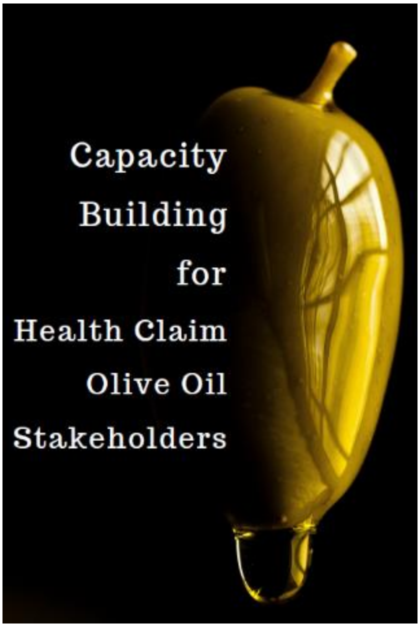
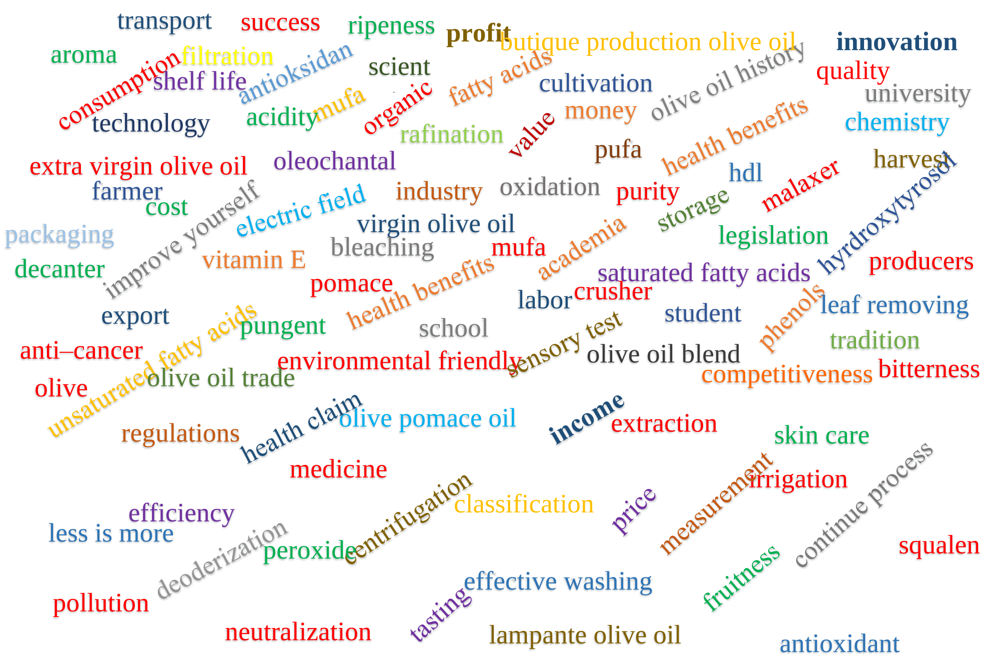


OLIVE OIL FROM ACADEMIA TO INDUSTRY

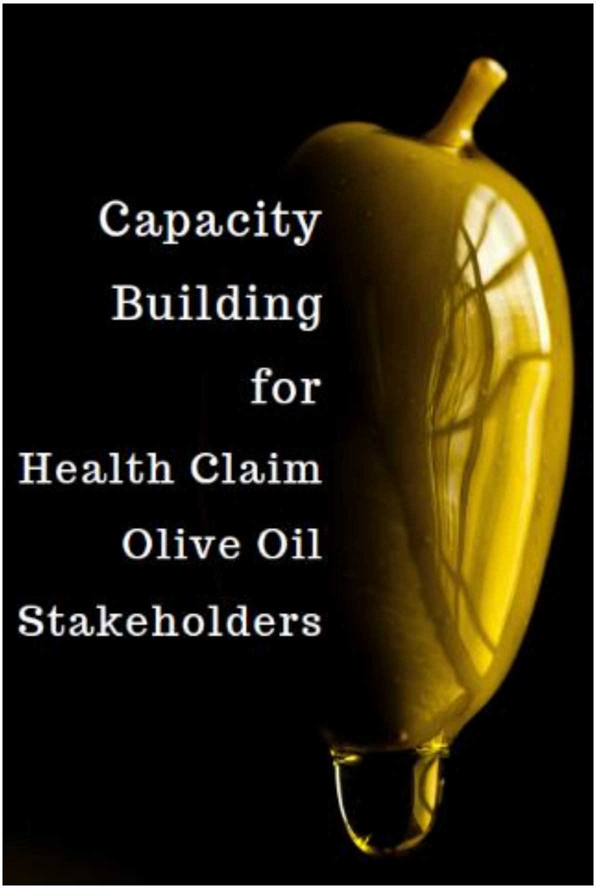


ARISTOIL CAPITALIZATION

ΙΔΡΥΜΑ ΚΡΑΤΙΚΩΝ ΥΠΟΤΡΟΦΙΩΝ IKY

Co-funded by the Erasmus+ Programme of the European Union

ARISTOIL CAPITALIZATION



Lead Partner

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This project is funded by the European Union.

https://aristoilcap.eu/

This book was written as part of the Aristoil Capitalization project.

CONTENT

PREFACE

Dear reader, this book was written describes the fascinating journey of olive oil in the light of scientific data within the scope of Aristoil Capitalization project. In this way, it is hoped that growers, industrialists, packers and restaurants, hotels, etc. using olive oil will benefit those who want to pursue a career in this field and consumers. By providing clear and up–to–date information collectively, it is aimed to reach as many people as possible with correct information and to provide added value.

Olive oil is a traditional product that started to be produced 6000 years ago, but this sector constantly renews itself and tries to increase its competitive power. For this reason, those who are trained or interested in this subject should constantly improve themselves, follow and scientific findings and use this information in cultivation, production and storage. These works will enable producers to reach olive oil with higher profitability and beneficial effects for consumers.

Although olive growers make the same effort and similar expenses for one year, the money earned from the sale of olive oil differs. Some producers have very low income from this work and are offended with production or olive. However, some producers gain high income and are motivated to produce more in the next year. The difference between these two producers is the lack of knowledge and practice in producing quality olive oil. It is possible to produce higher quality olive oil with the same labor and similar cost. A similar situation is valid for facilities that process and/or package olive oil. With this book, it is aimed to explain the information required for the production of high quality olive oil by visualizing as much as possible.

As in every field, it is hoped that young people will be a driving force in olive cultivation and olive oil and will do useful work by realizing efficient, quality and environmentally friendly productions. In this way, they will be able to ensure the implementation of new technologies as an example for the whole olive oil industry. As a result, olive oil, which is defined as both a traditional and a technological product, is likely to be brought to a better position by idealist students/producers/scientist who ever works in this field.

Dr. Yasin OZDEMIR
Ataturk Horticultural Central Research Institute, Yalova, Turkey

OLIVE OIL FROM HISTORY TO FUTURE

Olive is the common heritage of the Mediterranean culture and spread from Mesopotamia to the world. Olive has found a special place not only now but throughout history. While the olive branch is the symbol of peace, olives are one of the rare fruits that are included in the holy books. Olive oil has similarly contributed to society in both cultures and economic activities. Olives and olive oil were moved from Mesopotamia to Turkey's historic town on the Mediterranean coast (as Klozamani) and from there through the ports olive oil was traded in other Mediterranean countries, especially Greece.

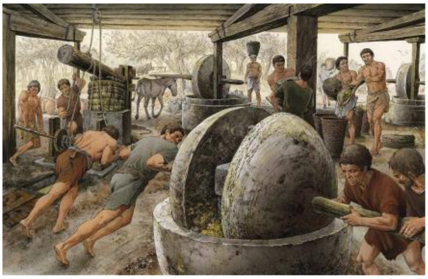
Although there are different scientific studies on where the first olive cultivation is located today, what matters is who grows the olives better and produces higher quality olive oil. Producers or countries that achieve this will have better competitive conditions in the future and thus gain higher profits. The first findings about olive oil in history and the spread of olive oil to the world are given in Figure 1.

Figure 1. The first findings of olive oil in history and its spread to the world–wide (Oliveoilsource, 2020)

It is seen that a system based on manpower and simple weight systems were used in the remains of the first olive oil production. It is understood that olives were crushed with wheel–like stones and oils were obtained by pressing using lever systems. Over the years, it is observed that besides manpower, the use of animal power and the use of simple mechanical systems are observed more and more. With the development of casting and iron workmanship, clamping systems have started to find a place in the olive oil industry. As technology progresses, continuous systems have begun to replace discontinuous systems such as wheel cutting and press systems. In this way, a higher amount of olive oil can be produced with less loss of olive oil quality.

Olive oil museums have been started to be built in recent years. These museums, where historical olive oil production machines, tools, storage containers and photographs/pictures of the region are exhibited, contribute to the tourism of the region. These museums enrich the regions where they were established especially in terms of cultural tourism. In olive harvest times, it increases both the visitors and consumers who want to buy olive oil from the production area. It is thought that these museums add vitality to the olive oil culture from the past to the future and the increasing number of them will be culturally and economically beneficial.

As in every field, it is hoped that young people will be a driving force in olive cultivation and olive oil and will do useful work by realizing efficient, quality and environmentally friendly productions. In this way, they will be able to ensure the implementation of new technologies as an example for the whole olive oil industry. As a result, olive oil, which is defined as both a traditional and a technological product, is likely to be brought to a better position by idealist students/producers/scientists working in this field.




OLIVE OIL IN WORLD

The interest in olive oil has increased in parallel with the agreement of the society about that healthy nutrition is necessary for protection from diseases and for a healthy–long life. However, since the properties of olive oil are not known enough in countries which are olive producer or not, olive oil still has not found the value it deserves. Production and consumption rates and per capita consumption amounts of important olive oil producing countries are given in Figure 2.

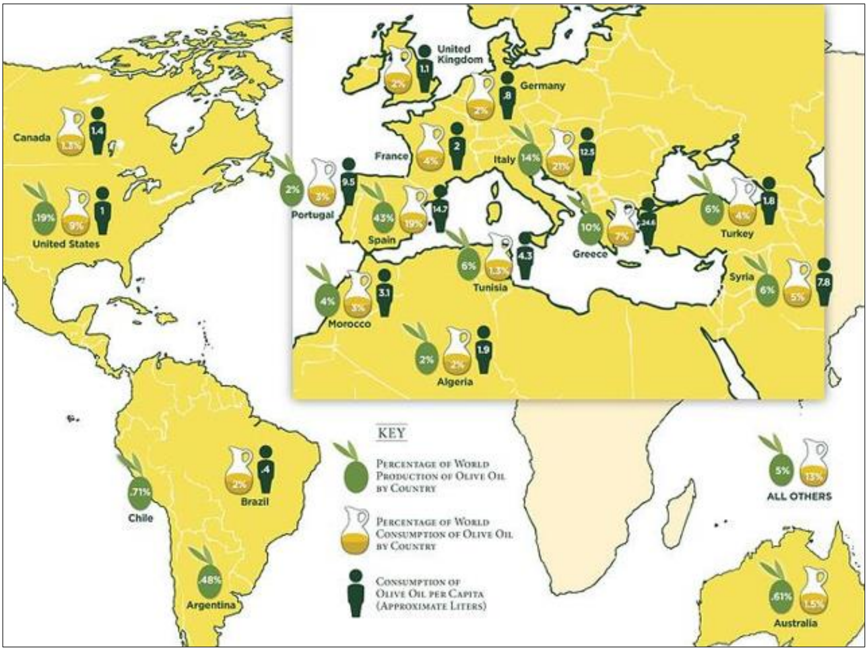


Figure 2. Countries olive oil production and consumption rates (About Olive Oil, 2015a)

Most people know that olive oil is mainly made in the Mediterranean region of the world, but many don't realize that Spain is actually the largest producer, consistently making about 45% of the world's olive oil. While Spain is the largest producer, Greece has the highest per capita olive oil consumption values. Per capita olive oil consumption amounts of the countries are given in Figure 3. Olive cultivation and olive oil production support local development in terms of providing employment and increasing economic activities. Also olive oil has an important place in international trade.

