Olea europaea

Scientific Name

***Olea europaea* L.**

Synonyms

Olea officinarum Crantz, *Olea pallida* Salisb.

Family

Oleaceae (Synonyms include: Bolivariaceae, Forestieraceae, Fraxinaceae, Jasminaceae, Lilacaceae nom. illeg., Nyctanthaceae, Syringaceae).

Common/English Names

Black Olive, Common Olive, Cultivated Olive, European Olive, Green Olive, Iberian Olive, Mediterranean Olive, Olive, Olive Tree, Pickling Olive, Pyrene Oil.

Vernacular Names

Albanian: Ullir;
Amharic: Oliva, Wayra, Zayt;
Arabic: Zeitoun, Zeytoon, Zeytun, Zitoon, Zitun;
Armenian: Jitabdoogh, Jitaptugh, Jiteni, Zeytoon, Zeytun;
Azeri: Zeytun;
Basque: Oliba, Oliondo;
Belarusian: Aliva;
Brazil: Azeitona, Olive, Oliveira (Portuguese);
Bulgarian: Maslina;
Chinese: Qi-Dun-Guo, Ch'i- Tun-Kuo, Yang-Gan-Lan, Yang-Kan-Lan, Gan Lan Shu, Mu Xi Lan, Yuan Ya Zhong;
Croatian: Maslina;
Cyprus: Elea;
Czech: Oliva Evropská, Olivovník;
Danish: Oliven, Olietrae, Oliventrć;
Dhivehi: Zaithooni;
Dutch: Olijf, Olijfboom;
Eastonian: Őlipuus, Euroopa Őlipuu, Oliiv;
Esperanto: Olivo;
Farsi: Zeitun;
Finnish: Öljypuu;
French: Olive, Olive Commune, Olivier, Olivier De Culture;
Frisian: Oliif;
Gaelic: Ola, Sgolag;
German: Ölbaum, Olive, Olivenbaum;
Greek: Elia, Oleia;
Hebrew: Zayit;
Hungarian: Európai Olajfa, Olajfa, Olajbogyó (Tree), Olíva;
Icelandic: Ólífa;
India: Olibh, Jolpai (Bengali), Oliv (Gujerati), Zaitun, Jaitun, Jalapai (Hindu), Aliv, Julipe, Julpai (Kannada), Oleevu, Oli (Malayalam), Jaitun (Punjabi), Alivceti, Caitun, Cimaikkalikacceti, Cimaikkalikam, Olivai, Olivu, Saidun (Tamil), Jaitun (Telugu), Zaitun (Urdu);

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Indonesian: Zaitun;
Irish: Ológ;
Italian: Oliva, Olivo, Ulivo;
Japanese: Oriibu, Oriibu No Ki;
Kazakh: Zäytwn, Zäytün Ağaşı (Tree);
Korean: Ol Li Bu;
Latin: Olea, Oliva;
Latvian: Olīvas;
Lithuanian: Alyvos, Europinis Alyvmedis;
Macedonian: Maslinka, Maslinovo Drvo (Tree), Maslinov Zejtin (Oil);
Malaysia: Zaitun;
Maltese: Żebbuġ;
Norwegian: Oliven;
Persian: Zeitun;
Peru: Aceituna;
Philippines: Langis Ng Oliba (Olive Oil), Oliba (Tagalog);
Polish: Drzewko Oliwkowe, Oliwka, Oliwka Europejska;
Portuguese: Azeitona (Fruit), Olivo, Oliveira (Tree);
Romanian: Măslină, Măslin (Tree);
Russian: Oliva, Maslina;
Serbian: Maslina, Maslinov;
Slovak: Oliva, Oliva Európska, Olivovník Európsky;
Slovaščina: Oljka, Oljka Divja;
Spanish: Aceituna, Aceituno, Oliva, Olivo;
Swahili: Zeituni, Mzeituni, Mzaituni;
Swedish: Oliv, Olivträd;
Taiwan: Gan Lan Shu, You Gan Lan;
Tajik: Zrytun;
Thai: Makok;
Turkish: Zeytin;
Turkmen: Zeýtin;
Ukrainian: Oliva;
Uzbek: Zaytun;
Vietnamese: Quả Ôliu (Fruit), Cây Ôliu (Olive Tree), Dầu Oliu(Olive Oil);
Welsh: Olewydden;
Yiddish: Eylbert, Eylbirt, Masline, Olive.

Origin/Distribution

Olive is native to the eastern Mediterranean region from Syria and the maritime parts of Asia minor and northern Iraq at the south end of the Caspian Sea. The olive tree is the oldest known cultivated tree in history. Olives were first cultivated in Africa, and then spread to Morocco, Algiers, and Tunisia. It was first cultivated in Crete and Syria over 5,000 years ago. Around 600 BC olive tree cultivation spread to Greece, Italy and other Mediterranean countries. It was introduced into Australia in the mid nineteenth century and has now become naturalised.

Agroecology

Olive thrives in places with a Mediterranean climate – dry, warm in the summer with a mild winter chill, and plenty of sun. It will also grow in a dry subtropical and sub temperate climate. Olives are now cultivated in many regions of the world with Mediterranean climates, such as South Africa, Chile, Australia, the Mediterranean Basin, Israel, Palestinian Territories and California and in areas with temperate climates such as New Zealand, under irrigation in the Cuyo region in Argentina which has a desert climate. They are also cultivated in the Córdoba Province, Argentina, which has a temperate climate with rainy summers and dry winters or dry subtropical climate in Cuba. Worldwide cultivation is concentrated between 30° and 45° latitudes in the northern and southern hemispheres, from sea-level to 900 m altitude but olive is also found growing at 1,000–3,150 m altitude. In tropical Africa wild olive occurs in montane woodland, rainforest and wooded grassland at these altitudes.

Olive needs full sun for fruit production, but also needs a slight winter chill, a vernalization period of 6–11 weeks below 9°C for the fruit to set. It is frost sensitive, freezing temperatures below −10°C will kill the tree. Frost in spring can damage young shoots and flowers, and the ripening fruits in late autumn. Optimum temperatures for shoot growth and flowering are 18–22°C. Temperatures above 30°C in spring can damage flowers, but the tree can withstand much higher temperatures in summer.

Olives can grow and be productive on a wide range of soils and soil quality. Productive groves

occur on hardpan soils and poor soils except when these are waterlogged, saline or too alkaline (higher than pH 8.5). Deep, well-drained, light-textured soils are preferred. Rich, fertile soils promote productive vegetative growth at the expense of flowering and fruit bearing. Olives will not produce commercial crops without irrigation although they are extremely drought tolerant. Annual precipitation of 500–800 mm per year during the critical growth stage is preferable.

Edible Plant Parts and Uses

Fruit and leaves are edible. Because of its distinct flavour it is often considered a condiment. An edible manna is obtained from the tree. Olive leaves are used in the human diet as an extract, an herbal tea, and a powder. Olives are harvested at the green stage or left to ripen to a rich purple-black color (black olive) and harvested. Olive fruits are widely used, especially in the Mediterranean, as a relish and flavouring for foods. Pickled or otherwise prepared fruits are eaten as relish or used in bread, soups, salads, etc. The fruit is usually pickled or cured with water, brine, oil, salt or lye (2% sodium hydroxide). The lye treatment is necessary to remove a bitter glucoside compound (oleuropein) from the outer tissues of the olive. Oleuropein is highly toxic to bacteria and therefore needs to be removed in order for a fermentation to take place. The optimum fermentation temperature is 24°C. The fermentation period usually takes between 2 and 3 months. Once fermentation is complete, the olives are packed in airtight jars and sterilised which produces a good quality product with a long storage life. The cured fruits are eaten as a relish, stuffed with pimentos or almonds, or used in breads, soups, salads etc. 'Olives schiacciate' are olives picked green, crushed, cured in oil and used as a salad. They can also be dried in the sun and eaten without curing when they are called 'fachouilles'. Olives can also be flavoured by soaking them in various marinades, or removing the pit and stuffing them. Popular flavourings are herbs, spices, olive oil, feta, capsicum (pimento), chili, lemon zest, lemon juice, garlic cloves, wine, vinegar, juniper berries and anchovies.

The fruit (fleshy mesocarp) is also processed into an edible non-drying oil, that is used in salads and cooking and, because of its distinct flavour, is considered a condiment. Olive oil is mono-unsaturated and regular consumption is thought to reduce the risk of circulatory diseases. Olive oil is classified into two main quality classes: cold-pressed unrefined or virgin oil and refined olive oil. Commercially there are several grades of olive oil:

1. Extra Virgin olive oil – top grade and best quality. The oil has less than 1% acidity, the ripe olives have been picked and cold-pressed the same day, and the oil has a strong, green colour with a perfect aroma. Essentially, extra virgin Olive oil has the fruitiest and most pronounced flavour.
2. Virgin olive oil is the next grade. It has less than 2% acidity with good colour and aroma. This may be the result of the second, next day olive pressing or from the second-best grade of olives by cold pressing.
3. Fino or fine olive oil is a blend of extra virgin and virgin olive oils, with an acid content not above 3%.
4. Pure olive oil. This is much lighter in colour with little or no aroma. Pure olive oil is the result of a blend of virgin olive oil and refined olive oil, which is generally extracted from olive pulp, skin and/or pits. Refining is carried out using combination of pressure, heat or chemical solvents.
5. Light olive oil. This oil type is not lower in calories, but has been so finely filtered that is has lost most of its colour, flavour and fragrance. It has a higher smoke point than the other types of olive oil and is well suited to high-temperature frying.
6. Extra light: More of a marketing term than a grade. Usually highly processed, may be mixed with other oils, or may be just pure olive oil grade. The "light" refers to flavour rather than caloric content.
7. Lampante or pomace or cake: not intended for human consumption, and generally used for industrial purposes, such as soap making or lamp oil.

