OLIVE OIL PROCESSING TECHNOLOGY INFLUENCES ON QUALITY

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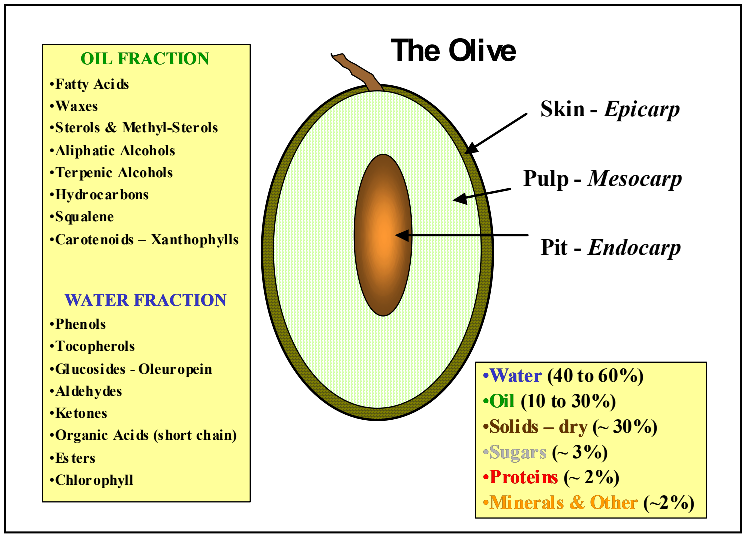

An olive consists of three basic parts: the skin (epicarp), the pulp (mesocarp), and the pit (endocarp). It is made up of about 70 % juice (water and oil) 40 - 60% water and 10 - 30% oil. An olive is about 30% solids on a dry weight basis. The solids are made up of 12 - 25% pit solids, 1 - 3% seed, 8 -10% skin and pulp solids, 3% sugars, 2% proteins, and 2% other compounds such as acids, vitamins, minerals, and pectins. On a dry weight basis, the skin, which represents only about 3% of the fruit weight, contains about 3% oil. The pit represents about 23% of the olive weight and contains about 1% oil. Most of the oil is in the pulp, which represents about 75% of the weight and contains about 50% oil. Not all of the oil can be extracted from the solids with just a physical process, so the solids usually contain about 6-10% oil depending on the variety, maturity, and efficiency of the extraction. The solids contain from 25-70% moisture depending on the processing system used.

The oil fraction is made up of six primary fatty acids: Oleic (55-83%) and Palmitoleic (0.3-3.5%), which are mono-unsaturated; Palmitic (7.5-20%) and Steric (0.5-5.0), which are saturated; and Linoleic (3.5-21%) and Linolenic (0.9-1.5%), which are poly-unsaturated fatty acids. Olive oil is classified as a monounsaturated fat because of the predominance of Oleic acid. Other fatty acids in olive oil at low concentrations are Myristic, Heptadecanoic, Arachidic, Gadoleic, Behenic, and Lignoceric.

Other oil-soluble or semi-oil-soluble compounds in the oil fraction are the waxes, which primarily come from the skin of the fruit. Levels are quite low in virgin olive oil, but appear in higher concentrations when the fruit skins are worked more intensely as in second and solvent extractions of the pomace. The composition and concentration of sterols in olive oil is used primarily to determine its genuiness or authenticity, so that it is labeled correctly in the marketplace. The aliphatic alcohols, terpenes, hydrocarbons, squalene and pigments (carotenoids and xanthophylls) give olive oil some of its flavor and color. They are there in only trace amounts and some are more important than others. The fatty acids, sterols, methyl-sterols, and some alcohols are nonvolatile compounds that do not add to the flavor of olive oil, but very important in authentication of olive varieties. The volatile aromatic hydrocarbons and some alcohols are responsible for much of the ultimate flavor of the oil.

