OLIVE OIL PRODUCTION

By Paul Vossen, Fruit, Vegetable & Marketing Advisor, Sonoma County
University of California Cooperative Extension

INTRODUCTION

The earliest records of Californians producing olive oil date to 1789. The first commercially produced olive oil in California came from the Camulos oil mill in Ventura, established in 1871. By 1885, California olive growers were producing competitive quality oil from several thousand acres of oil varieties planted in coastal and mountain foothill areas. Production increased significantly, but by 1900, prices dropped significantly and growers could no longer compete with seed oils and imported olive oils.

In the early 1900's the canning process was developed to produce the "California Style" olive and a new planting boom started, but this time with table varieties. Since 1945, California's olive oil industry has primarily been a salvage operation utilizing unharvested or cull fruit from the table olive industry. After the decline in olive oil prices in the early 1900s, only a few California oil producers remained.

In the late 1980's, however, resurgence in demand for olive oil in the high quality "gourmet" sector prompted the planting of several small orchards, primarily in the North Coast counties. Many old abandoned orchards have also been rejuvenated in order to harvest and process the fruit. Many of these orchards contain old European varieties or seedlings of unknown origin. Several new olive oil processing mills have been established just in the last few years. There are currently 14 major processing mills for olive oil in California with more in the planning stages, plus several very small scale family size operations.

The estimated acreage devoted to olive oil in 1997 was approximately 1,000 acres of specialty oil varieties. Another 1-2,000 acres of Mission and other varieties are in a semi-abandoned state in old North Coast and Sierra Foothill plantings, and are also harvested for oil.

OIL OLIVE CROP PRODUCTION

Generally, the cultural practices required for oil olive production are also those used for table olives, especially pruning, fertilization, irrigation, and pest and disease control. The main differences between growing table olives and oil olives are cultivar selection, crop load management for fruit size, harvest maturity, and harvest handling. Table olive cultivars are usually larger with a lower concentration of oil. Some dual-purpose cultivars, such as Mission and Piqual, are both large enough for traditional table fruit and very high in oil content.

Fruit size is not a primary concern in oil olives so fruit thinning is not practiced. Table olives are harvested at the green-ripe stage while oil olives are harvested at a more mature stage of ripeness, making them easier to remove from the tree with mechanical harvesters. Table olives must not be bruised in any way during harvest while oil olives do not need to be handled quite so delicately, particularly if they will be processed quickly.

The primary objective when growing olives for oil is to produce a heavy annual tonnage suitable for high-quality oil at low enough cost to earn a profit. Site, cultivar, cultural practices, and especially harvest all influence oil yield, quality, and costs.

Orchard Site

The highest yields for olives come from moderately vigorous trees. Tree vigor is influenced by soil type and water status. An ideal site for oil olive production has soil deep enough for good internal drainage and or a slight slope to improve surface drainage. A clay loam to gravel texture is best, with good water holding capacity. The best, deep sandy loam orchard soils in California, however, should be avoided since they produce trees that grow with excessive vegetative vigor and lower yields.

In California, high production can only be achieved with supplemental summer water to maintain moderate shoot growth for next year's fruit production and fruit size development. Irrigation water is often necessary to maintain fruit turgor in the late season so that fruit will not shrivel and dehydrate excessively. Shriveled fruit produces low quality oil. Olives are semi-tolerant of poor water quality. Levels of boron should be below 1-2 mg/L, EC below 3.0 dS/m, and bicarbonate below 3.5 meq/L.

The site should be free of hard winters and early fall freezing. It should have long hot and dry summers to produce fruit for maximum oil content. The olive is a Mediterranean climate plant, and small wood is injured by temperatures below 25°F (-4°C). Tree death can occur when temperatures fall below 15°F (-9°C). Most of the new oil varieties have not been adequately tested in California to determine their frost susceptibility.

Oil olives are normally harvested at full maturity in November and December. Sites should be avoided where frost probability before maturity is high. Frost injures fruit, and begins a rapid decomposition and oxidation process, rendering the fruit unsuitable for high-quality oil. Late season frosts are a greater risk for oil olives because they are normally harvested in November, December, and January.

Although the new gourmet olive oil industry got its recent start in the North Coast counties, the land costs are extremely high and it is not likely many large scale olive oil producers will locate there. The Central Valley has flatter land, and less expensive water & labor. Flat land makes for easier mechanical harvesting which may be essential for competitive economic production of olive oil.