Botany

An evergreen, small, densely branched tree, 6–10 m high with rough grey bark and extensive, moderately deep root system. Branchlets and leaf blades abaxially densely silvery-grey lepidote. Leaves opposite, simple, entire, lanceolate or oblanceolate or narrowly elliptic, 1.5–9 × 0.5–2 cm, apex acute to acuminate, mucronate, base cuneate, upper surface glabrous and grey green (Plates 1 and 2). Flowers white, small, bisexual, 4-merous, subsessile, in axillary cymose panicles, 2–6 cm long. Flower with four-cleft, cup-shaped calyx, white corolla with short tube and 4 elliptical lobes, two short stamens with large anthers, and bifid stigma on a short style. Drupe ellipsoid, 2–3 cm, mesocarp thick and fleshy, epicarp green when immature (Plate 1) becoming red to purplish–black (Plate 2) or ivory-white when ripe and containing one seed, enclosed by the oval and hard endocarp .

Plate 1 Unripe green olives and leaves

Plate 2 Ripe, purplish-red olives and leaves

Nutritive/Medicinal Properties

The food value of ripe, canned, jumbo-super colossal olive per 100 g edible portion is: water 84.34 g, energy 81 kcal (339 kJ), protein 0.97 g, total lipid 6.87 g, carbohydrate 5.61 g, total dietary fibre 2.5 g, Ca 94 mg, Fe 3.32 mg, Mg 4 mg, P 3 mg, K 9 mg, Na 898 mg, Zn 0.22 mg, Cu 0.226 mg, Mn 0.020 mg, Se 0.9 µg, vitamin C 1.5 mg, thiamine 0.003 mg, niacin 0.022 mg, pantothenic acid 0.015 mg, vitamin B-6 0.012 mg, total choline 6.6 mg, vitamin A (RAE) 17 µg, vitamin A, 346 IU, lutein + zeaxanthin 510 µg, vitamin E (α-tocopherol) 1.65 mg, vitamin K (phylloquinone) 1.4 µg, total saturated fatty acids 0.909 g, 16:0 (palmitic acid) 0.758 g, 18:0 (stearic acid) 0.152 g; total monounsaturated fatty acids 5.0711 g, 16:1 undifferentiated (palmitoleic acid) 0.055 g, 18:1 undifferentiated (oleic acid) 4.995 g, 20:1 (gadoleic acid) 0.021 g; total polyunsaturated fatty acids 0.586 g, 18:2 undifferentiated (linoleic acid) 0.544 g, 18:3 undifferentiated (linolenic acid) 0.041 g, threonine 0.031 g, isoleucine 0.036 g, leucine 0.058 g, lysine 0.038 g, methionine 0.014 g, phenylalanine 0.034 g, tyrosine 0.027 g, valine 0.044 g, arginine 0.078 g, histidine 0.027 g, alanine 0.050 g, aspartic acid 0.107 g, glutamic acid 0.108 g, glycine 0.057 g, proline 0.047 g and serine 0.036 g (USDA 2011).

The food value of olive oil used for cooking or salad per 100 g edible portion is: energy 884 kcal (3,699 kJ), total lipid 100 g, Ca 1 mg, Fe 0.56 mg, K 1 mg, Na 2 mg, total choline 0.3 mg, betaine 0.1 mg, vitamin E (α-tocopherol) 14.35 mg, β-tocopherol 0.11 mg, γ-tocopherol 0.83 mg, vitamin K (phylloquinone) 60.2 µg, total saturated fatty acids 13.808 g, 16:0 (palmitic acid) 11.20 g, 17:0 (margaric acid) 0.022 g, 18:0 (stearic acid) 1.953 g, 20:0 (arachidic acid) 0.0414 g, 22:0 (behenic acid) 0.129 g; total monounsaturated fatty acids 72.961 g, 16:1 undifferentiated (palmitoleic acid) 1.255 g, 17:1 0.125 g, 18:1 undifferentiated (oleic acid)

71.269 g, 20:1 (gadoleic acid) 0.311 g; total polyunsaturated fatty acids 10.523 g, 18:2 undifferentiated (linoleic acid) 9.762 g, 18:3 undifferentiated (linolenic acid) 0.761 g and phytosterols 221 mg (USDA 2011).

The following phenolic compounds were reported in virgin olive oil (Bendini et al. 2007):

Benzoic and derivatives acids: 3-hydroxybenzoic acid, p-hydroxybenzoic acid, 3,4-dihydroxybenzoic acid, gentisic acid, vanillic acid, gallic acid, syringic acid;

Cinnamic acids and derivatives: o-coumaric acid, p-coumaric acid, caffeic acid, ferulic acid, sinapinic acid;

Phenyl ethyl alcohols: tyrosol [(p-hydroxyphenyl)ethanol] or p-HPEA 4-OH, hydroxytyrosol [(3,4-dihydroxyphenyl)ethanol] or 3,4-DHPEA;

Other phenolic acids and derivatives: p-hydroxyphenylacetic acid, 3,4-dihydroxyphenylacetic acid, 4-hydroxy-3-methoxyphenylacetic acid; 3-(3,4-Dihydroxyphenyl) propanoic acid;

Dialdehydic forms of secoiridoids: decarboxymethyloleuropein aglycon (3,4-DHPEA-EDA), decarboxymethyl ligstroside aglycon (p-HPEA-EDA) [EDA- elenolic acid];

Secoiridoid aglycons: oleuropein aglycon or 3,4-DHPEA-EA, ligstroside aglycon or p-HPEA-EA, aldehydic form of oleuropein aglycon, aldehydic form ligstroside aglycon;

Flavonols: (+)-taxifolin;

Flavones: apigenin, luteolin;

Lignans: (+)-pinoresinol, (+)-1-acetoxypinoresinol, (+)-1-hydroxypinoresinol;

Hydroxyisochromans: 1-phenyl-6,7-dihydroxyisochroman, 1-(3′-methoxy-4′-hydroxy) phenyl-6,7-dihydroxyisochroman.

All 18 samples of Portuguese olive oil studied showed similar qualitative profiles of tocopherols and tocotrienols with six identified compounds: α-tocopherol, β-tocopherol, γ-tocopherol, δ-tocopherol, α-tocotrienol and γ-tocotrienol (Cunha et al. 2006). Alpha-tocopherol was the main vitamin E isomer in all samples ranging from 93 to 260 mg/kg. The total tocopherols and tocotrienols ranged from 100 to 270 mg/kg. Geographic origin did not seem to influence the tocopherol and tocotrienol composition of the olive oils under evaluation. Simple phenols (hydroxytyrosol, tyrosol, vanillic acid, vanillin, p-coumaric acid, hydroxytyrosol, and tyrosol acetates), lignans (pinoresinol and 1-acetoxypinoresinol), flavonoids (apigenin and luteolin), and a large number of secoiridoid derivatives were identified from polar part of olive oil (Christophoridou et al. 2005). Simple phenols, such as p-coumaric acid, vanillic acid, homovanillyl alcohol, vanillin, free tyrosol, and free hydroxytyrosol, the flavonols apigenin and luteolin, the lignans (+) pinoresinol, (+) 1-acetoxypinoresinol and syringaresinol, two isomers of the aldehydic form of oleuropein and ligstroside, the dialdehydic form of oleuropein and ligstroside lacking a carboxymethyl group, and finally total hydroxytyrosol and total tyrosol reflecting the total amounts of free and esterified hydroxytyrol and tyrosol, respectively were identified in the polar fraction of extra virgin olive oil (Christophoridou and Dais 2009). Simple phenols such as hydroxytyrosol, tyrosol, vanillic acid, p-coumaric acid, ferulic acid, and vanillin were found in most of the Spanish virgin olive oils (Brenes et al. 1999). The flavonoids apigenin and luteolin were also found in most of the oils. The dialdehydic form of elenolic acid linked to tyrosol and hydroxytyrosol was also detected, as were oleuropein and ligstroside aglycons. The new compound was elucidated as being that of 4-(acetoxyethyl)-1,2-dihydroxybenzene.Concentrations of hydroxytyrosol, tyrosol, and luteolin increased with maturation of fruits. In contrast, the levels of glucoside aglycons diminished with maturation.