When the cell walls are ruptured and all of these oil, water, protein, mineral components, and complex hydrocarbons are mixed together with air, enzymes, and microorganisms the oil fraction absorbs many of the volatile compounds and takes on their flavor and aroma characteristics. The harmony between the oil and water fractions produces the olive oil elixir unique compared to any other fruit product. It is a short-lived, delicate, and positive union that can be amplified, diminished, or disturbed by changing the quality of the fruit, way it is handled, manipulation of the paste, extraction process, and finally cleaning and storage of the oil.

The negative influence of oxidizing, rotting, and fermenting solids and water must be removed as quickly as possible once the oil has had sufficient contact with the positive aromatic volatiles. Some smaller droplets of oil remain with their protective lipoprotein covering and stay as a fairly stable emulsion within the paste. Some of the oil forms micro-gels; a sort of water-oil-solids mixture colloid, but most of the oil becomes free, rolls around with the water and solids, and begins to unite with other oil droplets.

Attention to Detail

Just like anything else of super high quality, there is no particular secret to the technique in making it, but rather an intense commitment to quality through great attention to detail. The first detail is starting with good quality fruit. You can't make good olive oil out of poor fruit; in fact the trick is to not ruin the oil that is in the fruit with bad harvesting, transport, fruit storage, processing, or oil storage techniques. The concept is really quite simple: Start with good fruit, and as quickly as possible - crush it, separate the oil from the fruit-water and solids, then store it in a cool, dark container that excludes oxygen. Then you have captured the essence of fruity olive oil that reflects the characteristics of the variety, fruit maturity, and terroir.

The detailed skills necessary to make great olive oil after that include knowledge and commitment to selecting the best equipment and running it at the proper flow rate and temperature along with good sanitation. Just don't goof it up!

Harvest, Transport and Storage

Within reason all of these should be done as carefully as possible. Hand harvest is best but unreasonably expensive. Mechanical shaker or straddle harvesters will bruise and slightly damage the fruit therefore it should get to the processor very quickly. Bulk transport with some depth support is important to keep the fruit from being crushed. Depth depends on the variety and maturity of the fruit. Storage time prior to milling should be kept to a minimum (about 2 – 10 hours) and immediate processing is the best. Cold storage of fruit can dramatically reduce the oxidation and microbial breakdown and some research indicates the fruit can be stored at about 3-5^{o}C for up to 40 days without significant changes in quality. Other work indicates that it will keep for only about 15 days without flavor changes. Temperatures below 3^{o}C can be harmful.

Mill Design and Layout

The mill should take into consideration the potential flow volume of fruit, how it will be unloaded, hours of delivery, and storage structures for fruit waiting to be milled. There should be an accommodation for expansion possibilities. The building has to meet local codes plus should be designed with good visibility (plenty of natural and electric light) and noise reduction in mind. Noisy machinery such as the hammermill does not have to be located in the building with the rest of the extraction equipment. The mill should have channels in the floor to remove and clean up spills of paste, oil, or wastewater. The flooring should be coated with some type of sealant material that prevents oil from staying within its pores and going rancid. Accommodation might be made for heating the paste and wash waters, and cooling may be necessary for the stored oil.

Cleaning, Sampling, Washing, and Weighing the Fruit

Small quantities of material other than olives are not really a problem, but large amounts of leaves, stems, or dirt can cause off flavors in the oil each with their own "classic" defect. A fruit sample of about 2-3 pounds should be taken automatically bit-by-bit out of the whole load to keep a record of the quality and for analysis. Fruit should not be washed unless it is dirty or contains a pesticide residue. A little field dust is not considered dirty fruit. Washed fruit has been shown to be consistently lower in fruitiness, bitterness, and pungency because washing adds 2-6% moisture. Dirty wash water can contaminate all of the good fruit. Just prior to milling the weight is taken.

Milling the Fruit

Grinding up the fruit into a paste depends on so many factors and is ultimately dependant upon the style of oil desired. Different varieties and fruit maturities have dramatic influences on choices of mill type and paste fineness. The ease and cost of operation plus the initial cost of the machinery will also influence the type of mill used.