The two potential advantages the coastal valleys have is the association with fine wines for symbiotic marketing relationships and the real or perceived difference in oil quality that is generally produced in cooler growing regions. No research data has been collected yet with direct comparisons of climatic influences on olive oil quality in California. It is likely, however, that the warmer Central Valley will have an agricultural advantage over the cooler coastal valleys when it comes to olive yields.   Without a significant agricultural advantage, the North Coast head start in premium olive oil production is not apt to result in wide scale economic success

Oil Cultivars

High-quality extra-virgin olive oils are usually made from varietal blends in order to balance the flavor components with shelf life. Oil quantity and quality are highly dependent on the variety. The best oil varieties in the world have developed their reputation over centuries of production for fruit yields, oil content, flavor, keeping quality, maturity date, and ease of harvest.

Most olive cultivars range in oil content from 10 to 35 percent of their fresh weight at full maturity. Growing varieties with an average oil yield of less than 20 percent ~ 45 gallons of oil per fresh ton of fruit are not usually profitable to use for oil.

Of the major olive cultivars grown in California, Manzanillo, Mission, Sevillano, Ascolano, and Barouni, only Mission contains a high enough oil content to plant for oil. The quality of oil made from all of these cultivars can be excellent, but is generally regarded as inferior because they are compared to specific oil varieties with tradition, name recognition, and marketing perception. This is similar to recognized wine varietals in the world.

Flavor components within each cultivar come from the water-soluble flavenoids, phenols, polyphenols, tocopherols, and esters that make up the bitter flavor of fresh olives. These compounds are also naturally occurring antioxidants that extend oil shelf life by reducing rancidity.

Table 1 Primary World Olive Oil Cultivars - Including Several California Table Varieties for Comparison.

CULTIVAR	% OIL	OIL APPRECIATION	FRUIT SIZE	POLYPHENOL CONTENT	PRIMARY COUNTRY
Arbequina	25-27	Very high	Small	Low	Spain
Aglandaou	23-27	High	Medium	Medium	France
Ascolano	15-22	High	Large	Medium	USA
Barouni	13-18	Low	Large	Medium	USA
Bouteillan	20-25	High	Medium	Medium	France
Chemlali	26-28	High	Very Small	High	Tunisia
Coratina	23-27	Very High	Medium	Very High	Italy
Cornicabra	23-27	High	Medium	Very High	Spain
Empeltre	18-25	High	Medium	High	Spain
Frantoio	23-26	Very High	Medium	Medium	Italy
Farga	23-27	High	Medium	Medium	Spain
Koroneiki	24-28	Very High	Very Small	Very High	Greece
Leccino	22-27	Medium	Medium	Medium	Italy
Lucca	22-24	Medium	Medium	Medium	USA
Manzanillo	15-26	Medium	Large	Very High	USA
Maurino	20-25	Medium	Medium	High	Italy
Mission	19-24	Medium	Medium	Medium	USA
Moraiolo	18-28	Medium	Small	Very High	Italy
Pendolino	20-25	Medium	Medium	Medium	Italy
Picudo	22-24	High	Large	Medium	Spain
Piqual/Nevadillo	24-27	Low	Medium	Very High	Spain
Picholine	22-25	High	Medium	Very High	France
Sevillano	12-17	Low	Very Large	Low	USA

The most prominent oil varieties in the world are Piqual, Empeltre, Arbequina, Frantoio, Coratina, Aglandaou, Picholine, Leccino, Chemlali, and Koroneiki. Many of these varieties along with their traditional pollenizer and blending varieties have been introduced into California in the past few years. Several nurseries now offer limited quantities of many of these varieties. Most are under test by UC farm advisors for adaptability to the wide array of growing conditions in California.

Regional adaptability of these oil varieties is within California is not known. In fact, little is known worldwide regarding the performance of different varieties outside their traditional growing regions.

Cultural Practices Influence on Olive Oil

There are many myths surrounding oil quality. In many oil producing regions within countries there are specific varieties, growing techniques, and processing methods used that in most cases have developed from information passed down from one generation to the next. Very little testing has been done to compare varieties between regions or from country to country. In some cases, quality is defined by the particular experiences of a regional people. It also depends on the use of the oil.

An olive oil consists of 98% lipids and 2% unsaponifiable volatiles, polyphenols, pigments, aromas, & flavors. The lipids consist of glycerides and fatty acids such as palmitic, linoleic, and oleic. Linoleic acid increases with olive maturity, palmitic decreases with maturity. Oil viscosity is low (thick) with low linoleic acid content.

The water soluble (unsaponifiable) flavor components of oil typically consist of terpenes 300 to 700 mg/kilo, chlorophyll 0-10 PPM = color & antioxidant, tocopherols - vitamin E & antioxidant, esters - flavor, and phenols & polyphenols 50 to 500 mg/kilo = flavor & antioxidant properties.

Fruit maturity has a strong influence on oil quality just as it does for the flavor components of any fruit. Ripe fruit has a very different flavor than an immature green one. As the olive fruit matures from green to purple-black skin color, the fruitiness increases dramatically. After this point, the fruit flesh turns black all the way to the pit, and is generally regarded as an over-ripe stage. With flesh coloration, the polyphenol and chlorophyll content of the fruit declines, making the fruit less bitter and less stable.