The HPLC chromatograms of the oils of the Meski, Sayali, and Picholine Tunisian olive varieties showed the presence of 15 triacylglycerols (TAG) species, among which triolein (OOO) was the most abundant (21–48%) (Sakouhi et al. 2010). In the Sayali cultivar, OOO was the predominant TAG species followed by palmitydiolein (POO) and linoleoyl-dioleoylglycerol (LOO). However, the minor TAG molecules were represented by α-linolenoyl-linoleoyl-oleoylglycerols (LnLO) and linoleoyl-3(1)-palmitoyl glycerol (LnLP). Human plasma and lipoprotein triacylglycerol concentrations were found to

increase rapidly over fasting values and peaked twice at 2 and 6 h during the 7-h postprandial period (Abia et al. 1999). The triacylglycerols in the lipoprotein fraction at 2 h generally reflected the composition of the olive oil, however, the proportions of the individual molecular species were altered by the processes leading to their formation. Among the major triacylglycerols, the proportion of triolein (OOO; 43.6%) decreased, palmitoyl-dioleoyl-glycerol (POO; 31.1%) and stearoyl-dioleoyl-glycerol (SOO; 2.1%) were maintained and linoleoyl-dioleoyl-glycerol (LOO; 11.4%) and palmitoyl-oleoyl-linoleoyl-glycerol (POL; 4.6%) significantly increased compared with the composition of the triacylglycerols in the olive oil. Smaller amounts of endogenous triacylglycerol (0.8%), mainly constituted of the saturated myristic (14:0) and palmitic (16:0) fatty acids, were also identified. Analysis of total fatty acids suggested the presence of molecular species composed of long-chain polyunsaturated fatty acids of the (n-3) family, docosapentaenoic acid, [22:5(n-3)] and docosahexaenoic acid (DHA), [22:6(n-3)] and of the (n-6) family arachidonic acid, [20:4(n-6)]. The fastest conversion of lipoproteins to remnants occurred from 2 to 4 h and was directly related to the concentration of the triacylglycerols in the lipoprotein particle. The rates of clearance were significantly different among the major triacylglycerols (OOO, POO, OOL (dioleoyl-linoleoyl-glycerol) and POL) and among the latter ones and PLL (palmitoyl-dilinoleoyl-glycerol), POS (palmitoyl-oleoyl-stearoyl-glycerol) and OLL (oleoyl-dilinoleoyl-glycerol). OOO was removed faster and was followed by POO, OOL, POL, PPO (dipalmitoyl-oleoyl-glycerol), SOO (stearoyl-dioleoyl-gylcerol), PLL, POS and OLL. The main phenols found in Cornicabra virgin oils were the dialdehydic form of elenolic acid linked to tyrosol (p-HPEA-EDA), oleuropein aglycon, and the dialdehydic form of elenolic acid linked to hydroxytyrosol (3,4-DHPEA-EDA) (Gómez-Alonso et al. 2002). The five variables that most satisfactorily characterised the principal commercial Spanish virgin olive oil varieties were 1-acetoxypinoresinol, 4-(acetoxyethyl)-1,2-dihydroxybenzene (3,4-DHPEA-AC), ligstroside aglycon, p-HPEA-EDA, and RT 43.3 contents.

Olive seed is the only seed known to contain albumen. The fruit pulp was found to be rich in oil and potassium and to contain 50–60% (by weight) water, 15–30% oil, 2.5%, N-matter, 3–75% sugars, 3–6% cellulose, 1–2% ash, 2–2.5% polyphenols (Duran 1990). Olive oil was reported to contain a high percentage of the monounsaturated oleic acid; and the unsaponifiable fraction of olive oil comprises phenol, tocopherols, chlorophyll, pheophytin, carotene, squalene and aroma components, all imparting a high nutritional and biological value, resulting in good human health (Kiritsakis 1998, 1999). Olive oil, as a highly monounsaturated oil, is resistant to oxidation. Also the presence of phenols, tocopherols and other natural antioxidants prevent lipid oxidation within the body eliminating the formation of free radicals which may cause cancer. The aroma and the flavour compounds of olive oil, as well as the chlorophyll and pheophytin pigments, facilitate the absorption of the natural antioxidants.

Results of studies by Ortega-García and Peragón (2009) suggested the existence of a coordinated response between phenylalanine ammonia-lyase, polyphenol oxidase, and the concentration of total phenols oleuropein, hydroxytyrosol, and tyrosol during ripening in the four Spanish olive varieties. The concentration of total and specific phenols differed between varieties and were altered during ripening. Twenty-two compounds belonging to monosaccharides, disaccharides, trisaccharides, sugar carboxylic acids and alcohols, cyclic polyols (cyclic sugar alcohols), and derived compounds were determined and characterised in the vegetal tissues from olive fruits, leaves, and stems (Gómez-González et al. 2010). The sugar fraction in *O. europaea* is of great relevance because of the role of sugars in the metabolism of lipids, proteins, and antioxidants. Analysis of olive tissue extracts revealed that mannitol and glucose, the primary photosynthetic products along with fructose and sucrose, were the predominant sugar compounds in the investigated samples of the leaves and roots (Cataldi et al. 2000). These sugars constituted more than 90% of the total soluble carbohydrates in olive

tissues. This is not surprising, as mannitol and glucose represent the major transport sugars in olive trees and contribute significantly to osmotic adjustment. Leaf sugar content (g dw) were determined as follows: myo-inositol 14.3 g (1.9%), mannitol 309 g (41%), galactose 4.8 g (0.6%), glucose 370 g (49.2%), sucrose 21.8 g (2.9%), fructose 20.7 g (2.8%), raffinose 2.7 g (0.4%), stachyose 9.7 g (1.2%). Root sugar content were determined as: myo-inositol 2.5 g (0.9%), mannitol 77.9 g (29%), galactose 1.2 g (0.4%), glucose 168 g (62.6%), sucrose 8.5 g (3.2%), fructose 6.5 g (2.4%), raffinose 1.0 g (0.4%), and stachyose 2.7 g (1.0%).

Eight flavonoidic compounds were identified and quantified in leaves of 18 Portuguese olive cultivars: luteolin 7,4′-O-diglucoside, luteolin 7-O-glucoside, rutin, apigenin 7-O-rutinoside, luteolin 4′-O-glucoside, luteolin, apigenin and diosmetin (Meirinhos et al. 2005). Seven phenolic compounds were identified and quantified in olive leaves: caffeic acid, verbascoside, oleuropein, luteolin 7-O-glucoside, rutin, apigenin 7-O-glucoside and luteolin 4′-O-glucoside (Pereira et al. 2007). The principal polyphenols recovered from olive leaves were luteolin 7-O-glucoside, apigenin 7-O-rutinoside and oleuropein, with smaller amounts of luteolin 3′,7-O-diglucoside, quercetin 3-O-rutinoside (rutin), luteolin 7-O-rutinoside and luteolin 3′-O-glucoside (Mylonaki et al. 2008). Two new secoiridoid glycosides, oleuricines A and B, together with five known triterpenoids, β-amyrin, oleanolic acid, erythrodiol, urs-2β,3β-dihydroxy-12-en-28-oic acid, and β-maslinic acid, were isolated from the ethyl-acetate-soluble part of ethanol extract of olive leaf (Wang et al. 2009). Olive fruits, leaves and olive oil are rich source of bioactive phytochemicals that impart a diverse range of pharmacological activities as elaborated below. Olive leaves have been used in the human diet as an extract, an herbal tea, and a powder, and they contain numerous potentially bioactive compounds that may have antioxidant, antihypertensive, antiatherogenic, anti-inflammatory, hypoglycemic, and hypocholesterolemic properties (El and Karakaya 2009). One of these potentially bioactive compounds is the secoiridoid oleuropein, which can constitute up to 6–9% of dry matter in the leaves. Other bioactive components found in olive leaves include related secoiridoids, flavonoids, and triterpenes.

The fruit and compression-extracted oil have a wide range of therapeutic and culinary applications (Waterman and Lockwood 2007). Olive oil also constitutes a major component of the "Mediterranean diet." The chief active components of olive oil include oleic acid, phenolic constituents, and squalene. The main phenolics include hydroxytyrosol, tyrosol, and oleuropein, which occur in highest levels in virgin olive oil and have demonstrated antioxidant activity. Antioxidants are believed to be responsible for a number of olive oil's biological activities. Oleic acid, a monounsaturated fatty acid, has shown activity in cancer prevention, while squalene has also been identified as having anticancer effects. Olive oil consumption has benefit for colon and breast cancer prevention. The oil has been widely studied for its effects on coronary heart disease (CHD), specifically for its ability to reduce blood pressure and low-density lipoprotein (LDL) cholesterol. Antimicrobial activity of hydroxytyrosol, tyrosol, and oleuropein has been demonstrated against several strains of bacteria implicated in intestinal and respiratory infections. Paiva-Martins et al. (2011) studied the structural behaviour of olive oil phenolic compounds hydroxytyrosol, oleuropein and the oleuropein aglycones 3,4-DHPEA-EA and 3,4-DHPEA-EDA-as well as some of their metabolites and established Raman spectroscopy as a rapid, non-destructive and reliable analytical technique for identifying these bioactive components in dietary extracts.

Antioxidant Activity

Olive Fruit

Oleuropein is the abundant phenolic compound in Chemlali olive, and its concentration increases during maturation (Bouaziz et al. 2004). An indirect relationship between oleuropein content in olive fruit and hydroxytyrosol was observed.

Weak changes in the amounts of the other phenolic monomers and flavonoids were also observed. The total phenolic content varied from 6 to 16 g/kg expressed as pyrogallol equivalents with Its highest level at the last maturation period. The antioxidant capacity of olive extracts as measured by the radical scavenging effect on 1,1-diphenyl-2-picrylhydrazyl produced IC_{50} values ranging from 3.2 to 1.5 μg/mL. There was a correlation between antioxidant activity and total phenolic content of samples. The antioxidant activity increased with maturation. This could be attributed to the increase of the total phenol level with fruit development. In another study, eight phenolic monomers and 12 flavonoids were also identified in Chemlali olives (Bouaziz et al. 2005). Oleuropein, a secoiridoid glycoside esterified with a phenolic acid, was the major compound. Five flavonoids were isolated and purified. The antioxidant activity of the extract and the purified compounds was evaluated by measuring the radical scavenging effect on 1,1-diphenyl-2-picrylhydrazyl and by using the beta-carotene-linoleate model assay. Acid hydrolysis of the extract enhanced its antioxidant activity. Hydroxytyrosol and quercetin showed antioxidant activities similar to that of 2,6-di-tert-butyl-4-methylphenol. A hydroxyl group at the ortho position at 3′ on the B ring of the flavonoid nucleus could contribute to the antioxidant activity of the flavonoids.