All mill types can produce excellent quality oils, but there is considerably more labor required and care necessary in the operation of stone mills. They are bulky, work very slowly, and are more costly, but may be better for some varieties and are quite romantic.

MILLING MACHINERY EFFECT ON OLIVE OIL QUALITY

MACHINE	*POSITIVE EFFECT*	*NEGATIVE EFFECT*
Hammermill	**+ Fruity + Green**	**- Sweetness + Pungent + Bitter**
Stone mill	**+ Sweetness - Pungent - Bitter**	**- Fruity - Green**
Disc mill	**+ - Sweetness + - Pungent + - Bitter**	**+ - Fruity + - Green**
Pitter mill	**+ Sweetness - Pungent - Bitter**	**- Fruity - Green**

Vossen, compilation of data from many sources

The disc mill produces oil that is similar to the stone mill, which are used for varieties with very high polyphenol contents. Hammermills are the most harsh, should be used with caution on some varieties, and yet are best for others. They are fast, easy to clean, take up less space, are less expensive, and work in a continuous flow system. The pitter mill is a relatively new invention that pits the fruit, but has no particular advantages.

If the paste is made too course (large chunks of pulp and pits) the cell walls containing the oil will not be broken up enough to release all the oil, consequently oil will be lost in the solid waste (pomace). If the paste and pits are ground too fine an emulsion is more likely to be created and fine particulates with oil can be lost in the wastewater. Each decision also affects the length of time and temperature necessary in the malaxation process later.

The mill operator needs to evaluate each batch of olives with an emphasis on quality and style. Each change in paste fineness should be evaluated for oil flavor. That is why the master miller needs to know what to look for. The best decision is one, of course, that produces the best oil with a high oil yield – that takes a lot of experience.

Malaxation – Slow Mixing

If an attempt is made to extract the oil from the newly milled paste, the extraction is very low, because during the milling process the oil becomes homogenized with the fruit-water and is lost with the water and solids. Malaxation is a process of slowly mixing the fruit in a stainless steel container at about 28 rpm and usually at a slightly warmer temperature. It is used to reverse the homogenization process and free the oil for easy extraction.

The temperature of the paste should not exceed 25°C in order to preserve most of the volatile aromatic compounds and the time of malaxation should never exceed 90 minutes. Slightly higher or lower temperatures can significantly influence the amount of oil extracted from the paste. Malaxation for longer than 90 minutes only reduces ultimate quality. Many excellent quality oil producers in Europe and America operate on the lower side of the temperature scale and mix for about 45 minutes or less. Some oil is lost, but quality can be higher. Higher temperature extracts more oil, increases polyphenol content and bitterness of the oil, but lowers the volatile aromatics. Longer malaxation (within the limits of 30-60 minutes) reduces polyphenols, bitterness, and stability, but increases color and oxidation of the oil.

Some olive oil pastes, usually from olives that are excessively high in moisture are difficult to extract, because the water remains with the oil as an emulsion even if malaxated perfectly. Talc, which is hydrated calcium magnesium silicate, is sometimes added to olive paste that has excessive moisture. It is a naturally occurring inert mined mineral that is purified and ground into a very fine powder according to International Olive Oil Council and European Union specifications. The mineral particles have a very large convoluted surface area that is very absorptive (can absorb 10-15 times its weight in water). Using talc in some problem pastes can increase extractability by up to 5%.

Good mill operators spend much of their time looking at the paste in the malaxation tanks watching for floating oil, the paste color, fluidity, and cleanliness of the paddles. They speed up or slow down the process, modify temperatures, and or add talc to perfect the process.

