to Improve Nutritional Value of Table Olives

Probiotic food products contain beneficial microorganisms large enough to reach the intestine and exert an equilibrating action on the intestinal microflora, reducing the amount of pathogens and helping boost the immune system, thus lowering the risk of gastrointestinal diseases. In the past two decades, probiotic health-promoting microorganisms have been included in commercial products as a response to the consumer demand for healthy foods that improve overall health, intestinal function, and digestion. Fermented foods, such as table olives, can be reinforced with probiotic bacteria and can be used as a vehicle for incorporating probiotic cultures. The incorporation of health-promoting bacteria into table olives would add functional features to their current nutritional properties (Arroyo-López et al., 2012; De Bellis et al., 2010; Gomez et al., 2014; Lavermicocca et al., 2005; Rodriguez-Gómez et al., 2013, 2014). Pure starter cultures of lactic bacteria are available in the market and used in several vegetable fermentations (Leroy and De Vuyst, 2004), but their use in table olive processing is still limited. A probiotic potential is expected to greatly enhance the already important nutritional value of table olives and convey a favorable economic impact.

New Genotypes of Table Olives

Few breeding programs have been oriented toward obtaining new table olive cultivars (Lavee, 2008; Rallo et al., 2012). New table olive genotypes that are released should be adapted to modern growing systems (high-density orchards, irrigation regimes, mechanized harvesting, and others) and industrial processing (appropriated fruit pitting, fermentation control, and low environmental pollution). Consumers demand fruits with good size, proper shape, high flesh/stone ratio, good texture and color (Garrido et al., 1997; Lavee, 2008; Rallo et al., 2011), and that are rich in substances with beneficial properties for human health. The new olive genotypes from the breeding programs could be considered "functional food" because they are rich in bioactives (Montilla et al., 2003). The beneficial properties of the compounds present in table olives are inspiring breeders to take into consideration the possibility of including nutritional quality as a breeding objective. Medina et al. (2012) evaluated 48 new table olive genotypes from cross-breeding. They concluded that phenolics found in the fruits should be considered as key selection criteria in olive breeding programs.

Conclusion

There are many types of table olives available worldwide, and each growing country produces local and regional styles that differ in their method of debittering. The three main types of commercial table olives are: Spanish-style green olives, Greek-style natural black olives, and California-style black ripe olives. Table olives have more or less the same health properties as olive oil, but this has been overlooked because, with the exception of Mediterranean countries, this product was seen as a piece of decoration for pizzas and breads. Table olives are a highly functional food with a balanced content of fats made up mainly of monounsaturated oleic acid. They contain fiber, vitamins, minerals, phytosterols, triterpenic acids, and squalene, and they contribute to the daily intake of nutritional antioxidants, mainly phenols, such as verbascoside, hydroxytyrosol, tyrosol, luteolin, and apigenin 7-O-glycosides, as well as phenolic acids. Raw olives are bitter and not fit for consumption due to the high levels of bitter secoiridoids, mainly oleuropein. Oleuropein can be removed by natural methods (dilution or microbial enzymes), alkali treatment, drying, or salt curing. Profiles of phenolic compounds in the end products, and consequently the nutritional value, are influenced by the olive cultivar, the pre- and postharvest factors, the debittering methods, and the processing style. Olives' ripening stage strongly influences changes in phenolic content and the profile of bioactive phenols. During olive ripening, the concentration of total phenols usually increases progressively to a maximum level at the green-skin stage, decreasing sharply as ripening progresses. The harvesting method is also important for table olive quality. Less bruising is encountered in hand-picked fruits, which is the most time consuming and expensive method. Other factors affecting quality are the transport conditions and the duration of storage. Numerous table olive processing methods are available. Each process is suitable for a particular olive variety and degree of ripeness, and the processes may vary according to tradition and other cultural factors. Whatever the method used, a significant loss in polyphenols occurs during the various processing steps. The potential use of enzymes instead of traditional lye treatment can result in products richer in polyphenols. Other targets in the table olive sector are:

- New table olive genotypes coming from cross-breeding programs
- Olives with a protected designation of origin (PDO) status that are: rich in phenols, debittered by traditional methods but innovated with modern technology, low in salt, and packed under vacuum

Products that can be used as vehicles for incorporating probiotic cultures because fermented olives contain probiotic bacteria from the olive's natural flora.