In a recent study, oleuropein was again the major phenolic compound at all stages of ripeness in the olive Chétoui cultivar. Unexpectedly, both phenolic compounds hydroxytyrosol and oleuropein exhibited the same trends during maturation (Damak et al. 2008). Indeed, the oleuropein levels decreased during the ripening process and were not inversely correlated with the concentrations of hydroxytyrosol. The antioxidant capacity of olive extracts was evaluated by measuring the radical scavenging effect on 1,1-diphenyl-2-picrylhydrazyl and the beta-carotene linoleate model system. The IC_{50} and AAC (Antioxidant Activity Coefficient) values of the olive extracts decreased from 3.68 to 1.61 μg/mL and from 645 to 431, respectively. There was a correlation between the antioxidant activity and the oleuropein concentration. The fatty acid composition was quantified in olive fruit during maturation and showed that fatty acids were characterized by the highest level of oleic acid, which reached 65.2%.

In a more recent study, oleuropein, the major olive fruit biophenolic compound, decreased significantly during all the ripeness stages, and its level decreased from 3.29 g/kg fresh olive (July) to 0.16 g/kg (October) in Dhokar cv. and from 5.7 g/kg (July) to 3.75 g/kg (October) in Chemlali cv (Jemai et al. 2009). This decrease inversely correlated with hydroxytyrosol concentrations until September. DPPH and ABTS assays showed that the more important antioxidant capacity of olive extracts was found at the last stage of maturation. The data obtained during the ripening indicated that polyphenol content and composition, in particular the oleuropein concentration, were in correlation with the measured beta-Glucosidase and esterase enzymatic activities. Glucosidase and esterase showed their maximum values in September reaching 179.75 and 39.03 U/g of olive pulp, respectively. Glucose and mannitol were the main sugars; they reached their highest level at the last stage of ripening: 8.3 and 79.8 g/kg respectively.

Some common phenolic compounds in identified in the extracts of leaves, fruits and seeds of olive, were verbascoside, rutin, luteolin-7-glucoside, oleuropein and hydroxytyrosol (Silva et al. 2006). Nüzhenide was also found in olive seeds and an oleuropein glucoside was also detected in olive tree leaves. There was a correlation between total antioxidant activity and total phenolic content with the exception of the seed extracts analysed. The apparent high antioxidant activity of seed extracts may be due to nüzhenide, a secoiridoid the major phenolic component of olive seeds. These results suggested a possible application of olive seeds as sources of natural antioxidants.

Studies also reported that olive polyphenols were absorbed and metabolized within the body, occurring in plasma mainly in the conjugated form with glucuronic acid and reaching C(max) in 1–2 hours after consumption (Kountouri et al. 2007). Excretion rates were maximum at 0–4 hours.

Tyrosol and hydroxytyrosol increased in plasma after intervention and total antioxidant potential increased. The results indicated that olive polyphenols possessed good bioavailability, which was in accordance with their antioxidant efficacy.

Olive Oil

Olive oil is the principal source of fats in the Mediterranean diet, which has been associated with a lower incidence of coronary heart disease and certain cancers (Visioli et al. 2002). Phenolic compounds, e.g., hydroxytyrosol and oleuropein, in extra-virgin olive oil are responsible for its peculiar pungent taste and for its high stability. Recent findings demonstrated that olive oil phenolics are powerful antioxidants, both in-vitro and in-vivo, and possess other potent biological activities that could partially account for the observed healthful effects of the Mediterranean diet. Accordingly, the incidence of coronary heart disease and certain cancers is lower in the Mediterranean area, where olive oil is the dietary fat of choice. The low EC_{50} values indicated both hydroxytyrosol and oleuropein compounds to be potent scavengers of superoxide radicals and inhibitors of neutrophils respiratory burst: whenever demonstrated in-vivo, these properties may partially explain the observed lower incidence of CHD and cancer associated with the Mediterranean diet (Visioli et al. 1998) Studies showed that extra virgin olive oils (EVOOs) with a low degradation level had a higher content of dialdehydic form of elenolic acid linked to 3′,4′-DHPEA (3′,4′-DHPEA-EDA) and a lower content the oleuropein derivatives hydroxytyrosol (3′,4′-dihydroxyphenylethanol, 3′,4′-DHPEA) than oils having intermediate and advanced degradation levels (Lavelli 2002). EVOOs with a low degradation degree were 3–5 times more efficient as 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) scavengers and 2 times more efficient as inhibitors of the xanthine oxidase – catalyzed reaction than oils with intermediate and advanced degradation levels. The diaphorase (DIA)/NADH/juglone – catalyzed reaction was inhibited by EC_{50} values having low or intermediate degradation levels but not by the most degraded oils. The secoiridoid compounds typical of extra virgin olive oils (EVOOs) were the oleuropein and ligstroside derivatives, hydroxytyrosol, tyrosol, and tocopherols (Lavelli and Bondesan 2005). Destoning lowered slightly the α-tocopherol content in EVOOs but increased the total secoiridoid content and the antioxidant activity of EVOOs (up to 3.5-fold) as evaluated by the xanthine oxidase/xanthine system, generating superoxide radical and hydrogen peroxide, and by the 2,2-diphenyl-1-(2,4,6-trinitrophenyl) hydrazyl test.

In a double-blind, randomized, crossover study, 3 olive oils with low (LPC), moderate (MPC), and high (HPC) phenolic content were given as raw doses (25 ml/day) for 4 consecutive days preceded by 10-day washout periods to 12 healthy men (Weinbrenner et al. 2004). Short-term consumption of olive oils was found to decrease plasma oxidized LDL (oxLDL), 8-oxo-dG in mitochondrial DNA and urine, malondialdehyde in urine and increased HDL cholesterol and glutathione peroxidase activity in a dose-dependent manner. At day 4, oxLDL after MPC and HPC, and 8-oxo-dG after HPC administration (25 ml, respectively), were reduced when the men were in the postprandial state. Phenolic compounds in plasma increased dose dependently during this stage with the phenolic content of the olive oils at 1, 2, 4, and 6 hours, respectively. Their concentrations increased in plasma and urine samples in a dose-dependent manner after short-term consumption of the olive oils. The authors concluded that the olive oil phenolic content modulated the oxidative/antioxidative status of healthy men who consumed a very low-antioxidant diet.

Olive Leaves

Studies showed that the relative abilities of the flavonoids from olive leaf to scavenge the 2,2′-azinobis (3-ethylbenzothizoline-6-sulfonic acid) (ABTS)$\sqrt{+}$ radical cation were influenced by the presence of functional groups in their structure, mainly the B-ring catechol, the 3-hydroxyl group and the 2,3-double bond conjugated with the 4-oxo function (Benavente-García et al. 2000).

For the other phenolic compounds present in olive leaves, their relative abilities to scavenge the ABTS√+radical cation were mainly influenced by the number and position of free hydroxyl groups in their structure. Also, both groups of compounds showed synergic behaviour when mixed, as occurs in the olive leaf. Total flavonoid and phenolic contents were significantly higher in the 80% ethanol extract, butanol, and ethylacetate fractions than hexane, chloroform and water fractions of olive leaf (Lee et al. 2009). Oleuropein was identified as a major phenolic compound with considerable contents in these major three fractions and the extract that correlated with their higher antioxidant and radical scavenging. Olive leaf was found to be a robust source of bioactive flavonoids regardless of sampling parameters such as olive cultivar, leaf age or sampling date (Goulas et al. 2010). Total flavonoids accounted for the 13–27% of the total radical scavenging activity assessed using HPLC-DPPH protocol. Luteolin 7-O-glucoside was one of the dominant scavengers (8–25%). Based on frequency of appearance, the contribution of luteolin (3–13%) was also considered important. Both the individual and combined phenolics from olive leaves exhibited good radical scavenging abilities, and also revealed superoxide dismutase (SOD)-like activity (Lee and Lee 2010).

Olive Mill Wastewater

Ingestion of an olive mill wastewater (OMWW) preparation containing olive phenolics by 98 healthy individuals found no difference in plasma antioxidant capacity observed between baseline and 1 h after the ingestion of the extract (Visioli et al. 2009). Conversely, a significant increase in total plasma glutathione concentration was measured. This increase involved both the reduced and oxidized forms of glutathione; hence, their ratio was unaffected by the treatment. The observed effects of OMWW on glutathione levels were postulated to be governed by the antioxidant response element (ARE)-mediated increase in phase II enzyme expression, including that of gamma-glutamylcysteine ligase and glutathione synthetase.

Anticancer Activity

Olive Oil

Owen et al., in their reviews in 2000, 2004 asserted olive oil, along with fruits, vegetables, and fish, to be an important constituent of the diet in the Mediterranean basin, and a major factor in preserving a healthy and relatively disease-free population. They presented evidence that it was the unique profile of the phenolic fraction, along with high intakes of squalene and the monounsaturated fatty acid, oleic acid, which confer its health-promoting properties. The major phenolic compounds identified and quantified in olive oil belonged to three different classes: simple phenols (hydroxytyrosol, tyrosol); secoiridoids (oleuropein, the aglycone of ligstroside, and their respective decarboxylated dialdehyde derivatives); and the lignans [(+)-1-acetoxypinoresinol and pinoresinol]. All three classes had been reported to have potent antioxidant properties. Recent studies had shown that olives and olive oil contained antioxidants in abundance. Olives contained acteosides, hydroxytyrosol, tyrosol and phenyl propionic acids. The authors maintained that high consumption of extra-virgin olive oils, particularly rich in the above phenolic antioxidants (as well as squalene, terpenoids and peroxidation-resistant lipid oleic acid), should afford considerable protection against cancer (colon, breast, skin), coronary heart disease, and ageing by inhibiting oxidative stress.