Phase Separation

Natural decantation would be considered the worst for oil quality because it is so slow and the fermenting solids and fruit-water remain in contact with the oil for a long time. The method that produces the best quality oil is generally recognized as the selective filtration system, because it uses no pressure or force on the paste to quickly remove the "free run" oil. Unfortunately the selective filtration system is complicated to operate and most people believe that the slight difference in quality is not worth the effort. The Sinolea and Acapulco systems use gravity and the physical adhesion law between oil and stainless steel, which removes the oil and leaves the water and solids behind. Neither removes more than 80% of the oil so some other type of extractor must also be used.

The press system simply stacks up layers of paste and under pressure pushes the liquids (oil and fruit-water) through a woven filter mat of some type leaving the solids behind. The big problem of keeping the filter mats clean, free of oxidized-rancid oil, and fermentation defects is difficult, but not impossible. The mats can be used continuously or placed in cold storage – frozen when not in use for short periods.

Centrifugal decanters spin on a horizontal axis at about 3,000 rpm and create enough force to separate the oil form the fruit-water and solids. There is an auger inside a stainless steel cylinder that moves the paste through in a continuous flow and very efficient system. The three phase decanter or horizontal centrifuge, requires the addition of water to the system, which dilutes out the water soluble components (polyphenols), separates the paste into three distinct phases (oil, fruit-water, and low moisture solids), and generates the most wastewater for disposal.

The two-phase system decanter does not require the addition of water in most cases, generates less wastewater for disposal, and most importantly does not dilute out the polyphenol content of the oil. Olive variety and fruit maturity may influence the choice of decanter type in that low polyphenol varieties made with a 3-phase decanter might be insufficiently fruity, bitter, pungent, and stable.

Most of the world's oil is made with centrifugal decanters and the trend is toward the 2-phase system. The mill operator needs to keep track of the cleanliness of the oil (water and fine solids content) and the oil content of the fruit-water, pomace, and or fruit-water/pomace. The master miller can change the speed of the machine, injection volume of the paste, water injection rate and temperature, plus the port location for each phase to manipulate the extraction efficiency and oil quality. There are some visual cues and laboratory analyses that can be used to kept track of the efficiency of the system. Tasting the newly made oil as a knowledgeable taster used in conjunction with the desired oil style is the best quality indicator.

PRINCIPLE ADVANTAGES and DISADVANTAGES of the PRESS, SELECTIVE FILTRATION, 2-PHASE, and 3-PHASE SYSTEMS

SYSTEM	***ADVANTAGES***	***DISADVANTAGES***
Press	***The old way romance factor, uses less energy, less cost to establish, produces relatively dry pomace***	***Less capacity, requires more labor, difficult to maintain cleanliness of mats, more paste and oil contact with oxygen***
Selective Filtration	***Extracts more oil in conjunction with decanter systems than decanter system alone, produces unique quality oil***	***Difficult to keep clean, greater maintenance, extracts only half of the oil, greater quality may not be worth the extra effort***
3-phase Decanter	***Produces relatively dry pomace, easier to monitor extraction efficiency than the 2-phase system, continuous flow***	***Uses more water, needs more power to heat extra water, washes out too many polyphenols in some oils, produces a lot of waste water, needs 2 vertical centrifuges***
2-phase Decanter	***No fruit-water effluent, oil has higher polyphenol content, uses less water, needs only one vertical centrifuge, continuous flow***	***Produces very wet pomace, more difficult to determine extraction efficiency***

Vossen, compilation of data from several sources

Vertical Centrifugation for Oil Cleaning

The vertical centrifuge is essentially a modified cream separator that spins on a vertical axis at about 6,000 rpm and achieves 4 times the separation of the horizontal centrifuge. Warm water is added, which passes through the oil to help clean it of fine solids. The water and oil are separated at the interphase point to also eliminate most of the fruit water. The mill operator can adjust the ring size, which changes the phase separation point by allowing more water and less oil or less water and more oil to exit. The flow volume and temperature of the wash water can also be adjusted. If not enough water is added, there is insufficient cleaning of the oil. If the temperature is too cold, oil will be lost going out with the wastewater and if the water is too warm the oil can be excessively washed of flavor.