Climate has very little influence on olive oil fatty acid composition (palmitic, linoleic, oleic, etc.). Polyphenol content can be 3-5 times different, however, in one area compared to another. This can have a dramatic effect on flavor. In fertilizer studies in Spain and other Mediterranean countries, there is no influence from soil nutrient content on oil quality or composition. Pruning also has no influence on oil composition or quality parameters.

In general, the polyphenol content of irrigated olives is slightly lower than dry farmed trees. Irrigation can however have a very positive effect on reducing drought stress and dehydration (shrivel) of olive fruit as well as increasing total yields.

Olive Harvest

While olives are on the tree, the oil inside the fruit is in perfect condition (low acidity level, flavorful as to variety, and non-oxidized. Changes that influence quality occur during and after harvest. Harvest methods all vary regarding how much damage they do to the fruit. Hand harvest is the best, but very expensive. If done properly with the right equipment, mechanical harvest can be almost as good and much less expensive. The key is to not break the fruit skin in any way and to process the fruit within a few hours.

Farm labor for olive harvest is expensive ($200 - 400/ton) for hand picking making it the single most expensive aspect of olive growing. In order to help make olive oil production more profitable researchers around the world have been experimenting with various pruning methods, different tree forms, and mechanical or machine assisted harvest. Tree shakers and tarps are used in many countries where land is flat enough and varieties are grown that have fruit that are easily removed from the tree. Hand held vibrating combs that knock the fruit down onto tarps could also significantly reduce costs compared to hand harvest.

Many oil olives around me world are still hand harvested where machine use is not practical. In areas where hand harvest is too expensive and mechanical harvest is impossible the fruit are allowed to fall naturally and then picked up from the ground.

Ground fruit produces a low quality, low value oil that is refined. In many countries, this oil forms the base for low cost oils.

Mechanical harvesting of fruit will be essential to economically rationalize oil olive production in California. Future olive orchards will have to be planted and pruned to accommodate mechanical harvesting of some type. Most production systems do not allow branch development below three feet in order to accommodate a shaker head. High-density plantings (900 trees/acre) using dwarf varieties and over-the-row harvesters are in the early stages of experimental evaluation. A new vibrating-finger type harvester for large trees is also being studied as an alternative to shakers for mechanical fruit removal. These systems should be available in the near future to reduce harvest costs.

One tree form, the central leader system has advantages for better fruit harvest, but comes into bearing later and is difficult to maintain. The bush system attempts to keep the trees low for hand harvest, but hard pruning to limit tree size in olives trees often promotes excessively vigorous vegetative growth. The open center pruned olive tree is still the most popular.

Olive trees tend to be alternate bearing: heavy crops are usually followed by light ones the next year. Cultural practices, such as heavier pruning during flowering, in years with excessive bloom, should be employed to moderate crops from year to year. The best overall oil yields are obtained from moderate crops of 3-6 tons per acre produced on an annual basis. Late January harvesting of black fruit also causes lighter cropping the following year.

The best-quality oil comes from olives matured to the red-ripe stage. Fully mature black fruit yield a "sweeter" oil, but during harvest they are soft and easily damaged. Immature olives that are green or straw colored are sometimes processed because of the unique flavor that less mature fruit impart to oil. The trend is to harvest earlier to achieve an oil with a green color and piquant character. Harvest date, however, is a maze of choices between type of oil desired, long-term stability of the oil, color, and linoleic acid content. For example, with low polyphenol content varieties a one-month delay in harvest can cause a four-month loss in oil stability due to the drop in polyphenol content.

Later harvest usually yields a better percentage of oil per ton of fruit so growers are often interested in harvesting as late as possible to allow the fruit to accumulate the greatest quantity of oil. The olive tree manufactures and stores oil in the fruit throughout the season but the rate of oil storage flattens out before maturity due to low Fight intensity and cool temperatures providing no real gain in oil content. Olives naturally lose moisture in the maturation process. The perceived rise in oil content, late in the growing season, is actually a loss of moisture.

Post harvest handling has a major effect on olive oil quality. Olives left in bins for long

periods before pressing will ferment and mold; the resulting oil must be refined to remove the disagreeable flavor. Olives should be transported in shallow bins to prevent smashing bottom fruit and the bins must have ventilation holes (to reduce fermentation).

If possible olives should not be stored, but harvested, transported to the processing plant and processed immediately. If storage is necessary olives should be kept cool by harvesting in the morning, placed in the shade or in cold storage at 45°F with 90-96% relative humidity. Olives will keep well with little quality deterioration for up to 15 days in cold storage if the fruit is in perfect condition. Fruit quality can be maintained for longer periods with controlled atmosphere storage at 3% CO_2 and 5% O_2.