Research findings revealed that oleic acid (18:1n-9), the main olive oil's monounsaturated fatty acid, could suppress the over-expression of HER2 (erbB-2), a well-characterized oncogene playing a key role in the etiology, invasive progression and metastasis in several human cancers through several mechanisms (Menendez and Lupu 2006). First, exogenous supplementation of oleic acid significantly down-regulated HER2-coded p185(Her-2/neu) oncoprotein in human cancer cells. Second, oleic acid exposure specifically repressed the transcriptional activity of the human HER2 gene promoter in tumour-derived cell lines. Third, oleic acid treatment induced the up-regulation of the Ets protein PEA3 (a transcriptional

repressor of the HER2 gene promoter) solely in cancer cells. Fourth, HER2 gene promoter bearing a PEA3 site-mutated sequence cannot be negatively regulated by oleic acid, while treatment with oleic acid failed to repress the expression of a human full-length HER2 cDNA controlled by a SV40 viral promoter. Fifth, oleic acid-induced inhibition of HER2 promoter activity did not occur if HER2 gene-amplified cancer cells did not concomitantly exhibit high levels of fatty acid synthase (FASN; oncogenic antigen-519).

Extra-virgin olive oil (EVOO) polyphenols lignans (i.e. 1-[+]-pinoresinol, 1-[+]-acetoxypinoresinol), flavonoids (i.e. apigenin, luteolin), and secoiridoids (i.e. deacetoxyoleuropein aglycone, ligstroside aglycone, oleuropein glycoside, oleuropein aglycone) were found to drastically suppress fatty acid synthase (FASN) protein expression in HER2 gene-amplified SKBR3 breast cancer cells (Menendez et al. 2008b). Fatty acid synthase (FASN), is a key enzyme involved in the anabolic conversion of dietary carbohydrates to fat in mammals. Equivalent results were observed in MCF-7 cancer cells engineered to overexpress the HER2 tyrosine kinase receptor, a well-characterized up-regulator of FASN expression in aggressive sub-types of cancer cells. EVOO-derived lignans, flavonoids and secoiridoids were significantly more effective than the mono-HER2 inhibitor trastuzumab (approximately 50% reduction) and as effective as the dual HER1/HER2 tyrosine kinase inhibitor lapatinib (≥95% reduction) at suppressing high-levels of FASN protein in HER2-overexpressing SKBR3 and MCF-7/HER2 cells. EVOO single (i.e. tyrosol, hydroxytyrosol, vanillin) and phenolic acids (i.e. caffeic acid, p-coumaric acid, vanillic acid, ferulic acid, elenolic acid) failed to modulate FASN expression in SKBR3 and MCF-7/HER2 cells. These findings revealed for the first time that phenolic fractions, directly extracted from EVOO, may induce anti-cancer effects by suppressing the expression of the lipogenic enzyme FASN in HER2-overexpressing breast carcinoma cells. Further studies showed that EVOO-derived single phenols tyrosol and hydroxytyrosol and the phenolic acid elenolic acid failed to significantly decrease HER2 tyrosine kinase activity (Menendez et al. 2008a, 2009). The anti-HER2 tyrosine kinase activity IC_{50} values were up to 5-times lower in the presence of EVOO-derived lignans and secoiridoids than in the presence of EVOO-derived single phenols and phenolic acids. EVOO polyphenols induced strong tumoricidal effects by selectively triggering high levels of apoptotic cell death in HER2-positive MCF10A/HER2 cells but not in MCF10A/pBABE matched control cells. The researchers asserted that their findings not only molecularly supported recent epidemiological evidence revealing that EVOO-related anti-breast cancer effects primarily affect the occurrence of breast tumours over-expressing the type I receptor tyrosine kinase HER2 but further suggested that the stereochemistry of EVOO-derived lignans and secoiridoids might provide an excellent and safe platform for the design of new HER2 targeted anti-breast cancer drugs.

Virgin olive oil phenols inhibited proliferation of human promyelocytic leukemia cells (HL60) by inducing apoptosis and differentiation (Fabiani et al. 2006). Virgin olive oil phenol extract (PE) inhibited HL60 cell proliferation in a time- and concentration-dependent manner. Cell growth was completely blocked at a PE concentration of 13.5 mg/L; apoptosis was also induced. Two compounds isolated from PE, the dialdehydic forms of elenoic acid linked to hydroxytyrosol (3,4-DHPEA-EDA) and to tyrosol (*p*HPEA-EDA), were shown to possess properties similar to those of PE; they accounted for a part of the potent effects exerted by the complex mixture of compounds present in PE. In a subsequent study, oxidative DNA damage was found to be prevented by extracts of olive oil, hydroxytyrosol, and other olive phenolic compounds in human blood mononuclear cells and HL60 (human promyelocytic leukemia cells) cells (Fabiani et al. 2008). Hydroxytyrosol [3,4-dyhydroxyphenyl-ethanol (3,4-DHPEA)] and a complex mixture of phenols extracted from both virgin olive oil (OO-PE) and olive mill wastewater (WW-PE) reduced the DNA damage at concentrations as low as 1 μmol/L when coincubated in the medium with H_2O_2 (40 μmol/L). At 10 μmol/L 3,4-DHPEA, the

protection was 93% in HL60 and 89% in PBMC. A similar protective activity was also shown by the dialdehydic form of elenoic acid linked to hydroxytyrosol (3,4-DHPEA-EDA) on both kinds of cells. Other purified compounds such as isomer of oleuropein aglycon (3,4-DHPEA -EA), oleuropein, tyrosol, [p-hydroxyphenyl-ethanol (p-HPEA)] the dialdehydic form of elenoic acid linked to tyrosol, caffeic acid, and verbascoside also protected the cells against H_2O_2-induced DNA damage although with a lower efficacy (range of protection, 25–75%). Overall, the results suggested that virgin olive oil and olive mill water waste may efficiently prevent the initiation step of carcinogenesis in-vivo, and the concentrations effective against the oxidative DNA damage could be easily reached with normal intake of olive oil.

Hydroxytyrosol, one of the major polyphenolic constituents of extra virgin olive oil, exerted strong antiproliferative effects against human colon adenocarcinoma cells via its ability to induce a cell cycle block in G2/M by inhibition of ERK1/2 phosphorylation and cyclin D1 expression (Corona et al. 2009). These findings are of particular relevance due to the high colonic concentration of HT compared to the other olive oil polyphenols and may help explain the inverse link between colon cancer and olive oil consumption.

Olive Fruit and Pomace

Studies showed that olive fruit skin extract composed of pentacyclic triterpenes with the main components maslinic acid (73.25%) and oleanolic acid (25.75%) exhibited antiproliferative effect on HT-29 human colon cancer cells (Juan et al. 2006). The dose-dependent effects showed antiproliferative activity at an EC_{50} value of 73.96 μmol/L of maslinic acid and 26.56 μmol/L of oleanolic acid without displaying necrosis. Apoptosis was confirmed by the microscopic observation of changes in membrane permeability in and detection of DNA fragmentation HT-29 cells incubated for 24 hours with olive fruit extract containing 150 and 55.5 μmol/L of maslinic and oleanolic acids, respectively. The extract containing 200 μmol/L maslinic acid and 74 μmol/L oleanolic acid increased caspase-3-like activity to sixfold that of control cells. The results revealed that the inhibition of cell proliferation without cytotoxicity and the restoration of apoptosis in colon cancer cells by maslinic and oleanolic acids present in olive fruit extracts. The anticancer activity observed for olive fruit extracts appeared to originate from maslinic acid but not from oleanolic acid (Juan et al. 2008a). Oleanolic acid showed moderate antiproliferative activity, with an EC_{50} of 160.6 μmol/l, and moderate cytotoxicity at high concentrations. In contrast, maslinic acid inhibited cell growth with an EC_{50} of 101.2 μmol/l, without necrotic effects. Oleanolic acid, lacking a hydroxyl group at the carbon 2 position, failed to activate caspase-3 as a prime apoptosis protease. In contrast, maslinic acid increased caspase-3-like activity at 10, 25 and 50 μmol/l by 3-, 3.5- and 5-fold over control cells, respectively. Studies showed that erythrodiol the precursor of pentacyclic triterpenic acids in olive also exhibited antiproliferative and proapoptotic activity in human colorectal adenocarcinoma HT-29 cells (Juan et al. 2008b). Erythrodiol inhibited cell growth with an EC_{50} value of 48.8 μM without any cytotoxic effects in a concentration range up to 100 μM. However, exposure of cells for 24 h to 50, 100, and 150 μM erythrodiol increased caspase-3-like activity by 3.2-, 4.8-, and 5.2-fold over that in control cells. In another study, maslinic acid, a pentacyclic triterpene, present in high concentrations in olive pomace was found to have antiproliferative activity on HT29 and Caco-2 colon-cancer cell lines (Reyes et al. 2006). At concentrations inhibiting cell growth by 50–80% (IC_{50} HT29 = 61 μM, IC_{80} HT29 = 76 μM and IC_{50} Caco-2 = 85 μM, IC_{80} Caco-2 = 116 μM), maslinic acid induced strong G0/G1 cell-cycle arrest and DNA fragmentation, and increased caspase-3 activity. However, maslinic acid did not alter the cell cycle or induce apoptosis in the non-tumoural intestine cell lines IEC-6 and IEC-18. The data revealed that in tumoral cancer cells, maslinic acid exerted a significant anti-proliferation effect by inducing an apoptotic process characterized by caspase-3 activation by a p53-independent mechanism,

which occurred via mitochondrial disturbances and cytochrome c release.