Technically, the wastewater effluent from the vertical centrifuge should have less than 0.1% oil and less than 0.5% suspended solids in it. The cleaned oil should contain less than 0.1% of water or solids.

Tank Sedimentation

The cleaned oil still contains some solids and water, which must be purged from the bottom as they settle out, so normally the oil is allowed to settle for about 2 months prior to bottling or filtering and bottling. If tank settling is not done correctly the defects of muddy sediment, or anaerobic fermentation (fustiness) can occur in the bottle. Tank settling and long term storage should be in sealed stainless steel tanks, with nitrogen topping, and kept at about 13-16°C so that is does not oxidize and breakdown due to light, high temperature or oxygen exposure. Temperatures below about 12°C will cause the oil to settle very slowly and some of the saturated fatty acids will congeal. New oil can be sold immediately from the vertical centrifuge, but the customers should be cautioned to use it up within about 2 weeks.

Blending

Blending oils should be done very carefully and methodically by a knowledgeable taster, so that the best composition is obtained. Each tank must be tasted and various blend ratios can be tried to achieve the ultimate oil. Since the oil will mellow with age, even in the bulk tank, some of the stronger oils should be saved for later release and blending in a just-in-time bottling scheme.

Filtration

Oil does not have to be filtered prior to bottling and the trend is toward selling unfiltered oils, but they must be properly settled and almost all will develop some sediment in the bottom of the bottle. Filtered oils are less stable, because some of the water-soluble components have been removed, but they will form fewer deposits in the bottle. The two principle types of filters use either diatomaceous earth (DE) or fine filter paper or both

Bottling

The ideal olive oil container would be recyclable, inexpensive, impermeable to oxygen, not transmit anything into the oil, block light, have an airtight closure, and resist impact. Before making a choice it would be prudent to first take a look at as many of the products on the market as possible. Then match the type of container with the price, label, and style for the targeted consumer. Some consumer study would be useful. Oils in clear glass exposed to light at room temperature can go flat in two months and rancid shortly thereafter. The following is a list of some common container characteristics:

CONTAINER CHARACTERISTICS FOR OLIVE OIL BOTTLING

ITEM	*ADVANTAGES*	*DISADVANTAGES*
Clear Glass	**Customer can see the oil color, image of high quality**	**Greatest light exposure, can see sediments, breaks easily, size limitations, heavy**
Colored Glass	**Excludes some light, image of high quality, and can't see sediments**	**Customer can't see product, breaks easily, size limitations, heavy**
Tin	**Excludes all light, does not break, can't see sediments, can be used for larger containers**	**Customer can't see product, cheap image, can impart off flavors during long term storage**
Plastic	**Light weight, unbreakable, customer can see color, can be used for larger containers**	**Does not exclude light, cheap image, can see sediments, some oxygen passage, possible migration of pvc's into oil**
Paper laminated (tetra-brik)	**Excludes all light, can be used for frozen oil, unbreakable, can't see sediments, light weight**	**Unknown in the marketplace, can't see the oil color, may be cheap image, size limitations**
Ceramic	**Image of high quality, excludes light, can't see sediments**	**Fewer closure choices, breakable, heavy**
Cork – wine type	**Image of high quality**	**Difficult to open, drips, leaks, and poor oxygen exclusion**
Cork with wide top	**Image of quality**	**Drips, leaks, and poor oxygen exclusion**
Screw- top w/plastic no drip	**Easy to open, drip less, excludes oxygen, no leaks**	**Cheap image**
Spout or spigot	**Image of quality**	**Leaks, difficult to package**
Tall narrow shape	**Elegance and image of quality**	**Difficult to package and store in the kitchen**
Short wide shape	**Elegance and image**	**Difficult to handle**
Round shape	**Same**	**Same**
Angular shape	**Same**	**Same**
Box enclosure	**Image of high quality**	**Can't see the product without opening**
Cylinder enclosure	**Image of high quality**	**Can't see the product without opening**