PROCESSING OLIVE OIL

Olive oil takes on odors and flavors readily. Fruit should be classified and separated by quality. Fruit with defects should be processed separately from good fruit, because a very small portion of bad fruit producing defective oil can ruin a large quantity of good oil.

Washing and Leaf Removal

The purpose of preliminary washing is to remove any foreign material that could damage machinery or contaminate the oil. Only olives that have been harvested from the soil or require removal of copper, sprays, etc. need to be washed. If olives are crushed in a hammermills, the extra moisture from the wash water can cause extractability problems because an emulsion forms between the oil and water.

Polyphenol content is lower in washed olives; there can be as high as a 49% loss in oil stability. Oil sensory ratings for washed olives is usually affected negatively and washed olives generally have a lower bitterness rating, lower "Piquant" rating, and a less fruity flavor. Wash water is often dirty and has a good chance of passing flavors into the oil.

It is important that no fruit remains stuck in the bins and hoppers at the processing plant as it can ferment and ruin the oil. Olives should be stored for as short a period as possible and at cool temperatures (40 - 45° F). Temperatures above 50° F can cause problems. Wet fruit is also much more likely to ferment than dry fruit.

Small quantities of leaves are not detrimental to the oil and sometimes leaves are added to produce a chlorophyll (green) color and flavor in the oil. Branches and wood) material are however very detrimental to olive oil flavor producing a woody taste.

Milling

Olive fruit is made up of approximately 1/3 solid material, 1/3 water, and 1/3 oil. The objective of the first true step of olive oil production, crushing the olives, is to produce a paste with easily extracted oil droplets. Two types of machines are used to crush olives: stone mills and stainless steel hammermills. Each has advantages. A new system just introduced, removes the olive pits prior to crushing.

Stone mills The older of the two methods, stone crushers consist of a stone base and upright millstones enclosed in a metal basin, often with scrapers and paddles to guide the fruit under the stones and to circulate and expel the paste. The slow movement of the stone crushers does not heat the paste and results in less emulsification so the oil is easier to extract without as much mixing (malaxation):

The major disadvantages of this method are the bulky machinery and its slowness, its high cost, and its inability to be continuously operated. The stones are also more difficult to clean, and the slow milling time can increase oxygen exposure and paste fermentation. Stone mills, because of their inefficiency, have been replaced by hammer mills in most large operations.

Hammermills generally consist of a metal body that rotates at high speed, hurling the olives against a metal grate. The major advantage of metal crushers is their speed and continuous operation, which translate into high output, compact size, and low cost. Their major disadvantage is the type of paste produced. The oil is more emulsified, requiring a longer mixing period to achieve a good oil extraction and the speed of metal crushing can produce elevated temperatures and possible metal contamination. Both factors reduce oil quality.

The hammer mill is easier to clean and much faster, allowing for the deployment of a continuous flow system. Oil produced from a hammermills is generally greener since the skins are broken up more. The emulsification problem is overcome by malaxation for a slightly longer period and new stainless steel mills do not impart a metallic flavor into the oil.

The size of the hammer mill mesh should be changed as the season progresses and the fruit becomes riper and softer. A smaller mesh screen is needed to produce a finer paste from firm olives. This improves the break up of the oil cells. As the fruit ripens, the cells break up and oil release is more rapid. A larger mesh screen can be used, and a more coarse paste can be worked.

Mixing of the Olive Paste (Malaxation)

Malaxation prepares the paste for separation of the oil from the pomace. This step is particularly important if the paste was produced in a hammermill. The mixing process optimizes the amount of oil extracted through the formation of larger oil droplets and a reduction of the oil-water emulsion.

The paste is slowly mixed, bringing small droplets of oil in contact with each other to form larger droplets. This improves the extractability of the oil. Optimally, the malaxator is designed to assure thorough mixing, leaving no portion unmixed. Malaxation usually requires 45 minutes to one hour. The longer the contact between the oil and the fruit water, the more the final polyphenol content of the oil is reduced.

Temperature of the paste during malaxation is very important. It should be warm (80° to 86° F, which is still cold to the touch) to improve the viscosity of the oil and improve extractability. Temperatures above 86° F can cause problems such as loss of fruit flavors, increases in bitterness, and increases in astringency.

Sometimes it is difficult to get good oil extraction from certain pastes and it is usually because the olives have too much moisture. The solution is to let the olives sit for a few days in a well-ventilated area, raise the temperature of the paste, or add talc to absorb the excess moisture. A paste moisture content of < 45% is easily worked but moisture content of > 50% is more difficult to extract oil.

Oil Extraction from the Paste

The next step is extracting the oil from the paste and fruit water (water of vegetation). The oil can be extracted by pressing, centrifugation, percolation, or through combinations of the different methods.