References

Alexandraki, V.; Georgalaki, M.; Papadimitriou, K.; Anastasiou, R.; Zoumpopoulou, G.; Chatzipavlidis, I.; Tsakalidou, E. Determination of Triterpenic Acids in Natural and Alkaline-Treated Greek Table Olives Throughout the Fermentation Process. *LWT—Food Sci. Tech.* **2014,** *58* (2), 609–613.

Amiot, M. J.; Fleuriet, A.; Macheix, J. J. Importance and Evolution of Phenolic Compounds in Olive during Growth and Maturation. *J. Agr. Food Chem.* **1986,** *34,* 823–826.

Amiot, M. J.; Fleuriet, A.; Macheix, J. J. Accumulation of Oleuropein Derivatives during Olive Maturation. *Phytochemistry* **1989,** *8,* 67–69.

Arroyo-López, F. N.; Durán-Quintana, M. C.; Ruiz-Barba, J. L.; Querol, A.; Garrido-Fernández, A. Use of Molecular Methods for the Identification of Yeast Associated with Table Olives. *Food Microb.* **2006,** *23,* 791–796.

Arroyo-López, F. N.; Querol, A.; Bautista-Gallego, J.; Garrido-Fernández, A. Role of Yeasts in Table Olive Production. *Int. J. Food Microbiol.* **2008,** *128,* 189–196.

Arroyo-López, F. N.; Bautista-Gallego, J.; Romero-Gil, V.; Rodríguez-Gómez, F.; Garrido-Fernández, A. Growth/No Growth Interfaces of Table Olive Related Yeasts for Natamycin, Citric Acid and Sodium Chloride. *Int. J. Food Microbiol.* **2012,** *155,* 257–262.

Attya, M.; Benabdelkamel, H.; Perri, E.; Russo, A.; Sindona, G. Effects of Conventional Heating on the Stability of Major Olive Oil Phenolic Compounds by Tandem Mass Spectrometry and Isotope Dilution Assay. *Molecules* **2010,** *15,* 8734–8746.

Bellincontro, A.; Taticchi, A.; Servili, M.; Esposto, S.; Farinelli, D.; Mencarelli, F. Feasible Application of a Portable NIR-AOTF Tool for On-Field Prediction of Phenolic Compounds during the Ripening of Olives for Oil Production. *J. Agr. Food Chem.* **2012,** *60,* 2665–2673.

Ben Othman, N.; Roblain, D.; Thonart, P.; Hamdi, M. Tunisian Table Olive Phenolic Compounds and Their Antioxidant Capacity. *J. Food Sci.* **2008,** *73* (4), C235–C240.

Blekas, G.; Vassilakis, C.; Harizanis, C.; Tsimidou, M.; Boskou, D. G. Biophenols in Table Olives. *J. Agr. Food Chem.* **2002,** *50,* 3688–3692.

Boskou, D. Sources of Natural Phenolic Antioxidants. *Trends Food Sci. Tech.* **2006,** 17, 505–512.

Boskou, G.; Salta, F. N. S.; Chrysostomou, C.; Mylona, A.; Chiou, F.; Andrikopoulos, N. Antioxidant Capacity and Phenolic Profile of Table Olives from the Greek Market. *Food Chem.* **2006,** *94,* 558–564.

Bouaziz, M.; Grayer, R. J.; Simmonds, M. S.; Damak, M.; Sayadi, S. Identification and Antioxidant Potential of Flavonoids and Low Molecular Weight Phenols in Olive Cultivar Chemlali Growing in Tunisia. *J. Agr. Food Chem.* **2005,** *53,* 236–241.