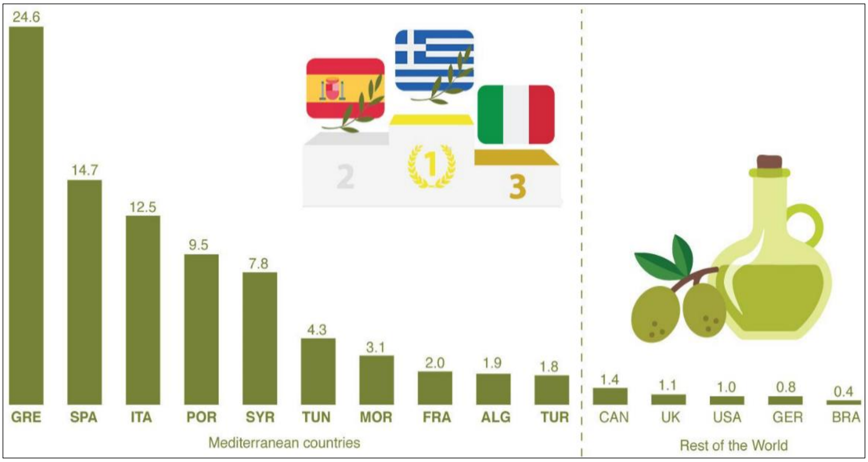


Figure 3. Average olive oil consumption per capita (About Olive Oil, 2015a)

EU Member States exported over 1.6 million tonnes of olive oil in 2018, worth €5.7 billion. Almost two thirds of these exports went to other EU Member States (63%, or 1.0 million tonnes). This represents a 15% increase in the value of EU Member States' total exports compared with 2013. In 2018, the EU Member States imported 1.2 million tonnes of olives, worth €3.9 billion. Majority of these imports came from other EU Member States (85%, or 1.0 million tonnes). The value of olive oil imports to the EU Member States increased 10% compared with 2013 (Figure 4).

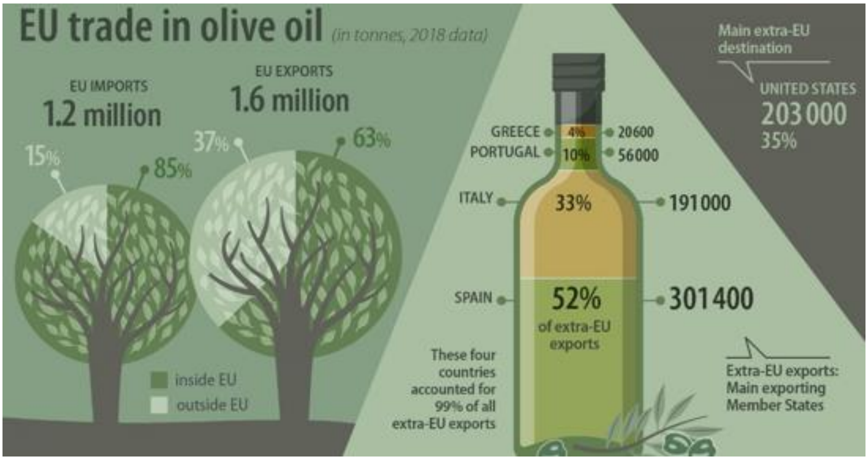


Figure 4. Olive oil trade of EU countries (Eurostat, 2019)

OLIVE OIL CHEMISTRY

In this section, olive oil will be examined in two groups as major components and minor components of olive oil. It should not be forgotten that although the content of minor ingredients is low, it has an effect on the quality, stability and price of olive oil. The oil part (98–99%) of olive oil consists of oil molecules and free fatty acids and defined as major component. The remaining 1–2% consists of compounds other than oil but dissolved in oil and defined as minor components. The composition of natural extra virgin olive oil is given in Figure 5.

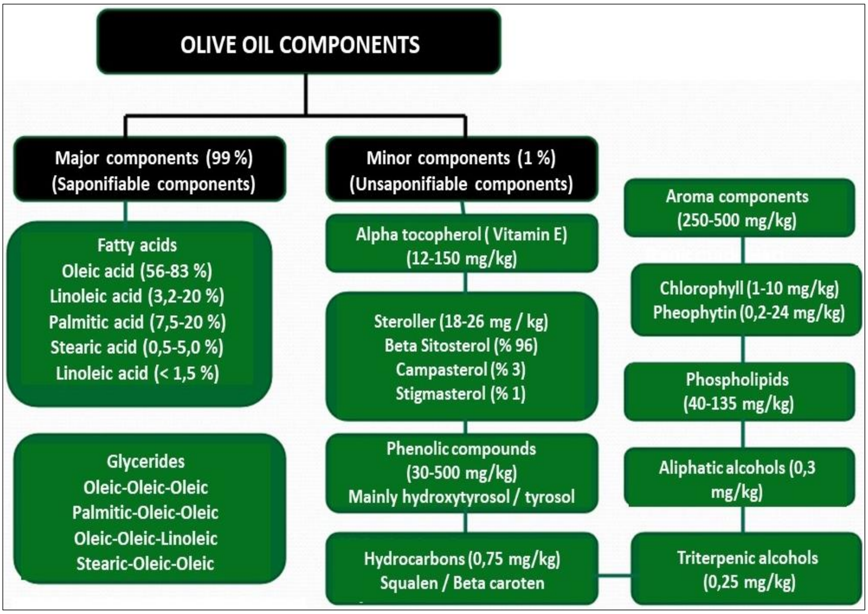


Figure 5. Olive oil components (Altinbas Ozdemir & Ozdemir, 2011)

Major Components of Olive Oil

Oil molecules consist of three fatty acids attached to a glycerol. Fatty acids consist of carbon chains. Fatty acid is named according to the number of carbons in the chain (chain length), the number of double bonds between carbons (unsaturated bond) and the location of the double bond (s). These properties determine the chemical and functional properties of fatty acids. There is no variation in the glycerol molecule. The simple representation of the formation of the triglyceride molecule is given in Figure 6 and the formulation representation is given in Figure 7.

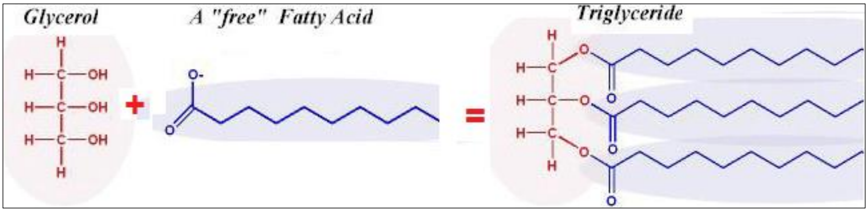


Figure 6. Simple representation of the formation of the triglyceride molecule (CVO, 2020)

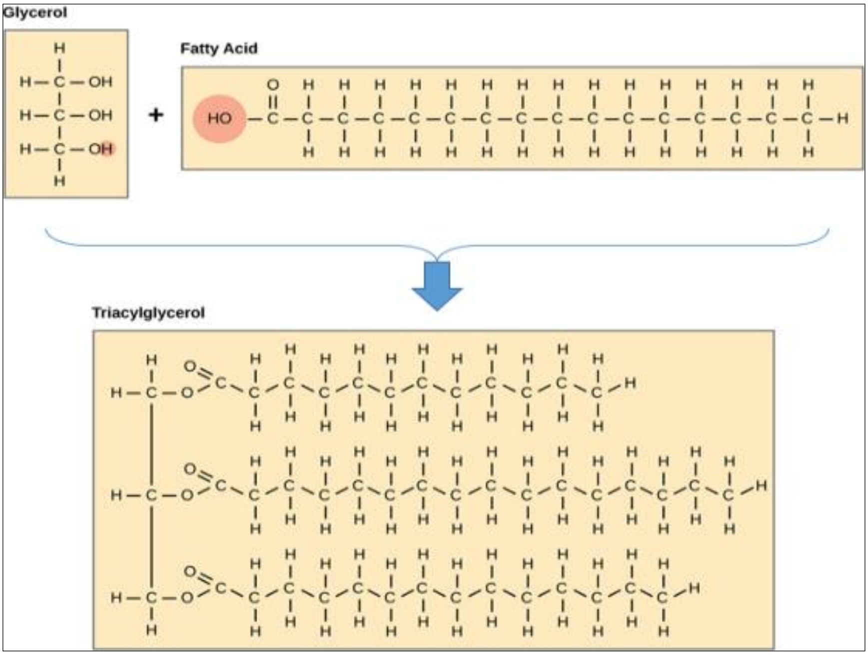


Figure 7. Schematic representation of triacylglycerol molecule structure (Lumen, 2020)

As mentioned, major components of olive oil are triglycerides (triacylglycerols or oils). Olive oil contains small quantities of free fatty acids which is the content in olive oil used as remark of quality and classification of olive oils with other contents or parameters.

Different plant or animal origin oils had different fat molecules formed according to the properties of fatty acids binding to glycerol. So that in addition to the determination of oil quality, it is also used to define the possible origin of oils. The representation of different triglyceride molecules formed by the binding of different fatty acids to glycerol is presented in Figure 8. Under normal conditions, the glycerol molecule is attached to three fatty acids. However, in some cases like oxidation or enzymatic activity, one, two or three of the fatty acids can be separated from glycerol. In the glycerol backbone, one, two, or three of the hydroxyl groups may be esterified with fatty acids to form monoglycerides (MAG–a fatty acid with glycerol), diglycerides (DAG–two fatty acids with glycerol), and triglycerides (TAG–three fatty acids with glycerol), respectively. The schematic representation of the triglyceride, diglyceride and monoglyceride structure is given in Figure 9.

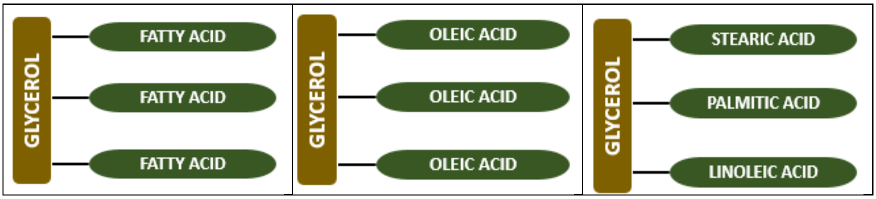


Figure 8. Different triglycerides formed by the binding of different fatty acids to glycerol

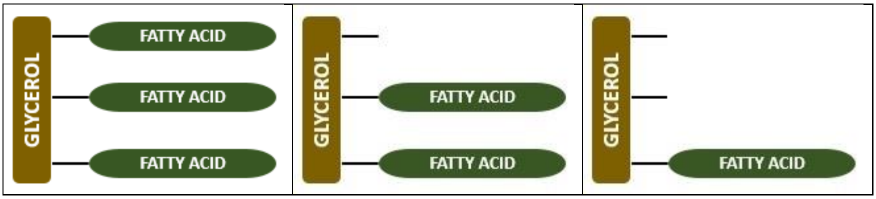


Figure 9. Examples of triglycerides, diglycerides and monoglycerides

Fatty acids are defined as unsaturated fatty acids if they have double bonds and defined as saturated fatty acids if they do not have double bonds. The formulas and structural representations of stearic acid, which is an example of a saturated fatty acid, and oleic acid, as an example of an unsaturated fatty acid, are given in Figure 10.

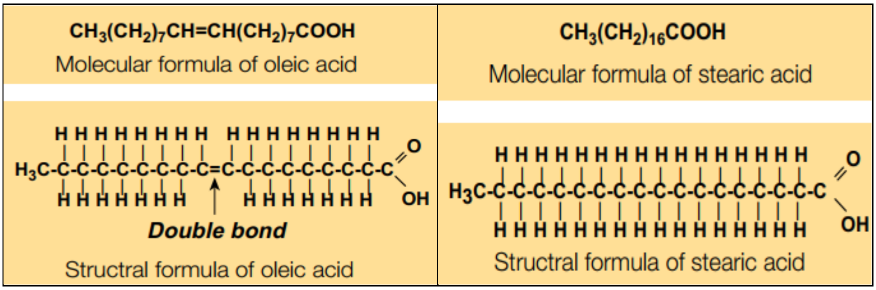


Figure 10. Formulas and structural representations of stearic and oleic acids as examples of saturated and monounsaturated fatty acids

Unsaturated fatty acids are called as monounsaturated fatty acids when they contain only one double bond, and are called as polyunsaturated fatty acids if they contain more than one fatty acid. Olive oil is one of the oils of the monounsaturated fatty acid group because it contains oleic acid up to 85% in fatty acids, which is a monounsaturated fatty acid.