Olive Leaves

Dry olive leaf extract (DOLE) was found to possess strong antimelanoma potential (Mijatovic et al. 2011). DOLE significantly inhibited proliferation and subsequently restricted clonogenicity of the B16 mouse melanoma cell line in vitro. Moreover, late phase tumour treatment with DOLE significantly reduced tumour volume in a syngeneic strain of mice. DOLE-treated B16 cells were blocked in the G(0)/G(1) phase of the cell cycle, underwent early apoptosis and died by late necrosis. Despite molecular suppression of the proapoptotic process, DOLE successfully promoted cell death mainly through disruption of cell membrane integrity and late caspase-independent fragmentation of genetic material. Fu et al. (2010) demonstrated using tetrazolium salt (MTT)-based assays that olive leaf extracts exhibited dose-dependent inhibitory effects on the metabolic status (cell viability) of three breast cancer models in-vitro. They identified several important isomers of secoiridoids and flavonoids in the extract.

Antiatherosclerotic, Antiatherogenic, Cardioprotective Activities

Recently, several studies had demonstrated olive oil phenolics to be powerful antioxidants, both in-vitro and in-vivo, and to exert additional potent biologic activities that could partially account for the observed cardioprotective effects of the Mediterranean diet (Visioli and Galli 2001). The antioxidant effects associated with olive oil consumption could explain part of this 'Mediterranean Paradox' (Covas et al. 2001). Virgin olive oils processed by two centrifugation phases and with low fruit ripeness were found to have the highest levels of antioxidant content. The total content of phenolic compounds (PC) from virgin olive oil could delay LDL oxidation. The Mediterranean diet, abundant in antioxidants, was found to be associated with a relatively low incidence of coronary heart disease. Olive oil and olives, containing the antioxidants hydroxytyrosol, oleuropein, and tyrosol, were found to be important components of this diet (Rietjens et al. 2007). In the study, hydroxytyrosol (10 μM) efficiently protected the aorta against the cumene hydroperoxide (CHP) induced impairment of the nitric oxide (NO^-)-mediated relaxation of rat aorta. Oleuropein, tyrosol, and homovanillic alcohol, a major metabolite of hydroxytyrosol, did not show protection. Moreover, hydroxytyrosol was found to be a potent OH^- scavenger, attributable to its catechol moiety. In one study, a mixed response was obtained with hydroxytyrosol with regards to its role in atherosclerosis. The study reported that 10 week administration of an aqueous solution of hydroxytyrosol, showed no significant changes in HDL cholesterol, paraoxonase, apolipoprotein B or triglyceride levels (Acin et al. 2006). However, hydroxytyrosol administration decreased apolipoprotein A-I and increased total cholesterol, atherosclerotic lesion areas and circulating monocytes expressing Mac-1. The results indicated that administration of hydroxytyrosol in low cholesterol diets increased atherosclerotic lesion associated with the degree of monocyte activation and remodelling of plasma lipoproteins. The data supported the concept that phenolic-enriched products, out of the original matrix, could be not only non-useful but also harmful.

In a randomized sequential crossover design involving 21 hypercholesterolemic volunteers, intake of the polyphenol-rich (virgin olive oil) breakfast was associated with an improvement in endothelial function, as well as a greater increase in concentrations of nitrates/nitrites (NO_x) and a lower increase in lipoperoxides LPO and 8-epi prostaglandin-F2alpha than the ones induced by the low polyphenol fat meal (Ruano et al. 2005). A positive correlation was found to exist between NOx and enhanced endothelial function at the second hour ($R^2 = 0.669$). Furthermore, a negative correlation was found between Ischemic reactive hyperemia (IRH) and LPO ($R^2 = -0.203$) and 8-epi prostaglandin-F2alpha levels ($R^2 = -0.440$). The results demonstrated that a meal containing high-phenolic virgin olive oil improved ischemic reactive hyperemia during the postprandial state. In another study, lower plasma oxidized LDL and lipid peroxide levels, together

with higher activities of glutathione peroxidase, were observed after Virgin olive oil (VOO) intervention in a placebo controlled, crossover, randomized trial involving 40 males with stable coronary heart disease (Fitó et al. 2005). Systolic blood pressure decreased after intake of VOO in hypertensive patients. No changes were observed in diastolic blood pressure, glucose, lipids, and antibodies against oxidized LDL. The results showed that consumption of VOO, rich in PC, could provide beneficial effects in CHD patients as an additional and complementary intervention to the pharmacological treatment. In another recent placebo-controlled, crossover, randomized trial involving 28 stable coronary heart disease patients, interleukin-6 and C-reactive protein decreased after virgin olive oil intervention over two periods of 3-weeks, preceded by 2-week washout periods (Fitó et al. 2008). No changes were observed in soluble intercellular and vascular adhesion molecules, glucose and lipid profile. In a separate randomized, crossover, controlled study, a linear increase in high-density lipoprotein (HDL) cholesterol levels was observed for low-, medium-, and high-polyphenol olive oil: mean change, 0.025, 0.032, and 0.045 mmol/L, respectively in participants (Covas et al. 2006). Total cholesterol-HDL cholesterol ratio decreased linearly with the phenolic content of the olive oil. Triglyceride levels decreased by an average of 0.05 mmol/L for all olive oils. Oxidative stress markers decreased linearly with increasing phenolic content. Mean changes for oxidized low-density lipoprotein levels were 1.21, −1.48, and −3.21 U/L for the low-, medium-, and high-polyphenol olive oil, respectively. The study showed olive oil to be more than a monounsaturated fat. Its phenolic content could also provide benefits for plasma lipid levels and oxidative damage.

Antiinflammatory Activity

The topical application of the olive oil compounds (0.5 mg/ear) produced a variable degree of antiinflammatory effect with both arachidonic acid (AA) or 12-O-tetradecanoylphorbol acetate (TPA) (de la Puerta et al. 2000). In the auricular edema induced by TPA, β-sitosterol and erythrodiol from the unsaponifiable fraction of the oil showed a potent antiedematous effect with a 61.4% and 82.1% of inhibition respectively, values not very different to that of the reference indomethacin (85.6%) at 0.5 mg/ear. The four phenolics, oleuropein, tyrosol, hydroxytyrosol and caffeic acid exerted a similar range of inhibition (33–45%). All compounds strongly inhibited the enzyme myeloperoxidase, indicating a reduction of the neutrophil influx in the inflamed tissues. The strongest inhibitor of arachidonic acid (AA) edema was the total unsaponifiable fraction with 34% inhibition similar to that obtained by the reference drug dexamethasone at 0.05 mg/ear. Among the phenolics, oleuropein also produced an inhibition of about 30% with the same dose, but all the other components were found less active in this assay. The anti-inflammatory effects exerted by both unsaponifiable and polar compounds might contribute to the potential biological properties reported for virgin olive oil against different pathological processes.

Phenolic compounds from extra virgin olive oil exhibited differential antiinflammatory effects in human whole blood cultures (Miles et al. 2005). Oleuropein glycoside and caffeic acid decreased the concentration of interleukin-1beta. At a concentration of 10(−4) M, oleuropein glycoside inhibited interleukin-1beta production by 80%, whereas caffeic acid inhibited production by 40%. Kaempferol decreased the concentration of prostaglandin E2. At a concentration of 10(−4) M, kaempferol inhibited prostaglandin E2 production by 95%. No effects were seen on concentrations of interleukin-6 or tumour necrosis factor-alpha and there were no effects of the other phenolic compounds. The data showed that some, but not all, phenolic compounds derived from extra virgin olive oil decreased inflammatory mediator production by human whole blood cultures. This may contribute to the antiatherogenic properties ascribed to extra virgin olive oil.

Studies reported that hydrolyzed olive vegetation water had antiinflammatory activity (Bitler et al. 2005). Olive vegetation water (OVW) or waste water is the wash water used in olive oil extraction, in addition to that endogenously

contained in the olives. OVW is a complex emulsion that includes many potentially valuable components, e.g., oil, sugars, polyphenolics, and antioxidants such as,4-dihydroxyphenyl ethanol or hydroxytyrosol (HT), oleuropein and its various derivatives. In lipopolysaccharide (LPS)-treated BALB/c mice, a model system of inflammation, OVW at a dose of 125 mg/mouse (500 mg/kg) reduced serum TNF-α levels by 95%. In the human monocyte cell line, THP-1, OVW reduced LPS-induced TNF-α production by 50% at a concentration of 0.5 g/L (equivalent to ~0.03 g/L simple and polyphenols). OVW had no toxic effects in-vitro or in-vivo. When OVW was combined with glucosamine, a component of proteoglycans and glycoproteins that was shown to decrease inducible nitric oxide synthase production in cultured macrophage cells, the 2 compounds acted synergistically to reduce serum TNF-α levels in LPS-treated mice. These findings suggested that a combination of OVW and glucosamine may be an effective therapy for a variety of inflammatory processes, including rheumatoid and osteoarthritis. Olive vegetation water, a waste product resulting from olive oil extraction, is a source of hydrophilic antioxidants, which are highly prized by the cosmetics and health food sectors.

Studies showed that the n-hexane extract of olive fruit displayed 12.7–27.8% inhibition on the carrageenan-induced hind paw edema model at the 400 mg/kg dose, without inducing any apparent acute toxicity as well as gastric damage (Süntar et al. 2010).