Brenes, M.; Garcia, P.; Duran, M. C.; Garrido, A. Concentration of Phenolic Compounds Change in Storage Brines of Ripe Olives. *J. Food Sci.* **1993,** *58,* 347–350.

Brenes, M.; Rejano, L.; Garcia, P.; Sanchez, A. H.; Garrido, A. Biochemical Changes in Phenolic Compounds during Spanish-Style Green Olive Processing. *J. Agr. Food Chem.* **1995,** *43,* 2702–2706.

Brenes, M.; de Castro, A. Transformation of Oleuropein and Its Hydrolysis Products during Spanish-style Green Olive Processing. *J. Sci. Food Agr.* **1998,** *3*, 353–358.

Brenes-Balbuena, M.; Garcia-Garcia, P.; Garrido-Fernandez, A. Phenolic Compounds Related to the Black Color Formed during the Processing of Ripe Olives. *J. Agr. Food Chem.* **1992,** *40,* 1192–1196.

Briante, R.; La Cara, F.; Febbraio, F.; Barone, R.; Piccialli, G.; Carolla, R.; Nucci, R. Hydrolysis of Oleuropein by Recombinant β-Glycosidase from Hyperthermophilic Archaeon *Sulfolobus Solfataricus* Immobilised on Chitosan Matrix. *J. Biotechnol.* **2000,** *77,* 275–286.

Campestre, C.; Marsilio, V.; Lanza, B.; Iezzi, C.; Bianchi, G. Phenolic Compounds and Organic Acids Change in Black Oxidized Table Olives. *Acta Hort.* **2000,** *586,* 575–578.

Camposeo, S.; Godini, A. Preliminary Observations about the Performance of 13 Varieties According to the Super High Density Oliveculture Training System in Apulia (Southern Italy). *Adv. Hort. Sci.* **2010,** *24,* 16–20.

Camposeo, S.; Vivaldi, G. A.; Gattullo, C. E. Ripening Indices and Harvesting Times of Different Olive Cultivars for Continuous Harvest. *Sci. Hort.* **2013,** *151,* 1–10.

Cardoso, S. M.; Guyot, S.; Marnet, N.; Lopes-Da-Silva, J. A.; Renard, C. M.; Coimbra, M. A. Characterisation of Phenolic Extracts from Olive Pulp and Olive Pomace by Electrospray Mass Spectrometry. *J. Sci. Food Agr.* **2005,** *85,* 21–32.

Castañeda-Ovando, A.; Pacheco-Hernández, M. D. L.; Páez-Hernández, M. E.; Rodríguez, J. A.; Galán-Vidal, C. A. Chemical Studies of Anthocyanins: A Review. *Food Chem.* **2009,** *113,* 859–871.

Charoenprasert, S.; Mitchell, A. Factors Influencing Phenolic Compounds in Table Olives (Olea Europaea). *J. Agr. Food Chem.* **2012,** *60,* 7081–7095.

Ciafardini, G.; Zullo, B. A. Microbiological Activity in Stored Olive Oil. *Int. J. Food Microb.* **2002,** *75,* 111–118.

Ciafardini, G.; Marsilio, V.; Lanza, B.; Pozzi, N. Hydrolysis of Oleuropein by Lactobacillus Plantarum Strains Associated with Olive Fermentation. *Appl. Environ. Microbiol.* **1994,** *60,* 4142–4147.

Conde, C.; Delrot, S.; Gerós, H. Physiological, Biochemical and Molecular Changes Occurring during Olive Development and Ripening. *J. Plant. Physiol.* **2008,** *165* (15), 1545–1562.

Damak, N.; Bouaziz, M.; Ayadi, M.; Sayadi, S.; Damak, M. Effect of the Maturation Process on the Phenolic Fractions, Fatty Acids, and Antioxidant Activity of the Chétoui Olive Fruit Cultivar, *J. Agr. Food Chem.* **2008,** *56,* 1560–1566.