Each double bond may be in a cis or trans configuration. In the cis configuration of the fatty acid, both hydrogens are on the same side of the hydrocarbon chain. In trans configuration, the hydrogens are on opposite sides. Cis double bond causes a twist in the chain. The schematic representation of the cis and trans structure of oleic acid is shown in Figure 11.

Although it is known that most of the fatty acids found in nature are in the form of cis. Trans fatty acids, which have been a popular subject in nutrition physiology, are not found naturally in fats and they can be formed as a result of technological applications (such as partial hydrogenation, refining and partially frying) that involve heat treatment (Dıraman, 2016). However, if appropriate technologies are used, trans fat formation can be prevented or minimized during refining or cooking processes.

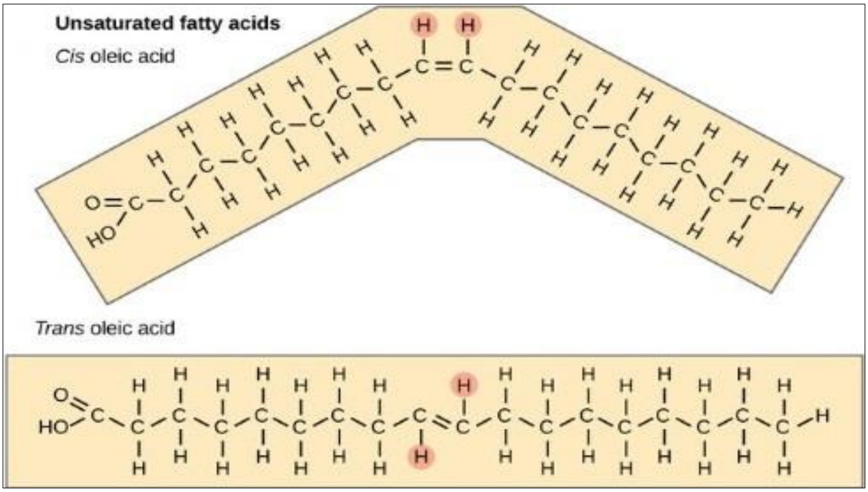


Figure 11. Schematic representation of the cis and trans structure of oleic acid

The proportions of saturated, monounsaturated and polyunsaturated fatty acids in the oil are responsible for the fat's being solid or liquid at room temperature, its intact resistance to cooking processes such as baking or frying, and its resistance to oxidation throughout its shelf life. These properties significantly affect the quality characteristics of oil and health–related properties such as cardiovascular occlusion or cholesterol. Examples of saturated, monounsaturated and polyunsaturated fatty acids are given in Figure 12.

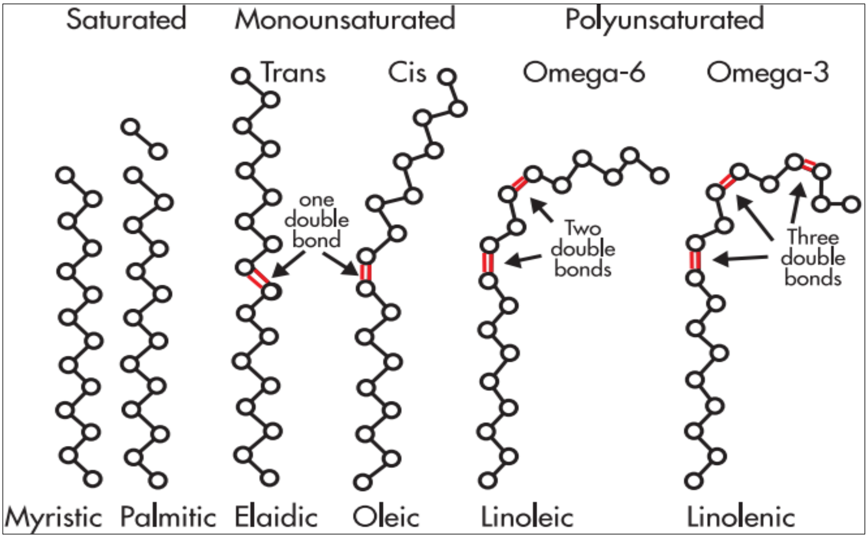


Figure 12. Examples of saturated, monounsaturated and polyunsaturated fatty acids (Mailer, 2006)

Classification of fatty acids based on their carbon chain length and their number and place of double bonds. The polyunsaturated fatty acids which contain multiple double bonds between carbon atoms can be classified into two families depending on the position of the double bond on the methyl terminal (ω; n–) end. Group of fatty acids are given in Figure 13.

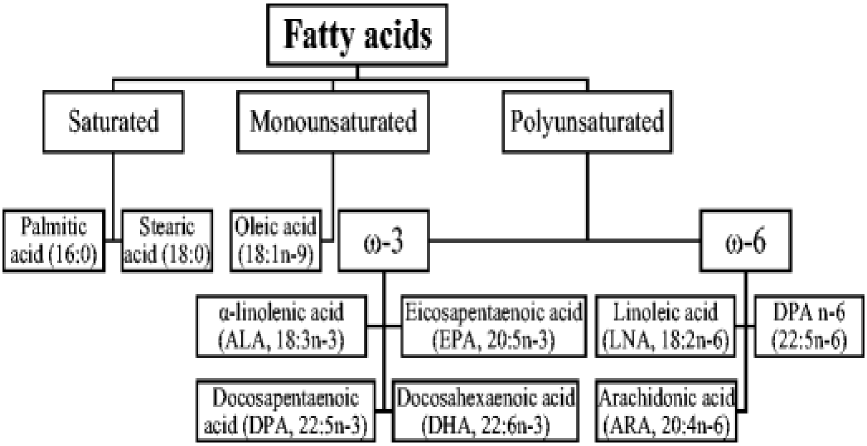


Figure 13. Distribution of some fatty acids (Satari & Karimi, 2018)

Even though there are a lot of fatty acids in olive oil, most of these are part of the triglycerides. However, processing can cause the release of some of these fatty acids, allowing them to become ‘free’. These free fatty acids are actually a component, which is not wanted in olive oil. A larger quantity of these free fatty acids shows that the olives have been treated more intensely or oil is processed with unfavorable conditions. Both national and international legislation put limits for maximum allowable content of free fatty acids for olive oils.

Refining olive oil can remove these fatty acids. However, refining will also remove other valuable components from the oil, overall resulting in lower quality of oil. Thus, the refining step causes decreases in the prices of oil. High values of free acidity in olive oil can be due to different factors such as: production from unhealthy olives (due to microorganisms and moulds contamination or attacked by flies and parasites), delayed harvesting, storage before processing or inappropriate processing conditions. The presence of free fatty acids in olive oil is caused by a reaction (lipolysis) started when lipolytic enzymes (that are normally present in the pulp and seed cells of the olive) come in contact with the oil (that is contained in particular vacuoles) due to loss of integrity of the olive (Peri, 2014). The schematic view of the separation of fatty acids from glycerol by lipase enzyme is given in Figure 14.

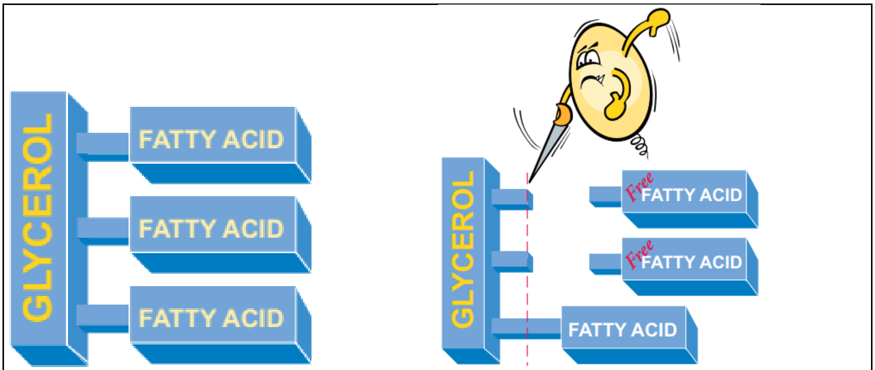


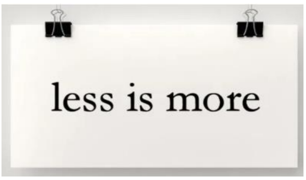
Illustration of oil molecule   Illustration of oil molecule splitting by lipase enzyme

Figure 14. Schematic view of the separation of fatty acids from glycerol by lipase enzyme (modified from Bylund, 1995)

The breakdown of fat into glycerol and free fatty acids is called lipolysis. Lipolysed fat has a rancid taste and smell, caused by the presence of low molecular free fatty acids (butyric and caproic acid). Lipolysis is caused by the action of lipases and is encouraged by high storage temperatures. But lipase cannot act unless the fat globules have been damaged so that the fat is exposed. The lipolysis reaction is greatly enhanced by the presence of an aqueous phase, so when oil is separated from water during processing, lipolysis slows down and stops (Bylund, 1995; Peri, 2014).

Minor Component of Olive Oil

As the name of olive oil, it is obtained from olives. Although it is named as oil, there is also a part of 1–2% except oil. In fact, the most important features that distinguish olive oil from other oils are due to the 1–2% non–oil components. Phenols, phosphatides, pigments, flavor compounds, sterols, tocopherols and carotenoids and microscopic bits of olive are minor components of olive oils.



These components, which are also named as minor components of olive oil, are very suitable for the concept of "less is more". Even though it is small in quantity, it provides many useful properties such as phenolic substances, alpha tocopherol and aroma components etc. that separate olive oil from all other oils and/or increase the shelf life or provide thermal stability of the oil.

Olive oil contains vitamin E, which is also known as tocopherols (12–150 mg/kg), which is an important feature that distinguishes it from other oils obtained by refining. Although it has tocopherol content in different forms in olive oil, it contains α–tocopherol with a rate of over 95% of this content (Figure 15).

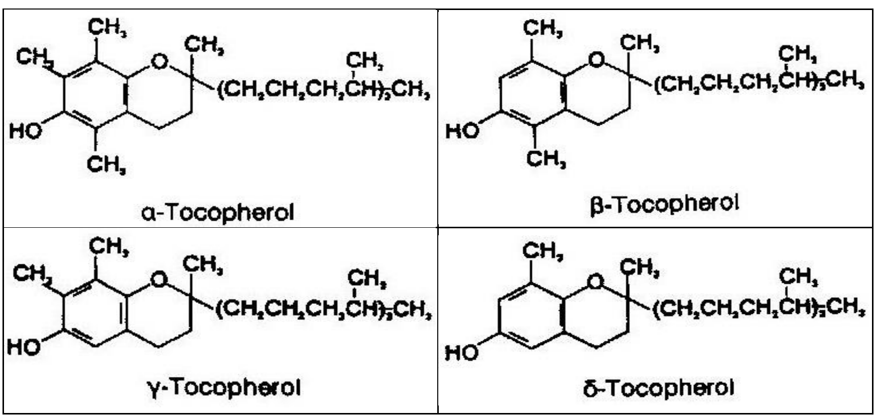


Figure 15. Tocopherols present in olive oil

Oleocanthal is an exciting compound with some potentially impressive health benefits. Firstly, oleocanthal is a phenol that occurs in olive oil, and research suggests that it has anti–inflammatory properties. If you try a good quality extra virgin olive oil in its cold state, you should feel a burning feeling in the back of your throat a few seconds after consumption. This taste is because of the oleocanthal; a peppery–tasting compound that shows an effect similar to ibuprofen in in vitro studies. In vitro refers to tests done outside of the body such as in test tubes. Schematic representation of oleocantal is given in Figure 16.