Antidiabetic, Antihyperglycemic Activity

The oral administration of the olive leaves extract (0.1, 0.25 and 0.5 g/kg body wt) for 14 days significantly decreased the serum glucose, total cholesterol, triglycerides, urea, uric acid, creatinine, aspartate amino transferase (AST) and alanine amino transferase (ALT) while it increased the serum insulin in streptozotocin-induced diabetic rats but not in normal rats (Eidi et al. 2009). The antidiabetic effect of the extract was more effective than that observed with glibenclamide (600 μg/kg), a known antidiabetic drug.

Oleanolic acid another constituent of olive plant was shown to be an agonist for TGR5, a member of G-protein coupled receptor activated by bile acids and which mediates some of their various cellular and physiological effect (Sato et al. 2007). Oleanolic acid lowered serum glucose and insulin levels in mice fed with a high fat diet and it enhanced glucose tolerance. The results further emphasized the potential role of TGR5 agonists to improve metabolic disorders. Studies showed that dry olive leaf extract improved pancreatic islet-directed autoimmunity in diabetic mice by down-regulating production of proinflammatory and cytotoxic mediators (Cvjetićanin et al. 2010). In-vivo administration of the extract significantly reduced clinical signs of diabetes (hyperglycaemia and body weight loss) and led to complete suppression of histopathological changes in pancreatic islets. Concurrently, insulin expression and release were restored in extract-treated mice. The results suggested the potential use of a olive leaf extract-enriched diet for prophylaxis/treatment of human autoimmune type 1 diabetes, and possibly other autoimmune diseases.

Antihyperlipidemic/ Hypocholesterolemic Activity

Studies demonstrated that antioxidants, possibly phenolic compounds present only in extra virgin olive oil, may contribute to the endogenous antioxidant capacity of low density lipoprotein (LDL), resulting in an increased resistance to copper-mediated oxidation as determined in vitro (Wiseman et al. 1996). The lag phase before demonstrable oxidation occurred was significantly increased in the high polyphenol, extra virgin olive oil group when compared with combined results from the low polyphenol group (refined olive oil and Trisun high oleic sunflower seed oil), even though the LDL vitamin E concentration in the high polyphenol group was significantly lower. The study demonstrated that antioxidants other than vitamin E may also function against oxidation of LDL in-vitro. In separate studies, extra virgin olive oil intake did not affect fatty

acid composition of LDL but significantly reduced the copper-induced formation of LDL hydroperoxides and lipoperoxidation end products as well as the depletion of LDL linoleic and arachidonic acid in patients with combined hyperlipidemia (Masella et al. 2001). A significant increase in the lag phase of conjugated diene formation was observed after dietary treatment. These differences were statistically correlated with the increase in plasma phenolic content observed at the end of the treatment with extra virgin olive oil; they were not correlated with LDL fatty acid composition or vitamin E content, which both remained unmodified after the added fat change. This report suggested that the daily intake of extra virgin olive oil in hyperlipidemic patients could reduce the susceptibility of LDL to oxidation, not only because of its high monounsaturated fatty acid content but probably also because of the antioxidative activity of its phenolic compounds. In a 2003 study, plasma total cholesterol and LDL cholesterol decreased significantly after 6 weeks of extra virgin olive oil dietary intervention in elderly lipidemic patients (Nagyova et al. 2003). A significant increase in the lag time of conjugated diene formation and the decrease in the rate of lipid oxidation were observed after olive oil consumption. The changes in the fatty acid profile were characterized by an increase in oleic acid content as well as by a decline in the content of linoleic acid and arachidonic acid. The data showed that the daily consumption of extra virgin olive oil in elderly lipidemic patients favourably affected serum lipoprotein spectrum and fatty acid composition that probably contributed to the increased resistance of serum lipids to oxidation.

In one study, all three olive oils differing in their phenolic content, caused an increase in plasma and LDL oleic acid content in a placebo-controlled, double-blind, crossover, randomized supplementation trial during three periods of 3 weeks separated by a 2-week washout period (Gimeno et al. 2007). Olive oils rich in phenolic compounds led to an increase in phenolic compounds in LDL. The concentration of phenolic compounds in LDL was directly correlated with the phenolic concentration in the olive oils. The increase in the phenolic content of LDL could account for the increase of the resistance of LDL to oxidation, and the decrease of the in-vivo oxidized LDL, observed in the frame of this trial. The results supported the hypothesis that a daily intake of virgin olive oil promoted protective LDL changes ahead of its oxidation. In a double-blind, randomized, crossover trial of 33 participants, intervention of refined olive oil (devoid of phenolic content), common olive oil and virgin olive did not modify the concentrations of serum and low-density lipoprotein cholesterol and triacylglycerol; but they exerted changes in the cholesterol, triacylglycerol, and phospholipid content of VLDL (Perona et al. 2011). The virgin olive oil consumption led to increased oleic and palmitic acids, as well as decreased linoleic acid, in very low-density lipoprotein (VLDL) triacylglycerol concentration. The main outcome was the significant dose-dependent linear trend between the phenolic compounds in the olive oils and the palmitic (16:0) and linoleic (18:2 n-6) acid and their corresponding triacylglycerol molecular species in VLDL.

Studies showed that a net effect of oleuropein and hydroxytyrosol, phenols in olive, on Cu2+–induced LDL peroxidation was determined by a balance of their pro- and antioxidant capacities (Briante et al. 2004). Cu^{2+}-Induced LDL oxidation was inhibited by oleuropein and hydroxytyrosol in the initiation phase of the reaction at concentrations of phenols higher than that of Cu^{2+} ions. At lower concentration, both phenols anticipated the initiation process of LDL oxidation, thus exerting prooxidant capacities. It was observed that during Cu^{2+}-induced LDL oxidation in the presence of bioreactor eluates, there was evidence of a synergistic effect among phenolic compounds that enhanced their antioxidant capacities so avoiding the prooxidant effects. A 2008 study showed that the cholesterol-rich diet induced hyperlipidemia resulting in the elevation of total cholesterol (TC), triglycerides (TG) and low-density lipoprotein cholesterol (LDL-C). Administration of polyphenol-rich olive leaf extracts significantly lowered the serum levels of TC, TG and LDL-C and increased the serum level of high-density lipoprotein cholesterol

(HDL-C) (Jemai et al. 2008). Further, the content of thiobarbituric acid reactive substances (TBARS) in liver, heart, kidneys and aorta decreased significantly after oral administration of polyphenol-rich olive leaf extracts compared with those of rats fed a cholesterol-rich diet. In addition, these extracts increased the serum antioxidant potential and the hepatic superoxide dismutase (SOD) and catalase (CAT) activities. These results suggested that the hypocholesterolemic effect of oleuropein, oleuropein aglycone and hydroxytyrosol-rich extracts might be due to their abilities to lower serum TC, TG and LDL-C levels as well as slowing the lipid peroxidation process and enhancing antioxidant enzyme activity.

Administration of a low-dose (2.5 mg/kg of body weight) of hydroxytyrosol and a high-dose (10 mg/kg of body weight) of olive mill wastewaters (OMW) extract to Wistar rats significantly lowered the serum levels of total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) while increasing the serum levels of high-density lipoprotein cholesterol (HDL-C) (Fki et al. 2007). In addition, the TBARS contents in liver, heart, kidney, and aorta decreased significantly after oral administration of hydroxytyrosol and OMW extract as compared with those of rats fed a cholesterol-rich diet. Further, OMW phenolics increased CAT and SOD activities in liver. The results suggested that the hypocholesterolemic effect of hydroxytyrosol and OMW extract might be due to their abilities to lower serum TC and LDL-C levels as well as slowing the lipid peroxidation process and enhancing antioxidant enzyme activity.

Antiobesity Activity

Olive oil and its phenolic compounds improved myocardial oxidative stress in standard-fed conditions (Ebaid et al. 2010). Study in male Wistar rats demonstrated that olive-oil, oleuropein and cafeic-acid enhanced fat-oxidation and optimized cardiac energy metabolism in obesity conditions. Obese-Olive, Obese-Oleuropein and Obese-Cafeic groups had higher oxygen consumption, fat-oxidation, myocardial beta-hydroxyacyl coenzyme-A dehydrogenase and lower respiratory-quotient than obese rats. Citrate-synthase was highest in Obese-Olive group. Myocardial lipid-hydroperoxide (LH) and antioxidant enzymes were unaffected by olive-oil and its compounds in obesity condition, whereas LH was lower and total-antioxidant-substances were higher in standard chow-olive and standard-oleuropein than in standard group.

Results of another study strongly suggested that an olive leaf extract (OLE) containing polyphenols such as oleuropein and hydroxytyrosol reversed the chronic inflammation and oxidative stress that induces the cardiovascular, hepatic, and metabolic symptoms in a rat model of high fat diet-induced obesity and diabetes without changing blood pressure (Poudyal et al. 2010).

Antihypertensive Activity

Susalit et al. (2011) reported on the antihypertensive effect and the tolerability of olive leaf extract in comparison with Captopril in patients with stage-1 hypertension in a double-blind, randomized, parallel and active-controlled clinical study. After 8 weeks of treatment, both the olive and Captopril groups experienced a significant reduction of systolic blood pressure (SBP) as well as diastolic blood pressure (DBP) from baseline; while such reductions were not significantly different between groups. A significant reduction of triglyceride level was observed in Olive group, but not in Captopril group. They concluded that olive leaf extract, at the dosage regimen of 500 mg twice daily, was similarly effective in lowering systolic and diastolic blood pressures in subjects with stage-1 hypertension as Captopril, given at its effective dose of 12.5–25 mg twice daily.

Extracts of African wild olive leaves containing 0.27% 1:1 mixture of oleanolic acid and ursolic acid, named oleuafricein; Greek olive leaves containing 0.71% oleanolic acid and Cape Town cultivar containing 2.47% oleanolic acid in a common dose of 60 mg/kg b.w. for 6 weeks

treatment, prevented the development of severe hypertension and atherosclerosis and improved the insulin resistance of the experimental animals (Somova et al. 2003).