De Bellis, P.; Valerio, F.; Sisto, A.; Lonigro, S. L.; Lavermicocca, P. Probiotic Table Olives: Microbial Populations Adhering on Olive Surface in Fermentation Sets Inoculated with the Probiotic Strain *Lactobacillus Paracasei* IMPC2. 1 in An Industrial Plant. *Int. J. Food Microb.* **2010,** *140* (1), 6–13.

Eissa, A.; Hafiz, A. Design and Manufacturing of Prototype for Orange Grading Using Phototransistor. *Int. J. Latest Trends Food Sci. Tech.* **2012,** *2* (1), 1–13.

Esti, M.; Cinquanta, L.; La Notte, E. Phenolic Compounds in Different Olive Varieties. *J. Agr. Food Chem.* **1998,** *46,* 32–35.

Fadda, C.; Del Caro, A.; Sanguinetti, A. M.; Piga, A. Texture and Antioxidant Evolution of Naturally Green Table Olives as Affected by Different Sodium Chloride Brine Concentrations. *Grasas Aceites* **2014,** *65,* 1–10.

Fernández, P. S.; George, S. M.; Sills, C. C.; Peck, M. W. Predictive Model of the Effect of CO_2, Ph, Temperature and NaCl on the Growth of *Listeria Monocytogenes*. *Int. J. Food Microbiol.* **1997,** *37* (1), 37–45.

Fernández-Bolaños, J.; Rodriguez, R.; Guillén, R.; Jiménez, A.; Heredia, A. Activity of Cell Wall-Associated Enzymes in Ripening Olive Fruit. *Physiol. Plantarum* **1995,** *93,* 651–658.

Frankel, E. N. Chemistry of Extra Virgin Olive Oil: Adulteration, Oxidative Stability, and Antioxidants. *J. Agr. Food Chem.* **2010**, *58,* 5991–6006.

Garcia, P. G.; Duran Quintana, C. M.; Balbuena, M. B.; Fernandez, A. G. Lactic Fermentation During the Storage of "Alorena" Cultivar Untreated Green Table Olives. *J. Appl. Bacteriol.* **1992,** *73* (4), 324–330.

García Borrego, A.; Romero Barranco, C.; García García, P.; Castro Gómez-Millán, A. D.; Medina Pradas, E.; Brenes Balbuena, M. Method and Device for Removing the Bitterness from Table Olives and Resulting Product. Patent WO 2009106669 (A1), 2009.

Garrido Fernandez. A.; Diez, M. J. F.; Adams, M. R. Table Olives: Production and Processing, Chapman and Hall: London, 1997.

Gikas, E.; Papadopoulos, N.; Tsarbopoulos, A. Kinetic Study of the Acidic Hydrolysis of Oleuropein, the Major Bioactive Metabolite of Olive Oil. *J. Liq. Chromatogr. R. T.* **2006,** *29,* 497–508.

Godini, A.; Mariani R.; Pacifico A.; Palasciano M. Repeatedly Reported but Hitherto Undescribed Olive Cultivars Native to Southern Italy. *Acta Hortic.* **2002,** *586,* 201–204.

Godini, A.; Vivaldi, G.; Camposeo, S. Sidebar: Olive Cultivars Field-Tested in Super-High-Density System in Southern Italy. *California Agr.* **2011,** *65* (1), 39–40.

Gómez-Rico, A.; Fregapane, G.; Salvador, M. D. Effect of Cultivar and Ripening on Minor Components in Spanish Olive Fruits and Their Corresponding Virgin Olive Oils. *Food Res. Intern.* **2008,** *41,* 433–440.

Gorinstein, S.; Martin-Belloso, O.; Katrich, E.; Lojek, A.; Číž, M.; Gligelmo-Miguel, N.; Trakhtenberg, S. Comparison of the Contents of the Main Biochemical Compounds and the Antioxidant Activity of Some Spanish Olive Oils as Determined by Four Different Radical Scavenging Tests. *J. Nutr. Biochem.* **2003,** *14,* 154–159.