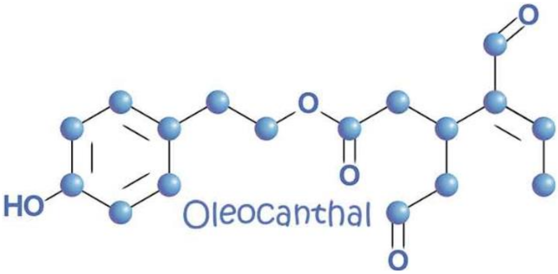


Figure 16. Schematic view of oleocanthal (Joseph, 2019)

However, the effects in the study were only seen in dosages of 50 grams, which is a substantial amount of oil to consume (Aristoil, 2020; Joseph, 2019). In recent years, many studies have been conducted on the health–protective properties of phenolic components in olive oil, especially oleocanthal. Studies conducted to slow down undesirable conditions such as Alzheimer's, cancer, cardiovascular diseases, tumor development, reduce the risk of getting caught, or to treat them show that olive oil phenols can be used more in the future (Aristoil, 2020).

CLASSIFICATION OF OLIVE OILS

Table olives or olive oil are produced from olives obtained after one year of agricultural practices. The olive growing process is a process that would require a lot of effort. For this reason, all oils obtained from olives are very valuable. However, among these, extra virgin olive oil and virgin olive oil are more valuable because they are obtained by only physical methods and therefore have a unique content. Production methods of olive oil groups are given in Figure 17.

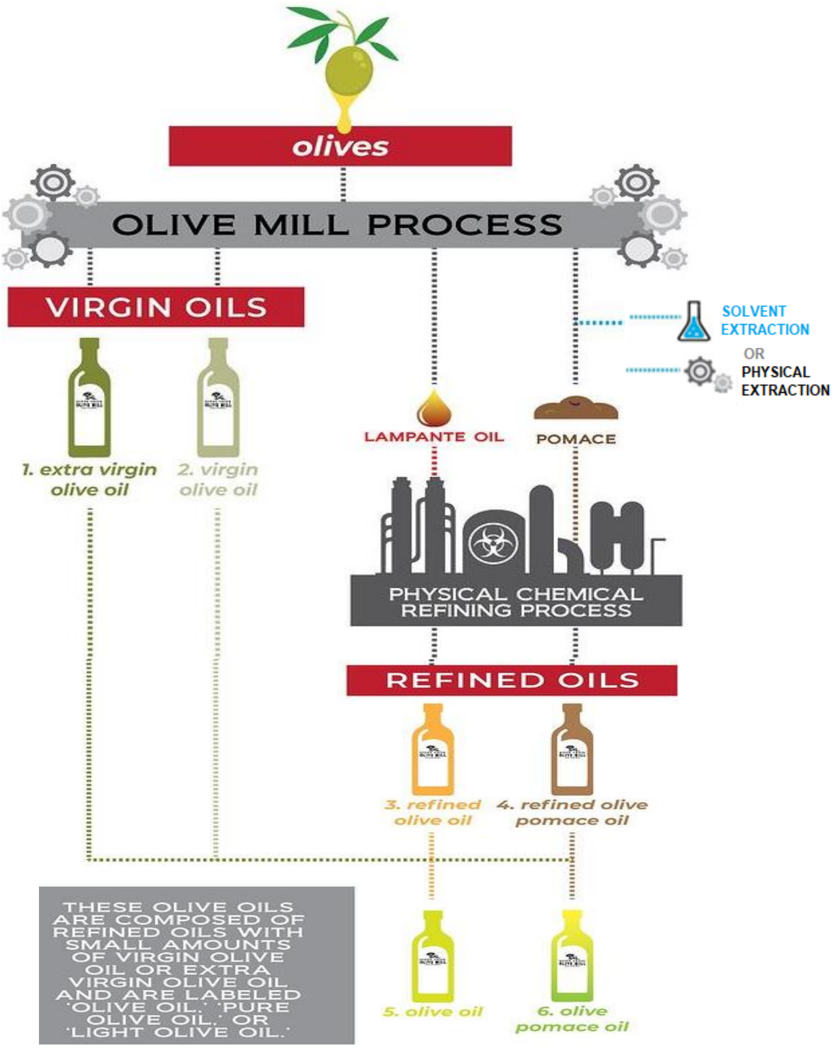


Figure 17. Production methods of olive oil groups

Riviera olive oil obtained by mixing these oils with refined olive oil is the 3rd most valuable oil group. This is followed by olive pomace oil obtained by mixing natural extra virgin or first olive oil with refined olive pomace oil. Refined olive oil ranks 5th, while refined olive pomace oil comes last. The grading of olive oils is given in Figure 18.

Figure 18. Grade of olive oils (Curejoy, 2018)

Extra virgin olive oil is the most valuable olive oil group. It can be obtained through careful production chain contains each activity in olive cultivation, harvesting, olive oil production and packaging. Basic information on extra virgin olive oil is given in Figure 19.

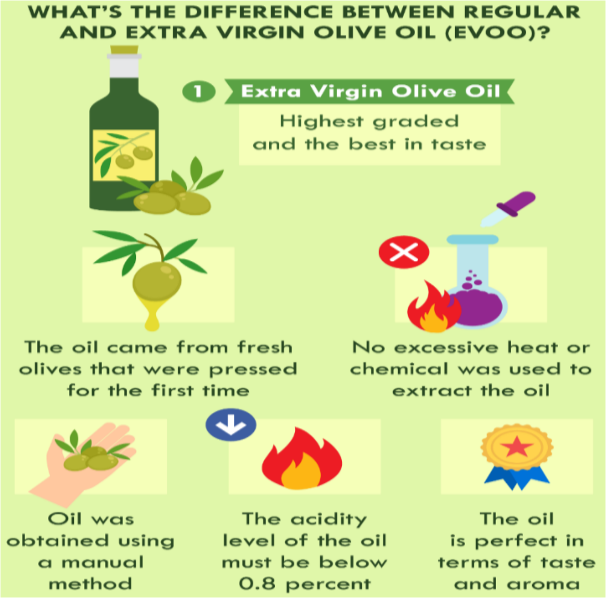


Figure 19. Basic information on extra virgin olive oil (modified from Black Paint, 2019)

Virgin olive oil is the second best quality group and produced with only physical methods same as extra virgin olive oil. It can be also obtained by careful production in whole production chain which contains cultivation, harvesting, olive oil production and packaging. Due to the misproduction techniques or sometimes due to the losses of production may not comply with the limits of extra virgin olive oil. In such cases, virgin olive oil group is used, which has a slightly expanded quality limit than extra virgin olive oil. Some properties of virgin olive oil are summarized in Figure 20.

All oils obtained from olives are valuable, but there are olive oils obtained by physical methods, but cannot be grouped as virgin oil or not suitable for direct consumption. This type of oil is defined as lampante olive oil and subjected to refining and defined as refined olive oil. Riviera olive oil is obtained by mixing refined olive oil with extra virgin and/or virgin olive oil. The representation of blend olive oil production is given in Figure 21.

Figure 20. Some properties of virgin olive oil (modified from Black Paint, 2019)

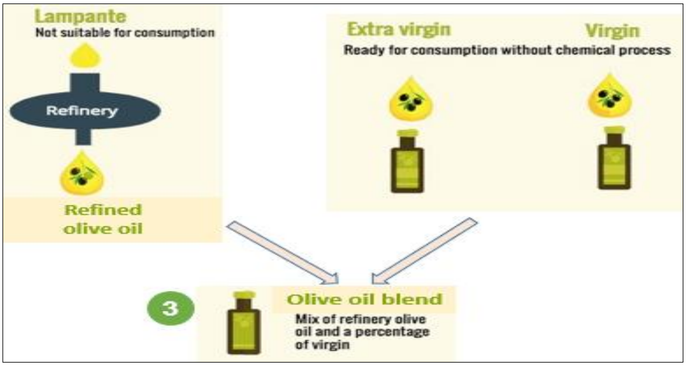


Figure 21. Summary representation of blend olive oil production

Olive Pomace oil, which is a mixture product similar to blend olive oil, is obtained by mixing refined olive pomace oil with natural extra virgin and/or first olive oils. The scheme summarizing the production of olive pomace oil and some features of olive pomace oil are given in Figures 22 and 23.

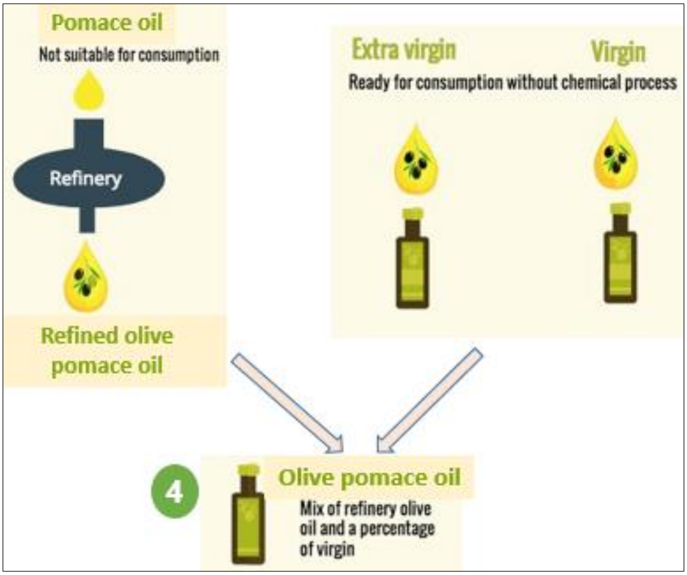


Figure 22. Summary representation of olive pomace oil production (modified from Black Paint, 2019)

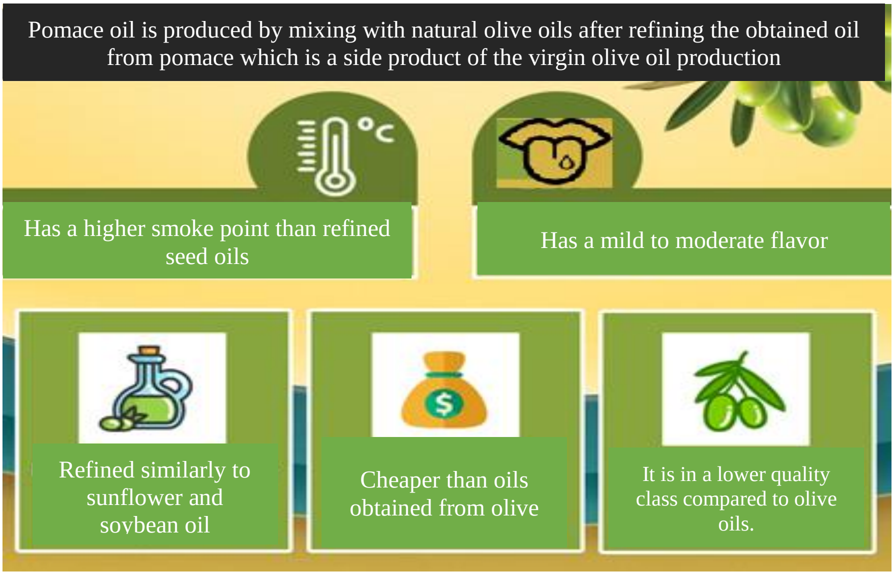


Figure 23. Some properties of olive pomace oil (Amritha, 2019)

As mentioned above, some olive oils cannot be consumed in their natural state due to the low quality of olives, sometimes due to inappropriate production process of olive oil and sometimes due to the poor production conditions. For this reasons, these olive oils have to be refined. Some properties of refined olive oil are given in Figure 24.

Figure 24. Some properties of refined olive oil

Crude olive pomace oil is not suitable for direct consumption like lampante olive oil. Generally, after the obtaining of oil from olives by physical methods, the oil remaining in the pomace is usually extracted by chemical methods. Sometimes it can also be obtained by physical methods. This obtained oil is defined as crude olive pomace oil. After the refining process of this oil, it is named as olive pomace oil. Some properties of olive pomace oil are given in Figure 25.