Traditional Press: Pressing is the oldest method of oil extraction. The method involves applying pressure to stacked filter mats, smeared with paste, that alternate with metal disks; a central spike allows the expressed oil and water (olive juice) to exit. The machinery, however, is cumbersome, the process requires more labor than other extraction methods, the cycle is not continuous, and the filter mats can easily become contaminated.

Cleanliness of the mats is extremely important. Each time the mats are used small particles of paste plug the filtration channels and can cause a loss of oil. The number one problem with the use of traditional presses is in getting fermentation defects into the oil from the mats. Mats can start to ferment if not used continuously or if not cleaned regularly. The solution is to wash the mats every day, or to use the presses continuously until harvest is finished.

Oil from presses falls into both extremes; producing the best oils when properly operated because they tend to have greater flavor and higher polyphenol content. Many defects, such as fermentation of mats are higher in press systems compared to continuous flow decanters. Studies vary in their conclusions for ratings of oils from presses in sensory analysis: some rate them higher, others lower. Management of the system seems to be the most important variable.

Selective Filtration -Sinolea Process*:* This process is the opposite of the press system since no pressure is applied to the paste. It operates on the principle that in a paste containing solid particles, water and oil the oil alone will adhere to metal. The machine has stainless steel blades that dip into the paste, the adhering oil then drips off the blades into a separate container while the solids and water are left behind. The lack of pressure produces light oil with unique quality and value.

The equipment is complicated and requires frequent cleaning, maintenance of the stainless steel blade mechanisms, and a constant heat source to keep the paste at an even temperature. Extraction is stopped when vegetable water begins to appear in the oil.

Decanters, 3-phase & 2-phase Historically, olive paste, or olive juice containing both water and oil was allowed to sit in containers until the oil, with a lower specific gravity, rose to the top naturally. The oil was then decanted away from the remaining water and solid material. This natural separation takes considerable time and the contact of oil with enzymes, breakdown products and fermenting fruit water produced defective oils. Modern decanters are large horizontal centrifuges that separate the oil from the solids and water in the same process as in a decantation tank, just faster. The savings in time increases the efficiency of the system, but also decreases the time the oil is in contact with the fermenting fruit water.

The decanters spin at approximately 3,000 rpm. Centrifugal force moves the heavier solid materials to the outside; a lighter water layer is formed in the middle with the lightest oil layer on the inside. There is no exact line of separation between the three phases of solid, water, and oil so the solid phase usually has some water in it, the water has some oil in it and the oil contains some water. In the latter case, which extracts the maximum quantity of oil, an additional vertical centrifugation is used to remove more of the vegetation water from the oil.

The 3-Phase system decanter separates the paste into a relatively dry solid, fruit-water, and oil. Water is added to this system to get it to flow through the decanter. A minimum quantity of water is added to separate the solid material better and to retain water-soluble polyphenols as much as possible.

The system should be run at approximately 65 to 70% of maximum capacity to get good separation of phases. Samples should be taken every hour and analyzed daily to determine the status of the separation. Preferably, the solid should have an oil content of no more than 6-7% and 50% moisture while the vegetation water should not contain over 0.3% oil and-8% solids.

2-Phase system decanters were introduced in the early 1990's. They function under the same principle as 3-Phase decanters except that the solid and fruit-water exit together. No water needs to be added to the 2-Phase system.

Experience with the two systems has shown that the 2-Phase system has some advantages, i.e., better retention of polyphenols because no water is added and less loss of oil if the system is operated properly. One problem with the 2-Phase system is a greater potential to lose oil when the olives are low in moisture because there is a thinner interface between the two phases during centrifugation. Another difficulty is less visual evidence of what is happening with waste characteristics because the solid and vegetation water phases are mixed.

Water can be added to the paste just prior to entering the 2-Phase decanter if the moisture content of the olives falls below 42%. Talc (a water absorbing neutral compound) can be added to the paste early in the season, if the olives have an excessive moisture content, to help extract a greater quantity of oil with no negative effect on quality.

Table 2 Differences between Oil Extraction Methods

	PRESS	3-PHASE	2-PHASE
Solid waste Kilos/ton olives	330	500	800
Waste moisture %	25	48	55
Waste water Kilos/ton olives	600	1,200	250
Fruit water moisture **%**	94	90	99
Biological Oxygen Demand PPM of water	100,000	80,000	10,000
Free Acidity %	0.89	0.65	-
Peroxide	6.5	7.9	-
Polyphenol Content PPM	203	164	200
Fermentation	0.75	0.00	0.00
K-232	1.86	2.06	-
Bitterness	1.4	0.5	-

The 2-phase system produces the greatest weight of solid waste because it has the highest moisture content. It also produces the least amount of wastewater with the lowest Biological Oxygen Demand (BOD). The polyphenol content of the oil is lowest in the 3-phase system because of the addition of water.