Guinda, A.; Rada, M.; Delgado, T.; Gutiérrez-Adánez, P.; Castellano, J. M. Pentacyclic Triterpenoids from Olive Fruit and Leaf. *J. Agr. Food Chem.* **2010,** *8,* 9685–9691.

Hamama, A. A.; Nawar, W. W. Thermal Decomposition of Some Phenolic Antioxidants. *J. Agr. Food Chem.* **1991,** *39,* 1063–1069.

Herrera, M. D.; Rodriguez-Rodriguez, R.; Ruiz-Gutierrez, V. Functional Properties of Pentacyclic Triterpenes Contained in "Orujo" Olive Oil. *Current Nutr. Food Sci.* **2006,** *2,* 45–49.

Kailis, S.; Harris, D. J. *Producing Table Olives.* Landlinks Press/CSIRO Publishing: Collingwood, Australia, 2007.

Kaliora, A. C.; Artemiou, A.; Giogios, I.; Kalogeropoulos, N. The Impact of Fruit Maturation on Bioactive Microconstituents, Inhibition of Serum Oxidation and Inflammatory Markers in Stimulated Pbmcs and Sensory Characteristics of Koroneiki Virgin Olive Oils From Messenia, Greece. *Food Funct.* **2013,** *4,* 1185–1194.

Lanza, B. Nutritional and Sensory Quality of Table Olives. In *Olive Germplasm—The Olive Cultivation, Table Olive and Olive Oil Industry in Italy;* Muzzalupo, I., Ed.; Intech: Rijeka, Croatia, 2012; pp 343–372.

Lavee, S. New table olive varieties intended for harvest facilitation. *In Jornadas Internacionales de la Aceituna de Mesa.* Dos Hermanas: Seville, Spain, March 26–27, 2008. CD-ROM.

Lavermicocca, P.; Valerio, F.; Lonigro, S. L.; De Angelis, M.; Morelli, L.; Callegari, M. L.; Visconti, A. Study of Adhesion and Survival of Lactobacilli and Bifidobacteria on Table Olives With the Aim of Formulating A New Probiotic Food. *Appl. Environ. Microbiol.* **2005,** *71,* 4233–4240.

Leroy, F.; De Vuyst, L. Lactic Acid Bacteria as Functional Starter Cultures for the Food Fermentation Industry. *Trends Food Sci. Tech.* **2004,** *15,* 67–78.

López, F. N.; Romero, C.; Del Carman, D. Q. M.; López, A.; García, P.; Fernández, A. G. Kinetic Study of the Physicochemical and Microbiological Changes in "Seasoned" Olives during the Shelf-Life Period. *J. Agr. Food Chem.* **2005,** *53* (13), 5285–5292.

Lopez, S.; Jaramillo, S.; Bermudez, B. New Benefits of the Fibre in Green Table Olives. In *Virgin Olive Oil, Production, Composition, Uses and Benefits for Man;* De Leonardis, A., Ed.; Nova: New York, 2014; pp 286–300.

Malik, N. S.; Bradford, J. M. Changes in Oleuropein Levels during Differentiation and Development of Floral Buds in "Arbequina" Olives. *Sci. Hort.* **2006,** *110,* 274–278.

Marsilio, V.; Lanza, B. Characterisation of an Oleuropein Degrading Strain of Lactobacillus Plantarum. Combined Effects of Compounds Present in Olive Fermenting Brines (Phenols, Glucose and Nacl) on Bacterial Activity. *J. Sci. Food Agr.* **1998,** *76,* 520–524.

Marsilio, V.; Campestre, C.; Lanza, B. Phenolic Compounds Change during California-Style Ripe Olive Processing. *Food Chem.* **2001,** *74,* 55–60.

Marsilio, V.; Seghetti, L.; Iannucci, E.; Russi, F.; Lanza, B; Felicioni, M. Use of a Lactic Acid Bacteria Starter Culture During Green Olive (*Olea Europaea* L cv *Ascolana Tenera*) Processing. *J. Sci. Food Agr.* **2005,** *85* (7), 1084–1090.