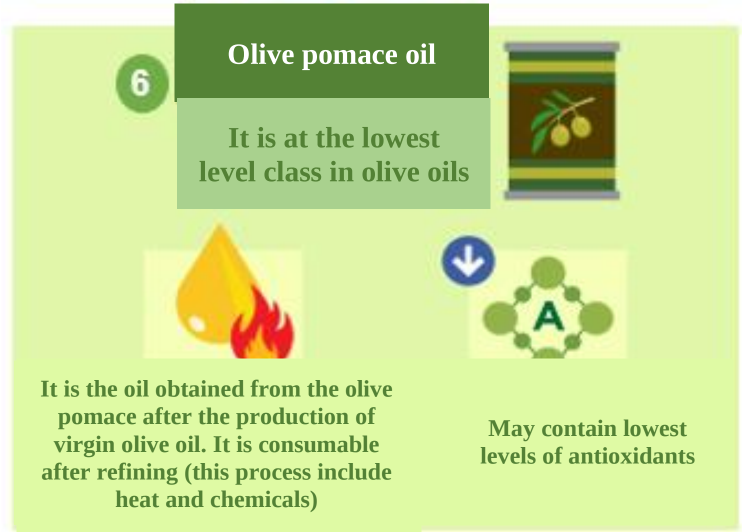


Figure 25. Some properties of olive pomace oil

HEALTH BENEFITS OF OLIVE OIL

There are numerous researches on the beneficial effects of extra virgin olive oil. In this way, both the properties of olive oil are scientifically revealed and more adopted by consumers. Some useful features of extra virgin olive oil are given in Figure 26.

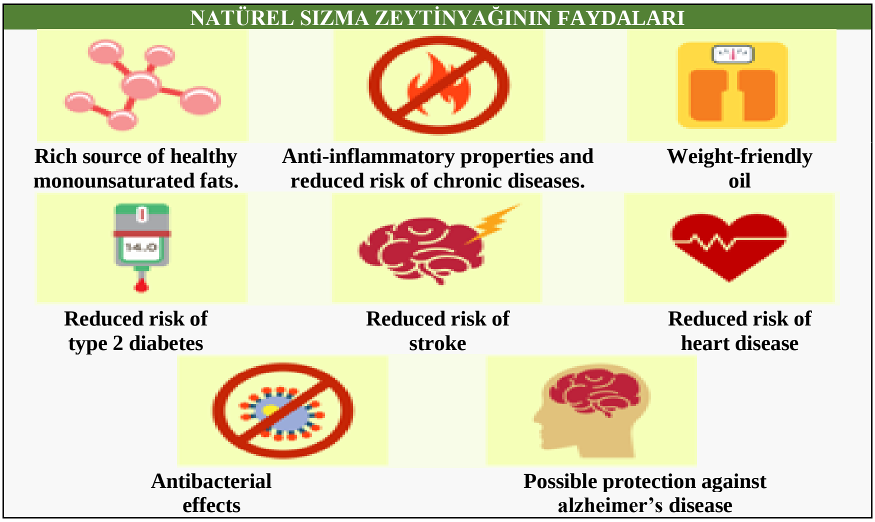


Figure 26. Some benefits of extra virgin olive oil (modified from Black Paint, 2019)

Olive oil has been considered valuable throughout its history and is used not only as food but also for medicinal purposes. Today, extra virgin olive oil is the group that includes the highest quality olive oils. As a general acceptance, beneficial ingredients are considered high quantities in high quality olive oil. Thanks to the minor components of extra virgin olive oil, especially antioxidants, it has both a unique taste and effects that protect the body against free radicals (Figure 27).

Figure 27. Some antioxidants in extra virgin olive oil

In parallel with the developing cosmetic industry, the use of extra virgin olive oil for cosmetic purposes has also increased. The use of extra virgin olive oil in cosmetic products is also thought to be effective on consumers' purchasing preferences in terms of evoking naturalness. The beneficial properties of extra virgin olive oil in terms of its contribution to skin and facial care are given in Figure 28.

Figure. 28. Usage areas of natural extra virgin olive oil in skin and face care (Black Paint, 2019)

It is well known that extra virgin olive oil is an important part of the Mediterranean diet and it has a protective effect on cardiovascular diseases in people in this region. The protective effect of extra virgin olive oil against cardiovascular diseases and its anti–aging properties are also widely known. In addition to these beneficial properties, it is reported to protective roles for diseases such as Alzheimer's, Parkinson's, and depression (Figure 29). In recent years, the inhibition effects of consuming herbal foods, extracts or drugs on the enzymes that cause these diseases have been studied intensively. Studies are also conducted on these properties of natural extra virgin olive oil.

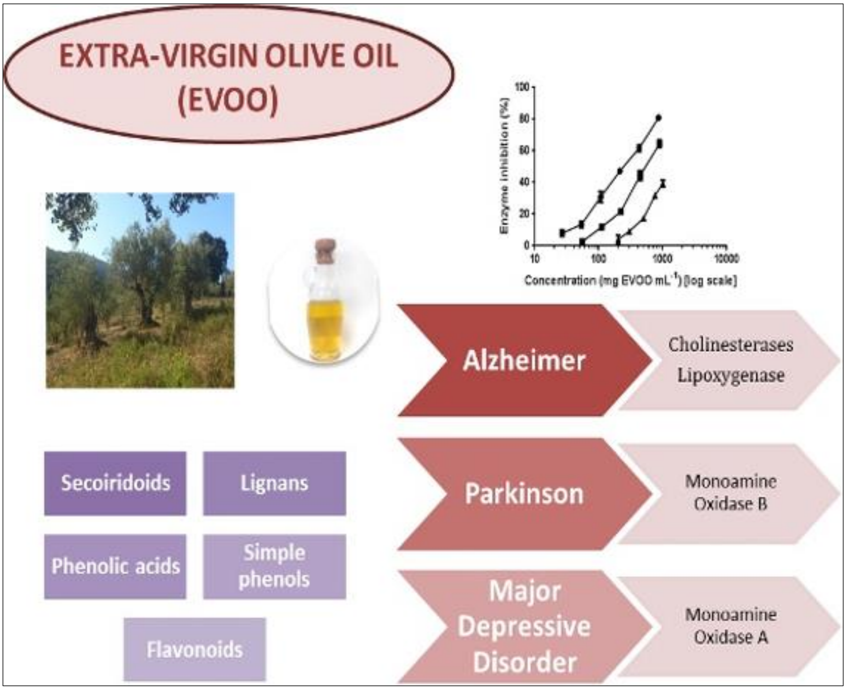


Figure 29. Protective potential of extra virgin olive oil from alzheimer, parkinson and depressive diseases (Figueiredo–González et al., 2018)

Extra virgin olive oil is defined as a functional food thanks to its beneficial ingredients. In addition, the unique fatty acid composition of extra virgin olive oil is associated with its protective role on cardiovascular diseases. However, it should be noted that each olive oil may contain different amounts of beneficial ingredients and its beneficial effects may vary accordingly. Some of the most important of these beneficial components and associated beneficial effects are given in Table 1.

Table 1. Some of the beneficial ingredients and associated beneficial effects of extra virgin olive oil

Component	Effects
Oleic acid	↑ HDL, ↓ LDL, ↓ LDL oxidation
Phenolic compounds	Antioxidant, antimicrobial effect
Vitamin E	Vitaminic action, antioxidant
Oleocanthal	Anti–inflammation
Squalene	Possible anticancer agent
Terpenic acids	Anti–inflammatory agent
Phytosteroles	↓ Cardiovascular disease risk

ORGANIC AND CONVENTIONAL OLIVE CULTIVATION

What is Organic Agriculture?

Organic Agriculture is an alternative production method that aims to preserve the natural balance deteriorated as a result of wrong practices in agricultural production. Continuity of the orchard's productivity and quality is aimed without using synthetic fertilizers, pesticides, growth materials and genetically modified organisms. However, organic farming in not an agriculture system with or without using specific inputs but is more of a sustainable agriculture system that cares about the agro–ecosystems and is more of a philosophy of life that includes many elements such as safe food, good nutrition, animal welfare and social justice.

Organic Farming Techniques and Orchard Management

In conventional agriculture, it is not strange to change the production area completely in line with the needs of the product we want to produce. However, harmonious production is an expected practice in organic agriculture instead of changing agro–ecology. In conventional agriculture, chemical (such as pesticides and fertilizer) inputs can be used, which can pose various risks. However, considering the insufficient knowledge of ecosystems and agricultural systems in general as a protective (pre–cautionary) approach in organic agriculture, it is expected that the steps to be taken will be determined with great care.

There are various restrictions and prohibitions in organic production compared to conventional production. Healthy products and environment are indispensable part of organic farming. In organic agriculture, it is expected that the inputs will be provided within the enterprise as much as possible and a holistic approach will be used in the construction of the production systems. In addition, decisions to be taken in organic agriculture are expected to take into account the values and needs of all parties, using transparent and participatory processes. Long term planning is inevitable perennial crop production such as olives, but in organic farming this becomes an even more important element. In particular, the 3–year transition period required in organic production should not be forgotten.

It is a process in which all organic farming rules must be followed in the transition period, but the product cannot be marketed organically. This process, which requires both technical and financial support, is the most difficult period for manufacturers. It is not a necessity to examine the agroecological and socio–economic structure of the land and its environment very well and bring together the best components, but it contributes significantly to the success and sustainability of production.

Regulations in Organic Agriculture

There are various legal regulations in conventional agriculture and food, but in organic agriculture, it is necessary to comply with the legal obligations related to conventional agriculture, as well as the organic agriculture law and regulations that regulate technical issues such as which inputs or techniques to be used on scientific grounds. This controlled production and certification process in organic agriculture has some important advantages. These are respectively:

•Validity in the international market,

•Certified product,

•Consumer confidence and easy perception,

Knowing which countries have certificates for organic products will prevent marketing problems. For example, due to the bilateral agreements between the European Union and the USA, when a producer producing in one of the European Union countries receives an organic certificate for his own country, he can market his product in other EU countries and the USA. However, if a producer got a certificate for Turkey to market this product in EU or the US, producer must also receive a certificate for the EU or the US.

Organic Regulations in the European Union

European Union Regulation No. 2092/91

•When the first official regulation was published in 1991, it included only crop production. In 1999, the Regulation on EU 1804/99 and the Organic Livestock Regulation were published and implemented on 24.08.2000.

•834/2007 and 889/2008 EU Organic Agriculture Regulation has entered into force since January 1, 2009.

Organic Regulations in the USA

"NOP–National Organic Program" published on 21.12.2000 was organized for the producers in the USA and started to be implemented in 2001.

Location, Production Method and Variety Selection

Olive is a long–lived, evergreen tree. It is a plant that is very resistant to drought, can live in conditions that many other plants cannot survive, strong, durable and can survive even in marginal soils. It is easier to produce olives organically than many products. Of course, it is more costly to produce 1 liter of organic olive oil or 1 kg of organic table olives compared to conventional. However, planning by taking into account the basic principles of organic farming rather than just meeting the requirements for certification during the orchard establishment will both reduce the difficulties that can be experienced in the organic production phase and increase the production efficiency.

Table 2. Some comparisons of conventional and organic farming

Conventional	Organic
•Easier weed control •Easier soil fertility practices •Easier to scale •Relatively easier to increase yield (short–medium) •Chemical residue problem •Increasing awareness of the risks of conventional agriculture	•Weed control costs more •More costly soil feeding applications •More complex scaling process •More difficult or costly to increase productivity •No chemical residue problem •Increasing awareness of the positive features of organic agriculture

Olive production potential in a specific area; Depending on factors such as climate, soil, water and nutrients, it depends on meeting the environmental adaptation and physiological needs of the olive tree. For the success of olive cultivation, the factors listed below should be taken into account and, if possible, should be brought to a level that will meet the needs of the olive.

Climate

The vitality of the olive plant is not affected, provided that very high temperatures and no excessive water loss. However, olives are more sensitive to frost. Suitable ambient temperatures for olives are 9,5–40°C.

Figure 30. Organic olive orchard

Damage begins in young trees when winter temperatures drop below –4℃, thin branches of large trees when it falls below –5.5℃ and large trees when it falls below –9.5℃. If the temperature drops below –1.7℃ in the autumn months, it may cause damage to the fruits.

In the spring, heavy rains, very high humidity and dry hot winds that can be seen during the flowering period limit fruit formation by negatively affecting pollination.

Olive is a plant that needs chilling. Olive is a plant that needs cooling. This need must be met in order to obtain fruit from plants. Although the required cooling varies according to olive varieties, the average periods of 200–400 hours below 6–8℃ are sufficient for many olive varieties. This need must be met in order to obtain proper bloom from plants. Although the required chilling varies related to olive cultivars, the average periods of 200–400 hours below 6–8℃ are sufficient for many olive varieties.