When very clean oil (containing no water) is obtained from a 2-Phase system, it means that there is a loss of oil to the waste solids because of the limited separation area within the decanter. The solution is to extract oil with some water in it and immediately run it through a vertical centrifuge to clean the oil further.

Vertical Centrifuge Vertical centrifuges spin at two times the velocity of a decanter and

Vertical Centrifuge Vertical centrifuges spin at two times the velocity of a decanter and provides four times the separation force for the solid, water, and oil phases. They provide an additional separation of the three phases to further remove solid particles and water from the oil.

Fresh warm water is added to "clean" the oil, creating a greater interface area between the phases. Many processors use two centrifuges, one for the "wet" oil from the decanter and a second one to separate the oil from the wastewater of the first centrifuge. Added water is only 2-4°F warmer than the water/oil mixture to be separated.

Processing Waste

There are two predominant olive oil processing waste products produced in the press and 3-phase decanter systems, the solid material (pomace), that is relatively dry, and the fruit water, often referred to as water of vegetation. The 2-phase system produces one waste product that is a mixture of the water and solid material. In countries where significant production occurs, the pomace is often sold for further oil extraction with solvents. No plants currently exist in California to make pomace oil.

The water of vegetation (fruit water) can be a significant pollutant because of its high organic load. If added to natural waterways the high biological oxygen demand (BOD) causes damage to aquatic life. Both the solid and liquid portions of the process are composed of the same organic materials as most fruits, leaves, or other organic material left in the field to decompose naturally. Because of the small particle size, however, it is difficult to filter out the pure water from dissolved organic substances.

If these substances decompose anaerobically, disagreeable odors are produced. Incorporation with dry solid materials in order to create aerobic conditions produces compost that can be spread back onto the land. Each city and or county government body regulates the disposal of processing plant waste products. Compost facilities are regulated to minimize odors and leachate runoff. Municipal discharge to sewage systems is expensive.

Oil Storage & Bottling

Premium quality oils should be stored in stainless steel and maintained at a constant temperature of between 45 - 65°F. After processing oil should be stored in bulk for 1-3 months to further settle out any particulate matter and fruit water. Bulk storage and decantation eliminates the problems of sediment in bottles and oil contact with processing water residues that could lead to off flavors in the oil.

The matching of bottling with sales (Just-in-Time Bottling) and delivery to customers in an efficient manner allows oil to be kept in bulk tanks under ideal storage conditions until a batch is being ordered. "New" oils bottled and sold immediately after processing must be consumed quickly (within a few weeks) to avoid flavor changes within the bottle.

OLIVE OIL GRADES & STANDARDS

The International Olive Oil Council (IOOC), has a United Nations charter to develop standards for quality and purity criteria for olive oil. Their main focus is regulating the legal aspects of the olive oil industry and preventing unfair competition. The standards they have developed are recognized by most of the countries of the world. The United States, however, is not a member of the IOOC and is not legally bound by their standards. In the 1950's, the USDA developed minimum standards based on Grade A, B, C, and utility oils, but these standards still exist, but are not in use today.

A private membership organization of oil olive producers and processors in California called the California Olive Oil Council (COOC) has adopted the international standards and is promoting the adoption of these standards by the State of California and the US government. Consumers have become familiar with the international standard and nomenclature that most labels indicate, such as "Extra Virgin Olive Oil," "Virgin Olive Oil", or "Olive Oil".

In 1997, the California legislature enacted a law for labeling olive oil that specifies truth in labeling as to location of production processing and bottling. Bill SB 920 makes it a crime to sell imitation olive oil or to sell olive oil labeled as "California" olive oil that contains oil from any other source. It also specifies that oils labeled according to designated American (USA) approved Viticultural Areas be composed of 75% of oil which is derived solely from olives grown in that designated American Viticultural Area.

The International standards were revised in 1997 to include nine grades of olive oil. The oils must meet certain criteria for inclusion into specific categories. The olive oils must not be adulterated with any other type of oil, pass a sensory analysis by a certified panel of tasters, and meet the analytical criteria of the standard. Table 3 is a summary of the quality criteria standards.

Olive oil is defined as: Oil obtained solely from the fruit of olive trees (Olea europaea sativa). Virgin oils further are obtained solely by mechanical means that do not lead to alterations in the oil. All oils must pass the tests of Free Fatty Acid, Peroxide, UV Absorbency, Water & Volatiles, Insoluble Impurities, Flash Point, Metal Traces, and Halogenated Solvents.

Extra virgin olive oil: Contains no defects and has some positive attributes, as evaluated by the mean of a certified taste panel. Extra-virgin oil also must have a free acidity percentage of less than 1.0 and a peroxide value of less than 20 meq/kg.