Medina, E.; Morales-Sillero, A.; Ramírez, E. M.; Rallo, P.; Brenes, M.; Romero, C. New Genotypes of Table Olives: Profile of Bioactive Compounds. *Int. J. Food Sci.* Tech. **2012,** *47,* 2334–2341.

Montaño, A.; Sanchez, A. H.; Rejano, L. Method for Determination of Brine Color in Table Green Olives. *Alimentaria* **1988,** *193,* 79–83.

Montilla, M. P.; Agil, A.; Navarro, M. C.; Jiménez, M. I.; García-Granados, A.; Parra, A.; Cabo, M. M. Antioxidant Activity of Maslinic Acid, a Triterpene Derivative Obtained from *Olea Europaea*. *Planta Med.* **2003,** *69* (5), 472–474.

Muzzalupo, I.; Stefanizzi, F.; Perri, E. Evaluation of Olives Cultivated in Southern Italy by Simple Sequence Repeat Markers. *Hort. Sci.* **2009,** *44,* 582–588.

Muzzalupo, I.; Lombardo, N.; Musacchio, A.; Noce, M. E.; Pellegrino, G.; Perri, E.; Sajjad, A. DNA sequence analysis of microsatellite markers enhances their efficiency for germplasm management in an Italian olive collection. J Am. Soc. Hortic. Sci. 2006, 3, 352-359.

Nanos, G. D.; Kiritsakis, A. K.; Sfakiotakis, E. M. Preprocessing Storage Conditions for Green "Conservolea" and "Chondrolia" Table Olives. *Postharvest Biol. Tec.* **2002,** *25,* 109–115.

Panagou, E. Z. Greek Dry-Salted Olives: Monitoring the Dry-Salting Process and Subsequent Physico-Chemical and Microbiological Profile during Storage under Different Packing Conditions at 4 and 20 C. *Food Sci. Technol.* **2006,** *39,* 323–330.

Pereira, J. A.; Pereira, A. P.; Ferreira, I. C.; Valentão, P.; Andrade, P. B.; Seabra, R.; Bento, A. Table Olives From Portugal: Phenolic Compounds, Antioxidant Potential, and Antimicrobial Activity, *J. Agr. Food Chem.* **2006,** *54,* 8425–8431.

Peres, C. M.; Peres, C.; Hernández-Mendoza, A.; Malcata, F. X. Review on Fermented Plant Materials as Carriers and Sources of Potentially Probiotic Lactic Acid Bacteria–With an Emphasis on Table Olives. *Trends in Food Sci. Tech.* **2012,** *26*(1), 31–42.

Piscopo, A.; De Bruno, A.; Zappia, A.; Poiana, M. Antioxidant Activity of Dried Green Olives (Carolea cv.). *LWT—Food Sci. Technol.* **2014,** *58,* 49–54.

Pistarino, E.; Aliakbarian, B.; Casazza, A. A.; Paini, M.; Cosulich, M. E.; Perego, P. Combined Effect of Starter Culture and Temperature on Phenolic Compounds during Fermentation of Taggiasca Black Olives. *Food Chem.* **2013,** *138,* 2043–2049.

Rallo, L.; El Riachy, M.; Rallo, P. The Time and Place for Fruit Quality in Olive Breeding. In *Breeding for Fruit Quality;* Jenks, M. A., Bebeli, P. J., Eds.; John Wiley & Sons: Hoboken, NJ, 2011; pp 323–347.

Rallo, P.; Jiménez, R.; Morales-Sillero, A.; Casanova, L.; Paz Suárez, M. Evaluation of Table-Olive Quality Parameters in Progenies Obtained by Cross-Breeding. *Acta Hort.* **2012,** *949,* 527–531.

Ramírez, E.; García-García, P.; De Castro, A.; Romero, C.; Brenes, M. Debittering of Black Dry-Salted Olives. *Eur. J. Lipid Sci. Tech.* **2013,** *115,* 1319–1324.