Wind Direction

The direction and strength of the prevailing winds in the breeding area are important to us. First of all, depending on the strength of the wind, it is necessary to decide whether we need to put windbreakers on our parcel border or not. If it is decided that it is necessary, the location of the windbreakers should be determined by looking from which direction the wind is coming from. Finally, we need to put the pollen from the pollinator varieties in a suitable direction so that it can be carried by the wind to all other trees in our production area.

Windbreakers:
•Taller than olive (10 m)
•Flexible
•Double–stage zigzag structure
•Root structure is durable

Soil

Soil is a non–renewable resource that supports the life of animals and plants. It consists of solid mineral particles of different sizes and varying percentages of organic matter to which it aggregates to form different soil types. Soil also acts as a reservoir of elements and water, so it is directly related to the growth and yield of plants. Olive is a plant genetically adapted to be content with less. When it is tried to be grown in very good class soil conditions, it shows an extremely strong vegetative development, which may cause limited fruit binding by disrupting the vegetative and generative development balance. In addition, intensive vegetative growth increases pruning needs and consequently the cost of production.

Figure 31. An olive garden with a drainage problem

Ideal soil properties for olives can be listed as follows:

•It should be preferred that the production area is medium–good class soils.

•The most important thing that can kill olive trees or limit their development is heavy soil conditions with high humidity and poor drainage. Therefore, good drainage of the areas where olive production will be made is very important for the success of the production.

•In olive production areas, the average depth of soil should be at least 1.5–2 m.

•The slight slope can be beneficial for the production system as it provides surface drainage, but the high slope may cause erosion risk and problems in mechanization applications.

•Light, coarse (sandy–loam) soils

•Phosphorus in the soil is required to be 10 ppm, potassium 125 ppm and boron 2 ppm.

•Olive is a plant that tolerates salinity. However, the high salinity is a factor that reduces the water intake capacity of olive trees.

•pH values should be in the range of 5–8.5 in the soils where olive production will be made.

It is preferable to have ideal conditions for olives, but for olives, which have a high adaptation to many problems, return of the improvements made with high expenditures to reach that conditions will not be economic.

Irrigation

Olive has developed physiological, biochemical and morphological adaptations to reduce water loss and tolerate dehydration. In this way, it is a species with high drought tolerance that can grow and provide yield even in the long–term lack of water in the summer months. However, it responds well to irrigation especially during droughts experienced in critical development stages. Irrigation becomes less important in olive cultivation except for some critical development stages. Although there are some differences in olive cultivation according to their varieties, an average of 3000–6000 m^3/year/ha of water is needed. The characteristics we expect irrigation water to show are listed below.

•Boron: < 1–2 mg/l (2 ppm)

•Bicarbonate: 3,5 ppm

•Sodium: EC < 3 dS/m (480 ppm)

Figure 32. Drip irrigation in an olive garden

Variety Selection

In the selection of the variety, after deciding whether the cultivation will be for table, oil or both, it should be paid attention to choose the varieties that have adapted to our regions where olive cultivation is carried out or have been at the forefront in the adaptation studies carried out in these regions and have economic value. Varieties that are susceptible to olive branch cancer in windy and frost–damaged areas, and those sensitive to ringed spot disease should not be used in moist and cold regions.

We can determine the type of production we will produce by considering the factors such as climate, soil structure and irrigation possibilities of our production area and evaluating the features listed below.

•Fruit Characteristics,

- Yield,
- For the varieties to be considered as oil: Oil yield and quality (aroma),
- For the varieties to be considered as table: Fruit size, Meat/seed ratio,

•Growth strength and shape–Harvest Method–Fruit separation power,

•Resistance to cold,

•Fruit maturity period,

•Disease resistance,

•Salinity tolerance,

•The need for cooling,

•Pollinator variety.

Although olive is a partially self–pollinating species, having a pollinator variety within 60 m will increase pollination and yield.

Table 3. Widely cultivated olive varieties

Variety	Origin	Usage Purpose
Memecik	Turkey	Oil and Table
Ayvalık	Turkey	Oil and Table
Gemlik (Triliye)	Turkey	Table and Oil
Picual	Spain	Oil
Arbequina	Spain	Oil and Table
Hojiblanca	Spain	Oil and Table
Leccino	Italy	Oil
Frantoio	Italy	Oil
Coratina	Italy	Oil
Kalamata	Greece	Table and Oil
Koroneiki	Greece	Oil
Cobrancosa	Portugal	Oil
Mission	US	Oil and Table

Tree Spacing and Production System

Different olive growing methods have been developed depending on the changing environmental factors and the level of technology applied.

Examples include an extensive olive grove of 200 or less trees per hectare, or super–dense systems with more than 1200 trees per hectare. The most common olive groves in Italy are scaled between 6×4 (416 trees/ha) and 6×6 (277 trees/ha). In Turkey, as in the areas of traditional olive tree spacing from and above 7×7m, 6×6m, it is 5×7 m.

One of the basic factors to consider when determining the distance between rows and above is that olive trees receive as much sunlight as possible. The more this amount of sunbathing, the greater the attachment to the fruit.

Sunbeam Falling On a Leaf = Flower = Fruit

Figure 33. Olive orchard established with 7×7 m row spacing

Figure 34. Super dense olive orchard

Table 4. High density and super high–density orchards

High Density	Super High Density
•2,5×5 m–3×6 m	•1,2×3,6–1,5×4 m
•500–900 tree/ha	•1500–2200 tree/ha
•Bearing by 5th year	•Bearing by 3rd year
•Full production 10th year	•Full production 5th year
•Harvest: Hand or shaker	•In–line harvester
•Substantial expense harvest	•Important expense pruning
•Initial setup costs are not very high	•First setup costs are high

High density planting systems can theoretically be used in organic agriculture. However, high density systems will be difficult to manage in organic orchards. The basic principles of organic agriculture, primarily the use of farm resources, the sustainability of soil fertility, the use of beneficial insects and natural preparations instead of pesticide control; Applications such as preventing diseases by ensuring that the density of trees does not cause excessive shading will not be possible in super dense planting plots. For this reason, a maximum density of 300 trees per hectare in the organic olive orchards is considered appropriate.

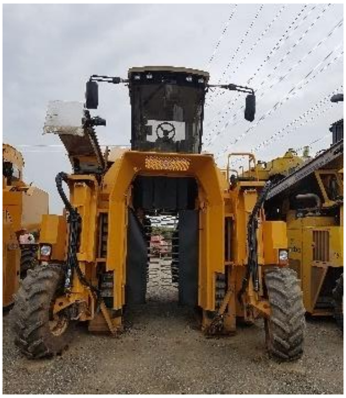


Figure 35. Harvester used in super dense orchards

Figure 36. A well–structured olive sapling suitable for sale

Planting Material

The factors to be considered in the selection of saplings are as follows.

- Must be single body,
- It should be about 1.2 m in length,
- There should be no side branches below 65–75 cm,
- Main branch structure must have formed,
- It should not be contaminated with diseases and pests,
- The roots should not be twisted together,
- Must have strong growth properties.

Tree Training and Pruning

Olive is a plant that responds negatively to frequent and intense pruning. Unlike deciduous plants, since they store a significant portion of their energy in their leaves, intensive pruning can hinder plant growth. The most important factor to be considered in pruning is to establish the vegetative and generative balance in the trees and to remove the diseased and damaged plant parts from the garden. Internal lighting and ventilation should be provided.

In organic olive groves, pruning can be done every 2 years. Pruning performed in the on year will reduce the yield of that year to a certain extent and cause an increase in productivity in the off year.

- Factors to which it depends;
    - How to harvest,
    - Preferred tree structure,
    - Pruning frequency,
- Responds negatively to frequent and intense pruning,
- Young trees are not pruned strongly (first 4–5 years),
- When olive tree reaches to 3 m length reaches and/or 2–2.5 m width (2–3 years) inner branches should be removed and permanent scaffold branches should be chosen,
- Until the age of 8 (3–4 years) continue to watch the internal branches,
- When the olive reaches the age of 8 (3.5–4.5 m), its basic shape must be formed.

Orchard Floor Management and Soil Nutrition

1. Traditional Tillage
2. No–Till Soil Management
3. Use of Mulch
4. Use of Cover Crops (Figure 37)

The most applied method is traditional tillage. With this application, it is aimed to eliminate weeds that compete with trees in the intake of water and plant nutrients, to increase the infiltration of rainwater to the soil, to allow organic material to mix into the soil and to aerate the soil. However, this method compresses the soil to form an impermeable layer, resulting in a drop of infiltration rate. In addition, roots in the upper parts of the soil can be damaged by deep plowing.

No–till systems, especially the use of cover crops has several benefits like:

- Convenience in field work,
- Adding nitrogen and organic matter to the soil,
- Water and air intake increase thanks to the cover plant root structures,
- Reduction of erosion.

Figure 37. Orchard floor management methods

Soil Nutrition

Olives trees are adapted to manage with low levels of nutrients, can develop intensely vegetative when excessive nutritional supplementation and irrigation is applied, resulting in limited flowering and fruit production. Even in some cases, it can cause diseases and pests to be more effective in the orchard. In case of deficiency in plant nutrients, the deficiencies can be eliminated with the following applications.

Table 5. Critical element values in leaf tissue samples taken in July (Beutel et al., 1983)

Element	Deficient	Enough	Toxic	Deficiency symptom	To fix the deficiency
Nitrogen (N) (%)	1,4	1,5–2,0		Light green or yellowish green old leaves	Blood meal, cotton seed flour, corn starch flour, feather meal, leather flour
Phosphorus (P) (%)		0,1–0,3		Dark green first, then red purple in older leaves	Increasing pH, bone meal, rock phosphate, bat manure
Potassium (K) (%)	0,4	0,8		Drying on the edges of the leaves in old leaves	Seaweed, granite flour, wood ash
Calcium (Ca)		1,0			
Magnesium (Mg) (%)		0,1			
Mangan (Mn) (ppm)		20			
Boron (B) (ppm)	14	19–150	185		

Use of Cover Crops (Green Manure)

Plowing and mixing of suitable plants into the soil at a certain stage of their development and while they are still green in order to provide the necessary organic matter in the soil. Rhizobium bacteria, which lives symbiotically with legume plants, transfer the free nitrogen from the air to the soil and provide the soil with nitrogen enrichment (approximately 100 kg N/ha). Depending on the soil type and climate, green manuring can be done by annual planting at least one legume and one type of wheat. For example, vetch and oats are the plant species that can be used in this way.

Figure 38. Cover crops (vetch/oat)

Composting

It is the biodegradation and restructuring of organic material by microbial organisms in an oxygenated (aerobic) environment under suitable temperature and humidity conditions.

Figure 39. Composting

Vermicompost

It is the composting process of plant and animal origin wastes and residues by worms under aerobic conditions. Composting is actually a natural process in nature, wherever plants grow.

Farm Manure (Cattle)

It is an indispensable organic fertilizer in organic agriculture. It is the basic organic fertilizer used to meet the nutritional requirement of the plants. Since its content varies, it must be used after analysis. It is also widely used in conventional agriculture.

Commercial Fertilizers

Commercial fertilizers are used to meet the nutritional requirement of the plants. They can be in liquid or solid form. While some of the products in this group are allowed to be used in organic agriculture, some of them can only be used in conventional agriculture systems.

Disease, Pest and Weed Control

Weed Control

We do not want the natural vegetation (plants other than olives) in our production area to compete with our olive trees for the intake of water and plant nutrients. Weeds in the tree projection are more important to us. Competition may be limiting, especially for young olive trees. In situations where trees are not young and where there is not much water competition, it is preferred to mow the weeds and leave them on the soil surface.

•Mechanical Methods,

•Soil Processing,

•Use of Mulch,

Figure 41. Various weed control methods

Animals fed naturally with weeds such as ducks, geese, sheep and goats can be used for the control of natural vegetation in our production area.

Olive Peacock Spot

Spilocaea oleagina (Fungus)

It causes round dark circles on the leaf. Then the leaves are become yellow and fall to the soil. This reduces the rate of blooming and fruit production by reducing the area of photosynthesis.