Antiplatelet Activity

Preincubation of platelet rich plasma with 2-(3,4-di-hydroxyphenyl)-ethanol (DHPE), a phenol component of extra-virgin olive oil, for at least 10 minutes resulted in maximal inhibition (Petroni et al. 1995). The IC_{50} (concentration resulting in 50% inhibition) of DHPE for ADP or collagen-induced PRP aggregations were 23 and 67 μM, respectively. At 400 μM DHPE, a concentration which completely inhibited collagen-induced PRP aggregation, thromboxane B2 production by collagen- or thrombin-stimulated PRP was inhibited by over 80%. At the same DHPE concentration, the accumulation of thromboxane B2 and 12-hydroxyeicosatetraenoic acid in serum was reduced by over 90% and 50%, respectively. The effects of PRP aggregation of oleuropein, another typical olive oil phenol, and of selected flavonoids (luteolin, apigenin, quercetin) were found to be much less active. In contrast, a partially characterized phenol-enriched extract obtained from aqueous waste from olive oil showed rather potent activities. The results suggested that components of the phenolic fraction of olive oil could inhibit platelet function and eicosanoid formation in vitro, and that other, partially characterized, olive derivatives share these biological activities.

Olive leaf polyphenols derived from olive leaves inhibited in-vitro platelet activation in healthy, non-smoking males (Singh et al. 2008). The active phenolic compounds in this extract are part of the secoiridoid family, known for their capacity to scavenge H2O2. Blood analysis revealed a significant dose-dependant reduction in platelet activity with olive extract concentrations of 1.0% v/v. The phenol content of high phenol olive oil ranged between 250 and 500 mg/kg, whereas the low phenol olive oil was 46 mg/kg (Dell'Agli et al. 2008). The compounds identified were hydroxytyrosol (HT), tyrosol (TY), oleuropein aglycone (OleA) and the flavonoids quercetin (QU), luteolin (LU) and apigenin (AP). Oleuropein aglycone was the most abundant phenol (range 23.3–37.7%) and luteolin was the most abundant flavonoid in the extracts. Oil extracts inhibited platelet aggregation with an 50% inhibitory concentration interval of 1.23–11.2 μg/ml. The inhibitory effect of individual compounds including homovanillyl alcohol (HVA) followed this order: OleA > LU > HT = TY = QU = HVA, while AP was inactive. All the extracts inhibited cAMP-PDE enzyme, while no significant inhibition of recombinant PDE5A1 enzyme (50 μg/ml) was observed. All the flavonoids and OleA inhibited cAMP-PDE, whereas HT, TY, HVA (100 microm) were inactive. The results indicated that olive oil extracts and some of its phenolic constituents inhibited platelet aggregation partly via cAMP-PDE inhibition. In another study, hydroxytyrosol acetate (HT-AC), a polyphenol present in virgin olive oil, hydroxytyrosol and acetylsalicylic acid inhibited platelet thromboxane B2 and leucocyte 6-keto-prostaglandin F1 alpha (6-keto-PF1 alpha) production (Correa et al. 2009). In quantitative terms HT-AC showed a greater antiplatelet aggregating activity than acetylsalicylic acid and a similar activity to that of acetylsalicylic acid. This effect involved a decrease in platelet thromboxane synthesis and an increase in leucocyte nitric oxide production.

Photopreventive Activity

Oral administration of an olive leaf extract and its component oleuropein separately to mice for 14 days was found to inhibit the increases in skin thickness induced by UVB radiation (Sumiyoshi and Kimura 2010). They also inhibited increases in the Ki-67- and 8-hydroxy-2′-deoxyguanosine-positive cell numbers, melanin granule area and matrix metalloproteinase-13 (MMP-13) expression. These preventive effects on UVB-induced skin damage might be caused in part by inhibiting the degradation of extracellular matrixes in the corium, and by the proliferation of epidermal cells through the inhibition of increases in MMP-13 levels and reactive oxygen species induced by irradiation.

Analgesic/Antinociceptive Activity

Studies showed that olive leaf extract had analgesic property in several models of pain and had useful influence on morphine analgesia in rats (Esmaeili-Mahani et al. 2010). The data showed that the extract (50–200 mg/kg i.p.) produced dose-dependent analgesic effect on tail-flick and hot-plate tests. Administration of 200 mg/kg extract (i.p.) caused significant decrease in pain responses in the first and the second phases of formalin test. In addition, the extract potentiated the antinociceptive effect of 5 mg/kg morphine and blocked low-dose morphine-induced hyperalgesia.

Neuroprotective Activity

Preincubation of brain cells with hydroxytyrosol, from olive mill waste-water, significantly attenuated the cytotoxic effect of both stressors Fe2+ or SNP (a nitric oxide donor), although with different efficiencies (Schaffer et al. 2007). Subchronic, but not acute, administration of 100 mg of hydroxytyrosol per kilogram body weight to mice for 12 days enhanced resistance of dissociated brain cells to oxidative stress, as shown by reduced basal and stress-induced lipid peroxidation. Also, basal mitochondrial membrane potential was moderately hyperpolarized, an effect suggestive of cytoprotection. Overall, the ex-vivo data provided the first evidence of neuroprotective effects of oral hydroxytyrosol intake. Schaffer et al. (2010) confirmed their previous observation of promising cytoprotection of brain PC12 cells by ortho-diphenol hydroxytyrosol (HT)-rich olive mill waste-water extract in different stressor paradigms. Further, correlation analyses revealed that the observed cytoprotective effects in PC12 cells were likely due to HT present in the extract.

Wound Healing Activity

Studies showed that the aqueous extract of *O. europaea* leaves displayed wound healing activity (Koca et al. 2011). The group of animals treated with the aqueous extract demonstrated increased contraction (87.1%) on excision and a significant increase in wound tensile strength (34.8%) on incision models compared to the other groups. Moreover, the antioxidant activity assay showed that aqueous extract had higher scavenging ability than the n-hexane extract. Secoiridoid oleuropein (4.61%) was identified as the major active compound.

Antimicrobial Activity

At low concentrations olive leafs extracts showed an unusual combined antibacterial and antifungal action against gram positive (*Bacillus cereus, B. subtilis* and *Staphylococcus aureus*), gram negative bacteria (*Pseudomonas aeruginosa, Escherichia coli* and *Klebsiella pneumoniae*) and fungi (*Candida albicans* and *Cryptococcus neoformans*) (Pereira et al. 2007). Olive leaf extract was found to be most active against *Campylobacter jejuni, Helicobacter pylori* and *Staphylococcus aureus* [including methicillin-resistant *S. aureus* (MRSA)], with minimum inhibitory concentrations (MICs) as low as 0.31–0.78% (v/v) (Sudjana et al. 2009). In contrast, the extract showed little activity against all other test organisms (n = 79), with MICs for most ranging from 6.25% to 50% (v/v). Given this specific activity, olive leaf extract may have a role in regulating the composition of the gastric flora by selectively reducing levels of *H. pylori* and *C. jejuni*. Oleuropein and caffeic acid from olive leaves showed inhibition effects against microorganisms (Lee and Lee 2010). The antimicrobial effect of the combined phenolics was significantly higher than those of the individual phenolics.

Traditional Medicinal Uses

The olive oil is considered a cholagogue, a nourishing demulcent, emollient and laxative. Consuming the oil was reported to reduce gastric secretions and to be beneficial to patients suffering from hyperacidity. The oil is also used

internally as a laxative and to treat peptic ulcers. It is used externally to treat pruritis, the effects of stings or burns and also as a base for liniments and ointments. Used with alcohol, olive oil is a good hair tonic and used with rosemary oil provides a good treatment for dandruff. Leaves and fruits of olive are used for the treatment of various kinds of diseases, i.e., rheumatism and hemorrhoids, and as a vasodilator in vascular disorders in Turkish folk medicine (Süntar et al. 2010).

The leaves are antiseptic, astringent, febrifuge and sedative. A decoction of leaves have a tranquillising effect on nervous tension and hypertension and is employed for treating obstinate fevers. Externally, leaves can be applied to abrasions.

The bark is regarded ad astringent, bitter and febrifuge. It is said to be a substitute for quinine in the treatment of malaria. In warm countries, the bark exudes a gum-like substance that has been used as a vulnerary.

Other Uses

Low-grade olive oils are used mainly for making soaps, lighting and as lubricant. Maroon and purple dyes are obtained from the whole fresh ripe fruits and blue and black dyes are obtained from the fruit skin. A yellow/green dye is obtained from the leaves. Olive trees are planted to stabilize dry dusty hillsides. The hard and beautiful grained wood is used in turnery and cabinet making, and is much valued.

Olive oil production industry is characterized by relevant amounts of liquid and solid by-products [olive mill wastewater (OMW) and olive husk (OH)], and by economical, technical and organizational constraints that make difficult the adoption of environmentally sustainable waste disposal approaches (Caputo et al. 2003). Waste treatment technologies aimed at energy recovery represent an interesting alternative. Olives are now being looked at for use as a renewable energy source, using waste produced from the olive plants as an energy source that produces 2.5 times the energy generated by burning the same amount of wood. The smoke released has no negative impact on the environment, and the ash left in the stove can be used for fertilizing gardens and plants. The process has been patented in the Middle East and the US.

Comments

The cultivated form of olive probably arose as ancient natural hybrid between the wild *Olea ferruginea* Royle and *O. laperrinii* Battand. & Trab.

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