Rejano, L.; Sánchez, A. H.; Vega, V. New Trends on the Alkaline Treatment "Cocido" of Spanish-Style Green Table Olives. *Grasas Aceites* **2008,** *59,* 195–202.

Rodriguez-Gomez, F.; Romero-Gil, V.; Garcia-Garcia, P.; Garrido-Fernández, A.; Arroyo-López, F. N. Fortification of Table Olive Packing with the Potential Probiotic Bacteria Lactobacillus Pentosus TOMC-LAB2. *Front. Food Microbiol.* In press.

Rodríguez-Gómez, F.; Bautista-Gallego, J.; Romero-Gil, V.; Arroyo-López, F. N.; Garrido-Fernández, A.; García-García, P. Effects of Salt Mixtures on Spanish Green Table Olive Fermentation Performance. *Food Sci. Technol.* **2012,** *46,* 56–63.

Rodriguez-Gómez, F.; Bautista-Gallego, J.; Arroyo-López, F. N.; Romero-Gil, V.; Jiménez-Díaz, R.; Garrido-Fernández, A.; García-García, P. Table Olive Fermentation with Multifunctional *Lactobacillus Pentosus* Strains. *Food Control* **2013,** *34,* 96–105.

Rodríguez-Gómez, F.; Romero-Gil, V.; Bautista-Gallego, J.; García-García, P.; Garrido-Fernández, A.; Arroyo-López, F. N. Production of Potential Probiotic Spanish-Style Green Table Olives At Pilot Plant Scale Using Multifunctional Starters. *Food Microb.* **2014,** *44,* 278–287.

Rodriguez-Rodriguez, R.; Ruiz-Gutiérrez, V. Vasorelaxant Effects of Oleanolic Acid and Erythrodiol in Pomace Olive Oil. In *Olives and Olive Oil in Health and Disease Prevention*; Preedy, V. R., Watson, R. R., Eds.; Academic Press: Amsterdam, 2010; pp 813–820.

Romero, C.; Brenes, M.; García, P.; Garrido, A. Hydroxytyrosol 4-B-D-Glucoside, An Important Phenolic Compound in Olive Fruits and Derived Products. *J. Agr. Food Chem.* **2002a,** *50,* 3835–3839.

Romero, C.; Garcia, P.; Brenes, M.; García, A.; Garrido, A. Phenolic Compounds in Natural Black Spanish Olive Varieties. *Eur. Food Res. Technol.* **2002b,** *215,* 489–496.

Romero, C.; Brenes, M.; García, P.; García, A.; Garrido, A. Polyphenol Changes during Fermentation of Naturally Black Olives. *J. Agr. Food Chem.* **2004,** *52,* 1973–1979.

Romero, C.; García, A.; Medina, E.; Ruíz-Méndez, M.; Castro, A. D.; Brenes, M. Triterpenic Acids in Table Olives. *Food Chem.* **2010,** *118,* 670–674.

Sahan, Y.; Cansev, A.; Gulen, H. Effect of Processing Techniques on Antioxidative Enzyme Activities, Antioxidant Capacity, Phenolic Compounds, and Fatty Acids of Table Olives. *Food Sci. Biotechnol.* **2013,** *22,* 613–620.

Sánchez, A. H.; Rejano, L.; Montaño, A. Kinetics of the Destruction by Heat of Colour and Texture of Pickled Green Olives. *J. Sci. Food Agr.* **1991,** *54,* 379–385.

Sánchez, A. H.; Montaño, A., Rejano, L. Effect of Preservation Treatment, Light, and Storage Time on Quality Parameters of Spanish-Style Green Olives. *J. Agr. Food Chem.* **1997,** *45,* 3881–3886.

Sánchez, A. H.; García, P.; Rejano, L. Elaboration of Table Olives. *Grasas Aceites* **2006,** *57,* 86–94.