Virgin Olive Oil: Oil with a sensory analysis rating of the mean of tasters to have defects from 0 to < 2.5, a free acidity of < 2% and a peroxide value of < 20. An oil of slightly lower quality.

Ordinary Virgin Olive Oil: Oil with a slightly lower organoleptic rating (defects from the mean of tasters 2.5 to < 6.0) and a free acidity of < 3.3% with a peroxide value of < 20.

Virgin Lamp-Oil (Lampante): Oil with many defects, not fit for human consumption, and intended for refining. These oils come from bad fruit.

Refined Olive Oil: Oil obtained from virgin oils by refining methods that do not alter the glyceridic structure.

Olive Oil: Blends of refined and virgin oils.

Crude Olive-Pomace Oil: Oil obtained by treating pomace with solvents and fractional distillation to obtain the residual oil in the pomace. This is the crude product after solvent extraction with intention of further refining for use in human consumption.

Refined Olive-Pomace Oil: **Oil** obtained from crude pomace oil by refining methods that do not alter the initial glyceridic structure.

Olive-Pomace Oil: Blend of refined olive-pomace oil and virgin olive oil fit for human consumption. In no case shall this blend be called "olive oil."

Table 3 Quality Criteria & Standards for Olive Oil (International Olive Oil Council)

	EXTRA VIRGIN	VIRGIN	ORDINARY VIRGIN	LAMP VIRGIN	REFINED OLIVE	OLIVE OIL	CRUDE POMACE	REFINED POMACE	OLIVE POMACE
Organoleptic Characteristics Mean Defects Mean Attribute	= 0 > 0	0< 2.5 > 0	2.5<6.0	>6.0	Acceptable	Good		Acceptable	Good
Free Acidity %	< 1.0.	< 2.0	< 3.3	> 3.3	< 0.3	< 1.5	No limit	< 0.3	< 1.5
Peroxide Value meq/kg	< 20	< 20	< 20	No limit	< 5	< 15	No limit	< 5	< 15
UV Absorbency 270nm ^K	<0.25 <0.01	<0.25 <0.01	<0.30 <0.01	No limit	<1.10 <0.16	<0.90 <0.15		<2.00 <0.20	<1.70 <0.18
H_2O & Volatiles %	<0.2	<0.2	<0.2	<0.3	<0.1	<0.1	<1.5	<0.1	<0.1
Insol. Impurities %	<0.1	<0.1	<0.1	<0.2	<0.05	<0.05		<0.05	<0.05
Flash Point °C							>120°C		
Metal Traces mg/kg Iron Copper	<3.0 <0.1	<3.0 <0.1	<3.0 <0.1	<3.0 <0.1	<3.0 <0.1	<3.0 <0.1		<3.0 <0.1	<3.0 <0.1
Halogenated Solvents mg/kg Each Solvent Sum of Solvents	<O.1 <0.2	<O.1 <0.2	<O.1 <0.2		<O.1 <0.2	<O.1 <0.2		<O.1 <0.2	<O.1 <0.2

Laboratory analysis of oils is used to measure the presence or absence of seed oils in an olive oil. It also measures free acidity and peroxide values which indicates the amount of oxidation and fatty acid chain separation in an oil. Oxidation is the process by which oils break down, turn rancid, and develop spoiled flavors.

SENSORY EVALUATION OF OILS

One of the most important aspects of olive oil classification and value determination is sensory analysis. Human sensory evaluation is much more accurate (100 times) for olive oil than laboratory equipment for certain characteristics. Aroma and taste are very complex and can not be determined in the laboratory. The tongue can also detect texture differences difficult to measure analytically. The first and primary objective in sensory evaluation for olive oil is to determine if oils contain one or more of the defects that commonly occur in oils from improper fruit storage, handling, pest infestation, oil storage, or processing problems.

Olive oil should have a fruity olive flavor that is characteristic of the variety or blend of varieties making up the oil. There should be no vinegary or fermented odor or flavor. The oil should also not be rancid or possess any other off flavor that is essentially not of the olive. The second objective of oil sensory evaluation is to describe the positive characteristics of the oil in relation to its intensity of olive fruity character. This sometimes is described as having similar aromas or flavors similar to other ripe fruits. Table 4 shows a comparison of varietal flavor characteristics from five Italian varieties.