To keep olive peacock spot disease under control:

•Heavy, soils with limited infiltration capacity should not be preferred as a production area

•If there is lack of lime in the soil, it should be corrected

•Providing ventilation and sun with pruning

•Cleaning the leaves is important

•Another method is Bordeaux mixture application. Although there are differences according to the climate and the region, it should be applied twice once before shoot growth and another time before flowering.

Figure 42. Olive peacock spot

Figure 43. Bordeaux mixture application

Verticillium With

Verticillium dahliae (Fungus)

It is a soil–derived fungus which develops in vascular tissues. This causes the branches to dry by clogging the tissues. Unlike root rot, the leaves turn brown and do not fall off. The best way to prevent disease is to start growing in an uncontaminated garden. Cotton is a plant sensitive to this pest. If it is planned to start olive cultivation in cotton regions, attention should be paid. There is no olive variety resistant to this disease.

Armillaria Root Rot

Armillaria mellea (Fungus)

It is an effective disease in different trees, but not a very critical disease for olives. Unlike Verticillium, leaves and branches are affected more slowly, the exposure occurs step by step and leaves do not fall off at once.

After contamination, there is not much that can be done, our chance to save the tree is not too much, so in order to prevent the spread, the infected trees should be removed from the production area with the tree roots as quickly as possible.

Olive Knot

Pseudomonas syringae pv. *savastanoi* (Bacteria)

Bacterial infection can start from the wounds of fallen leaves (most importantly) from pruning wounds and frosts. Contamination may occur in autumn, winter and spring. When the plant growth starts in the spring period, it causes the formation of galls in different parts of the tree. It can cause death in very thin branches but does not cause the death of the plant. It reduces the fertility of the plant. There is no effective treatment method. It should be avoided to open a wound to the plant during rainy periods. Contaminated tissues should be removed by pruning whenever possible. In the period when wounds that may cause contamination occur (spring, autumn), the application of Bordeaux mixture application prevents entry from those wounds.

Figure 44. Olive knot disease

Olive Quick Decline Syndrome (OQDS)

Xylella fastidiosa (Bacteria)

OQDS is a disease spread by insects. It can cause the death of olive trees. It was first seen in Italy in 2013 and affected 17 percent of the country. Apart from Italy, it spreads in Greece and Spain. Diseased tissues must be destroyed by hard pruning to prevent the spread of the disease. It is not very easy to control, as it also spreads in (more than 300) plants such as almond and oleander. There is no cure, but methods of developing resistance are under investigation.

Common Insects Harmful to Olives

Olive Fly

Bactrocera oleae or *Dacus oleae*

The olive fly is a very common pest that causes damage (monophagous) only on wild or cultivated olive varieties. Depending on the local climatic conditions, the olive fly can produce up to 3 or even 6 offspring per year. The following methods can be used in the control of olive pests.

- Removal of contaminated olives,
- Providing ventilation and sun with pruning,
- Early harvest (if possible),
- Trap use;
  - McPhail trap,
  - Yellow sticky pheromone traps,
  - Attractive and deadly traps,
  - OLIPE trap,
- Repellents:
  - Kaolin,
  - Slaked lime,
  - Sodium silicate,
  - Burgundy slurry,
- Plant–derived insecticides: such as Azadirachtin obtained from the neem tree
- Microorganism–derived insecticides: Bacillus thuringiensis 114 A, such as Spinosad
- In addition, many different chemical pesticides that are not allowed to be used in organic agriculture can be used in conventional olive cultivation.

If olive fly damage has occurred, the olive fruits should be harvested to prevent further oxidation and the formation of olive anthracnosis. It is possible to obtain olive oil with an acidity of less than 1% from olive fruits that have only olive fly damage. However, when anthracnose occurs, this possibility disappears completely because this situation greatly reduces the quality of olive oil. In such a case, olives that fall to the ground but can still be used should have a separated oil extraction process.

Figure 45. Olive fly

Warning Regarding the Use of Chemicals

- Care should be taken in the use of chemicals in olive farming. Chemical substances used in the control of diseases and pests are **POISON**. The descriptions on the boxes of the products should be read carefully and these warnings should be paid attention to. These chemical products should be stored in their original containers, away from food, animals and children.
- Producers are legally responsible for chemical residue problems in their products and contamination in neighboring orchards.
- When the pesticide boxes are empty, they should never be burned or thrown around. Authorities should be consulted about what to do.
- Chemicals can also be harmful to the plant if the appropriate method, dosage or mixture is not used.

Olive Moth

Prays oleae

Each of the 3 progeny that emerge during the year causes damage to a certain part of the plant. These organs, which are consumed as food, allow the pest to grow slowly or rapidly, which can be compatible with the phenology of the tree. Adults from May to June lay eggs on small fruits, especially calyx. After the eggs are opened, the larva moves forward by opening a gallery towards the fruit and enters the fruit before the seed hardens, feeds on the fruit until mid–September, and then leaves the fruit and turns into chrysalis in the soil until the end of October. The newly emerged adults leave an egg on the leaf and go to the progeny stage, which eats plants again. As can be seen, the host adaptation between olive and olive moth is very high. BT toxin (insecticide) is a toxin obtained from Bacillus thuringiensis bacteria. Another application that we can use is paraffin (insecticide). Figure 47 shows some other pests of olive.

Figure 46. Olive moth

Olive psyllid (*Euphyllura olivine*)

Black Scale (*Saissetia oleae*)

Figure 47. Some other insects that are harmful to olives

Whether organic or conventional olive oil production, the production process should be handled as a whole. Figure 48 shows the important factors for high quality olive oil production. From choosing olive tree variety and planting sapling to the storage and packaging each step should be worked carefully. From olive cultivation to olive oil production and finally to packaging, necessary measurements should be made and necessary precaution should be taken.

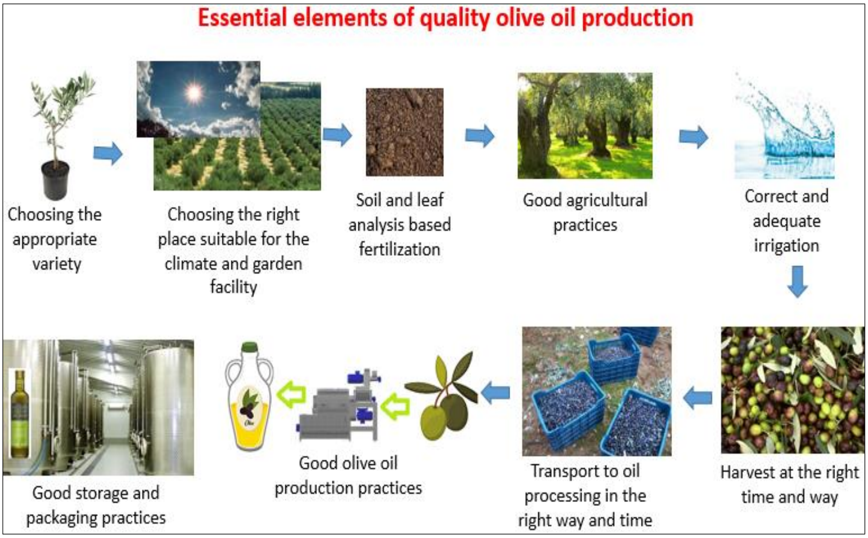


Figure 47. Essential elements of high quality olive oil production

Careful attention and obey in scientific rules during different phases of the production of olive oil also enhance not only high quality but also for phenolic content that fits the health claim for phenolic content that fits the health claim for polyphenol concentration (250 mg/kg) (Aristoil Guide, 2019).

THE IMPORTANCE OF OLIVE MATURITY AND CALCULATION OF THE MATURITY INDEX

It is extremely important to determine the correct harvest time in order to obtain the highest quality and high amount of olive oil. The right harvest time for olives can be defined as the time when the lowest quality loss of the oil and the highest quality obtained from oil. Determination of the right harvest time in the most accurate way is possible by regularly monitoring the maturity of the olives in the orchard. The fruitiness, bitterness and polyphenol content of four olive varieties harvested at different maturities are shown in Figure 48.

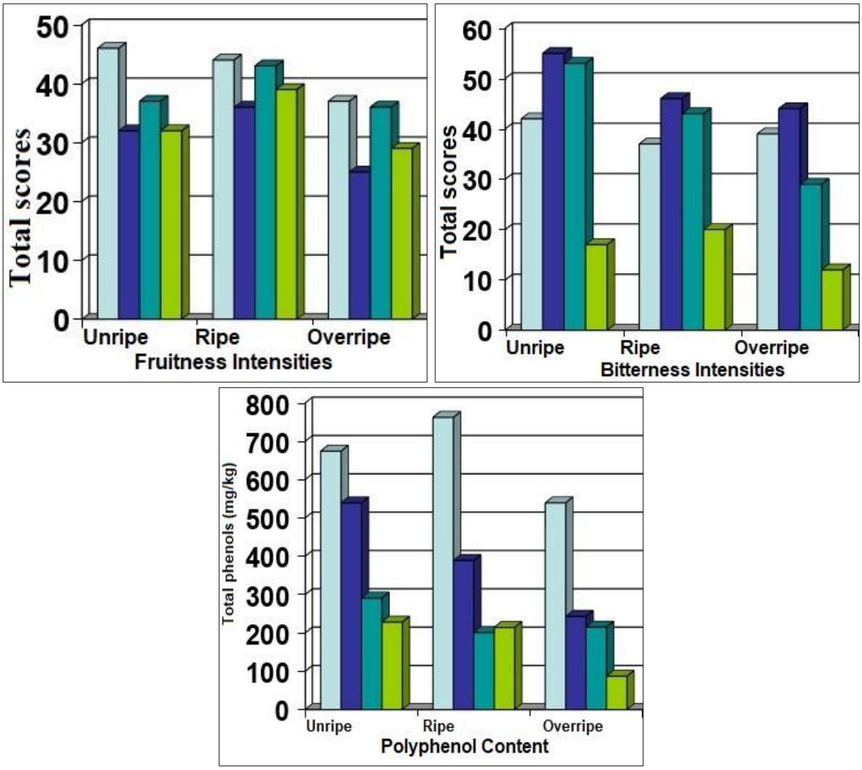


Figure 48. The change in fruity and bitterness values and polyphenol contents of unripe, ripe and over ripe olives belonging to four olive varieties (each color represents different olive varieties) (Oberg, 2010).

Olive ripening level affects both the oil content of the olive and the quality of the obtained oil. While the amount of oil in olives increases with ripening, the positive sensory properties and phenolic component contents, which are important quality indicators of the oil, decreases during ripening.

Therefore, it is important to determine the harvest time that will achieve an optimum balance between these values. The comparison of the oil content and aroma (polyphenol) content of the olive depending on the ripening is given in Figure 49.

The internationally accepted method used to monitor olive maturity is the following the changes in olive skin and flesh color. The parts of the olive as well as color changes depending on the ripeness are shown in Figures 50 and 51.