Sánchez Gómez, A. H.; García García, P.; Rejano Navarro, L. Elaboration of table olives. *Grasas Aceites*, **2006**, 1, 86–94

Sánchez, A. H.; Romero, C.; Ramírez, E.; Brenes, M. Storage of Mechanically Harvested Manzanilla Olives under Controlled Atmospheres. *Postharvest Biol. Tec.* **2013,** *81,* 60–65.

Sayavedra-Soto, L. A.; Montgomery, M. W. Inhibition of Polyphenoloxidase by Sulfite. *J. Food Sci.* **1986,** *51* (6), 1531–1536.

Segovia-Bravo, K. A.; Jarén-Galán, M.; García-García, P.; Garrido-Fernández, A. Characterization of Polyphenol Oxidase From the Manzanilla Cultivar (*Olea Europaea Pomiformis*) and Prevention of Browning Reactions in Bruised Olive Fruits. *J. Agr. Food Chem.* **2007,** *55,* 6515–6520.

Segovia-Bravo, K. A.; Jarén-Galán, M.; García-García, P.; Garrido-Fernández, A. Browning Reactions in Olives: Mechanism and Polyphenols Involved. *Food Chem.* **2009,** *114,* 1380–1385.

Segovia-Bravo, K. A.; García-García, P.; López-López, A.; Garrido-Fernández, A. Effect of Bruising on Respiration, Superficial Color, and Phenolic Changes in Fresh Manzanilla Olives (*Olea Europaea Pomiformis*): Development of Treatments to Mitigate Browning. *J. Agr. Food Chem.* **2011,** *59,* 5456–5464.

Servili, M.; Baldioli, M.; Selvaggini, R.; Macchioni, A.; Montedoro, G. Phenolic Compounds of Olive Fruit: One-And Two-Dimensional Nuclear Magnetic Resonance Characterization of Nüzhenide and Its Distribution in the Constitutive Parts of Fruit. *J. Agr. Food Chem.* **1999,** *47,* 12–18.

Sivakumar, G.; Bati, C. B.; Uccella, NHPLC-MS Screening of the Antioxidant Profile of Italian Olive Cultivars. *Chem. Nat. Compd.* **2005,** *41* (5), 588–591.

Sousa, A.; Ferreira, I. C.; Barros, L.; Bento, A.; Pereira, J. A. Effect of Solvent and Extraction Temperatures on the Antioxidant Potential of Traditional Stoned Table Olives "Alcaparras." *Food Sci. Technol.* **2008,** *41,* 739–745.

Sousa, A.; Casal, S.; Bento, A.; Malheiro, R.; Oliveira, M. B. P. P.; Pereira, J. A. Chemical Characterization of "Alcaparras" Stoned Table Olives from Northeast Portugal. *Molecules*, **2011**, *11*, 9025–9040.

Tuna, S.; Akpinar-Bayizit, A. The Use of beta Glucosidase Enzyme in Black Table Olives Fermentation. *Not. Bot. Hort. Agrobot. Cluj.* **2009,** *37* (2), 182–189.

Ünal, K.; Nergiz, C. The Effect of Table Olive Preparing Methods and Storage on the Composıtıon and Nutrıtıve Value of Olives. *Grasas Aceites* **2003,** *54,* 71–76.

Valero-Muñoz, M.; Martín-Fernández, B.; Ballesteros, S.; Quintela, J. C.; Lahera, V.; Las Heras, N. Protective Effect of a Pomace Olive Oil Concentrated in Triterpenic Acids in Alterations Related to Hypertension in Rats: Mechanisms Involved. *Mol. Nutr. Food Res.* **2014,** *58* (2), 376–383.

Zoidou, E.; Melliou, E.; Gigas, E.; Tsarbopoulos, A.; Magiatis, P.; Skaltsounis, A. Identification of Throuba Thassos, a Traditional Greek Table Olive Variety, as a Nutritional Rich Source of Oleuropein. *J. Agr. Food Chem.* **2010,** *58,* 46–50.