Table 4 Positive Attributes of Several Italian Olive Oil Varieties as Determined through Sensory Analysis

Intensity of Sensory Characteristics - Single Variety Tuscan Oils (Florence 1995)

Variety	Fruity	Green	Bitter	Pungent	Sweet
Frantoio	*****	**	**	****	**
Moraiolo	****	**	****	***	**
Leccino	***	*	*	**	*****
Pendolino	****	*	***	**	***
Maurino	****	**	**	***	****

Bitterness and pungency (piquant) are often present in olive oils, especially when newly made. They are not defects and will mellow as the oils age. They are actually positive aspects of oil because they are related to keeping quality or shelf life. Astringent, bitter, and or pungent oils have a higher polyphenol content and will store much longer than sweet oils with little or no bitter or piquant flavor. Sweetness is an expression of a lack of bitterness, not due to sugar content, and is not a sensory analysis criteria.

In most cases, single varietal oils are not as complex as blended oils and do not possess a balance of fragrance, soft mouth appeal, and full-bodied flavor. Blending offers the opportunity to mask astringency, add longevity to a low polyphenol oil, and create depth.

The California Olive Oil Council is in the process of establishing a certified sensory evaluation taste panel using the methods outlined by the International Olive Oil Council. The panel meets periodically to evaluate olive oils for their members. The University of

California has served to assure an unbiased and blind analysis of oils and suitable training of official tasters.

WORLD OLIVE OIL PRODUCTION & CONSUMPTION

The average world production of olive oil is 1.75 million metric tons or about 507 million gallons per year (olive oil weighs 7.61 pounds per gallon & there are 2,205 pounds per metric ton). On the average, world consumption is 1.85 million metric tons or about 535 million gallons. A holdover from year-to-year assures a steady supply because the range in production is highly variable mostly due to the influence of rainfall in the dry farmed production areas.   Table 5 indicates the production and consumption by selected countries.

Table 5 World Production and Per Capita Consumption of Olive Oil by Selected Countries.

Spain	30	48
Italy	24	46.4
Greece	18	-
Turkey	7	-
Tunisia	7	-
Syria	5	-
Portugal	2.1	-
Argentina	0.4	-
USA	0.1	0.002
UK	0	0.88
Germany	0	0.66

Per capita consumption in Spain and Italy is around 47 cups per person.   As a comparison, the UK consumes 0.88 cups, Germany 0.66 cups, and the USA 0.002 cups per person.   The Spanish and Italians consume 24,000 times more olive oil than Americans do. Traditionally, consumption in most of the non-Mediterranean countries has been very low; however, it has been moderately increasing. Consumption in Europe, Canada, Australia, Japan, Saudi Arabia, France, Portugal, UK, Germany, and the US continues to rise at a steady rate.

Price has a big influence on olive oil consumption in the world commodity market; a limited supply raises prices and demand decreases. In 1997, world production rose by 47%, which replenished low stocks, lowered prices, and increased consumption by 27%. Overall, world consumption trends are up by 2.5%. Production trends are also up due to expanded plantings of olives in Europe, Latin America, USA, and Australia.

The European, and North African countries produce over 99% of the world's olive oil and consume most of it. Although California produces about 160,000 tons of olives on 35,000 acres (4.6 tons/acre each year) most of this is table fruit. Only an estimated 16-17,000 tons (10%) are processed into oil; producing about 325,000 gallons of oil each year (early harvest table olives typically yield <20 gallons of oil per ton).

US consumption of imported olive oil was 115,000 tons in 1992-93 and increased to 130,000 tons (~ 35 million gallons) in 1996-97 (6.5% of world consumption). Sales of olive oil in the USA rose by 12% from 1994 to 1995, by 27% from 1995 to 1996, and again rose by 31% from 1996 to 1997.

The US (mostly California) produces less than one-tenth of I percent of the world's olive oil. That represents just under 1% of the oil consumed in the USA. In order to meet the current USA consumptive demand (average yield of 3 tons/acre and 40 gallons of oil/ton) an estimated 290,000 acres would have to be planted to oil olives in this country.

MARKETING

Spain, the world's largest olive oil producer, exports much of its excess production in bulk to other European Union (EU) countries where it is consumed or repackaged and exported. Italy, the second largest producer, actually consumes more olive oil than it produces, but also imports oil for redistribution and marketing to other countries.

The EU countries pay direct subsidies to their olive growers and processors. Most of the subsidies are in the beginning stages of a 15-year phase out period. They also have marketing campaigns to boost the consumption of olive oil through promotion of the healthful aspects of a Mediterranean diet and regional loyalties. Brand advertising is based on personal taste, confidence in companies, and price aggressiveness. Price is a very important factor in the world commodity market for olive oil.

Recently a gourmet market has developed in the United States for special oils with specific flavor characteristics and a reputation for higher quality. Many of these oils are presented in luxury styled bottles for the gourmet consumer. Labels indicating that the product is produced in California are popular and bring a premium price in the marketplace. Further differentiation as to viticultural appellations or county origins can add a further premium to the gourmet oils. Currently the US market is underdeveloped for olive oil. If the price is reasonable, there is a great potential here for this popular product especially for the health conscious consumer.

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