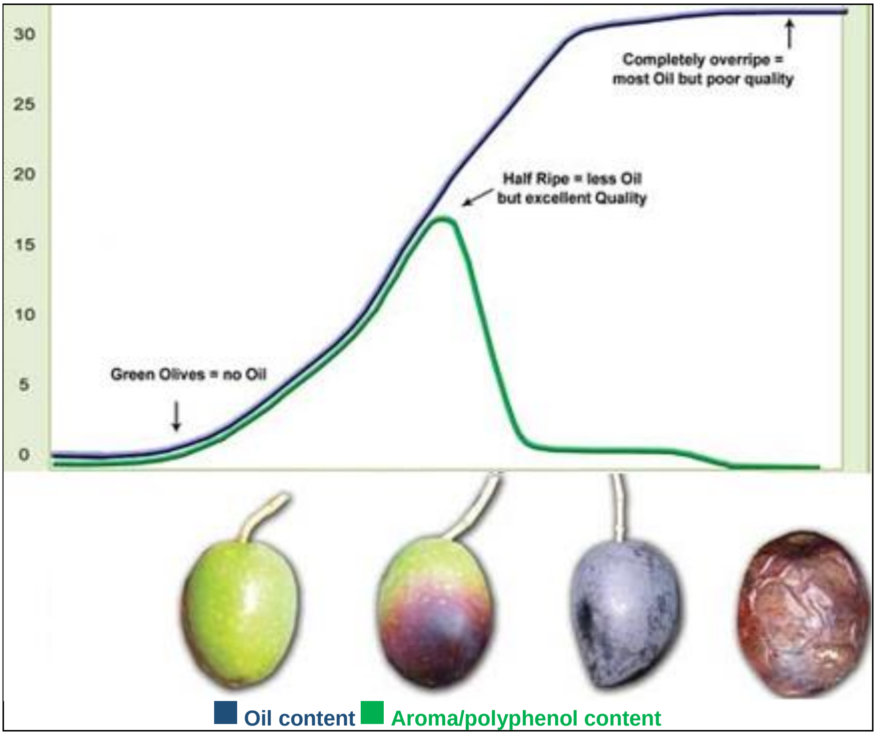


Figure 49. Comparison of oil content and aroma (polyphenol) content of olives depending on ripening (Olivessa, 2020)

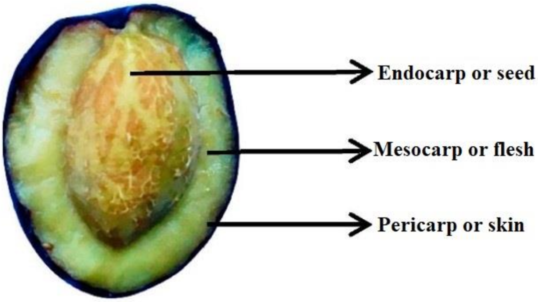


Figure 50. Parts of the olive

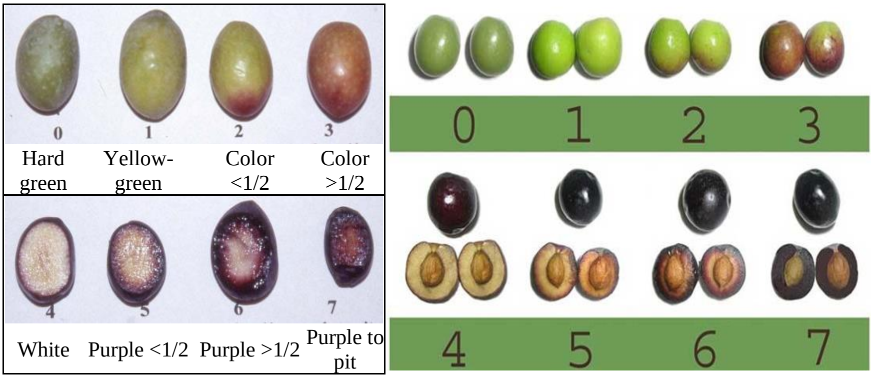


Figure 51. Color changes in olives by ripening (Montaño et al., 2018; Kesen et al., 2017)

The maturity indexes are calculated according to International Olive Oil Council method (IOOC, 2011). In this method, a numerical value is obtained by color values of randomly selected 100 olives. As seen Figure 34, skin and flesh color of olives are determined. Numerical maturity index groups are given in Table 2.

Table 6. Maturity Index (MI) classification groups of olives based on skin and flesh color

Maturity Index Group	Description
0	Skin color deep green
1	Skin color yellow–green
3	Skin color with < half the fruit surface turning red, purple or black
4	Skin color all purple or black with all white or green flesh
5	Skin color all purple or black with < half the flesh turning purple
6	Color all purple or black with > half the flesh turning purple
7	Skin color all purple or black with all the flesh purple to the pit

The total number of olives in each category was counted and recorded. The following equation was then applied to determine the maturity index:

$$\text{Maturity Index} = [(0 \times n_0) + (1 \times n_2) \ldots + (7 \times n_7)] / 100$$

Where n is the number of fruit with that score (Boskou, 1996).

As a result, the amount of phenolic substance of olive oil has is accepted as an important indicator of its quality and beneficial components. Olive oil with high phenol content can be marketed at higher prices. Each grower should determine the optimum harvest time for his/her orchard, as it causes the change in the oil and phenolic component content of the oil, depending on the progress of olive maturity. The harvest time affects the amount of the olive oil to be obtained, the amount of healthy ingredients, the taste, the resistance against quality losses during its shelf life and during its cooking, the cost and the sales price, in other words it affects the fate of the olive oil.

HARVEST OF OLIVES AND SHIPPING

Olives must be protected from crushing during harvest and transportation. When olives suffer from physical damage such as hitting, scratching or crushing, firstly unnoticed damages occurs. However, depending on the severity of the damage, progressive deterioration occurs as time passes. These physical damages cause defective or low quality products in both olive oil and table olive production. The appearance of olives that were exposed to impact and not exposed during the harvest is given in Figure 52.

(a) (b)

Figure 52. The visual observations of and exposed olives (a) and unexposed olives (b) to impact during harvest

The harvesting process should be done without damaging the olives, at the lowest cost and without leaving olives on the tree.

(Tsocho Peev, 2015)

The imperfections of the impact that are not noticed after the harvest cause black spots that become visible after waiting in brine. Although the impacts of olives to be processed into olive oil are not visible to the eye, they manifest themselves by causing a decrease in the quality of the oil if they are not processed immediately after harvest. Damage to olives during harvest causes defects, especially the rapid oxidation of the oil.

Damage to olive cells or the breakdown of the cell wall causes enzymes that cause defects such as lipase and peroxidase to work faster and oxidative deterioration occurs rapidly. For this reason, showing an egg sensitivity to olives during harvest and transportation will increase the quality of olive oil.

Olive harvest by hands minimizes damage to the olives as predicted. However, it causes an increase in cost. The combs used to harvest the olives made the manual picking method easier to apply and accelerated the harvest a little more (Figure 53). Olive harvesting cost in olive oil production is one of the most important cost items. Therefore, reducing the cost of harvesting can provide significant increases in the profitability.

Figure 53. Comb samples used in olive harvesting

Depending on the working system, the machines used in the harvesting of olives can be examined under two groups. These are shaker machines and beater machines. Shakers make the olives fall off the branch by applying vibration to the branch or the trunk, while the beaters shake the branches close to the olive. Shaker machines can perform harvesting in two different ways as branch shaker and trunk shaker (Figure 54). Beaters are manually operated beaters and row–mounted beaters (Figure 55). If it is desired to reduce labor costs by mechanized harvesting, it is necessary to determine the distance between the row and row during the olive garden setup and to choose varieties and pruning systems suitable for harvesting with mechanization.

Harvesting is carried out by whisking the olive branches by moving the whisk unit of the manually operated beaters through the tree crown. The branch shaker and manually operated beaters are relatively easy to use on slopes or small gardens. Olives fall on a soft ground thanks to an upside down umbrella system in shaking machines. In this way, olives are not damaged and can be collected automatically. There is no need to lay a cover on the ground and collect from the ground.

During the transportation of the olive from the orchard, the necessary precautions should be taken to prevent the olives from being crushed, damaged and heated. Olives should be transported in plastic cases with holes to provide ventilation. Incorrect transportation in bulk or in sacks made to save shipping or labor can cause significant reductions in oil quality and may result in greater financial losses than the planned savings.

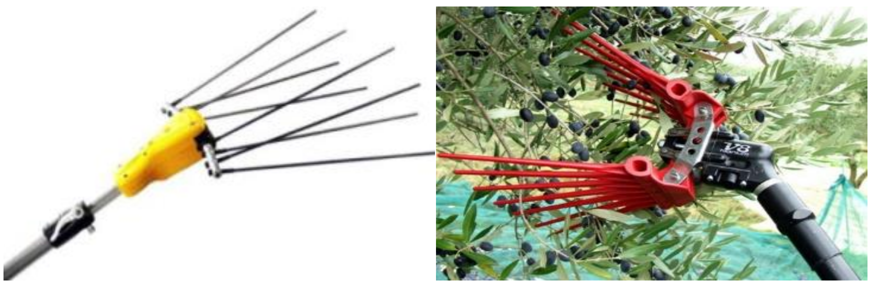
Branch shaker carried on the back

Self–propelled body shaker harvester

Mobile umbrella

Umbrellas attached to the machine

Figure 54. Branch shaker and trunk shaker (with and without umbrella) harvester

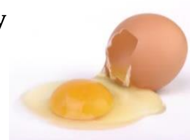


Manually operated beater

Self–propelled beater

Figure 55. Manual and on–line self–propelled beater machines

Approach olives with egg sensitivity during harvest and transportation do not damage them



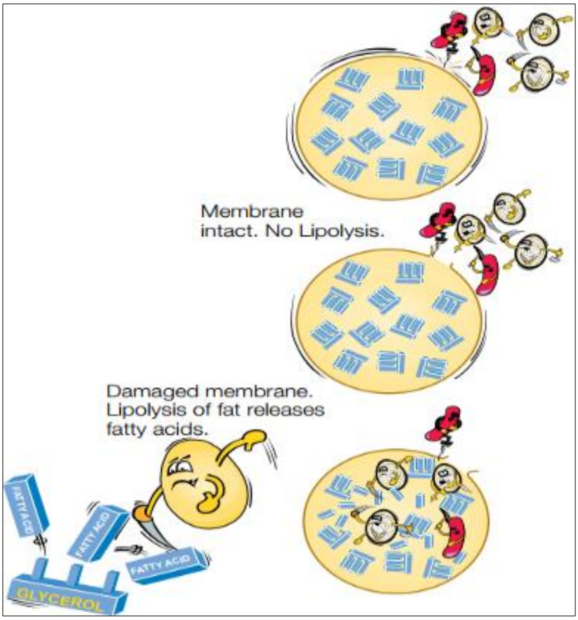


Figure 56. When fat globule membranes are damaged, lipolysis can release fatty acids (Bylund, 1995)

Due to damages of olive tissues that occurred during harvesting, transportation or oil production while waiting in an unsuitable environment (such as high temperature, unventilated environment or high stacking), the free acid content of the oil increases, and defects in sensory values occur. As a result, the value of the oils obtained from these olives decreases.

If the olive tissue is not damaged, the oil molecules in the olive are produced intact. In this case, enzymatic (lipase) or oxidative degradation of the fat molecule is prevented. Figure 56 shows the working status of the lipase enzyme when the cell wall damage is occurred or not.

It is important for the olives not to be damaged during and after the harvesting and not to be exposed to high temperature after the harvesting to obtain high quality olive oil. Similarly, in order to preserve the quality, olive oil must be protected from air, light and high temperature after production.

OLIVE OIL PRODUCTION

The olive oil production process starts with the acceptance of olive to the factory and ends with the filling of the olive oil in the final packaging. However, in order to obtain quality olive oil, a wide process starting from olive growing to the consumer's acceptance must be carried out properly. The properties required for the olive acceptance to the olive oil factory before production of oil are shown in Figure 57.

The establishments that producing olive oil can be divided into two as factories that produce in a batch and continuous system. The batch system allows lower capacity production. In the batch system, olives consist of sorting, washing, crushing/crushing, pressing and oil separation based on density difference (Figure 58). Although batch production was a method used in the past, today olive oil production with continuous systems is used in almost all enterprises.

Figure 57. The properties required for the olive acceptance to the olive oil factory before production of oil

Figure 58. Photos of olive oil production in batch system (with press) (Dawson, 2020; Orfion, 2017)

Olive oil production in the continuous system enables both high capacity and high quality production. An example of olive oil production facilities operating in batch and continuous system is given in Figure 59.

It is possible to divide the continuous system olive oil producing factories, into two as small and large scale according to their capacities. Although the systems used in both are the same, the amount of olives they can process per unit time is different. Small scale enterprises are also named as boutique olive oil producers. These facilities can be installed with lower investment costs. Some producers with olive groves produce their own oils with small investments. A more meticulous production is possible with a small–scale facility, so that high quality olive oil can be produced, albeit in low quantities. Boutique olive oil production is given in Figure 60.

Figure 59. Olive oil production facility operating in batch and continuous system (modified from Clodoveo & Amirante, 2017)

Figure 60. Boutique olive oil production

Continuous production of olive oil consists of sorting, leaf removal, washing, breaking, malaxation, decantation, centrifuge, filtering and filling steps. Olive sorting is extremely important for obtaining high quality olives. The schematic view of continuous system olive oil production and fabrication layout are given in Figures 61 and 62.

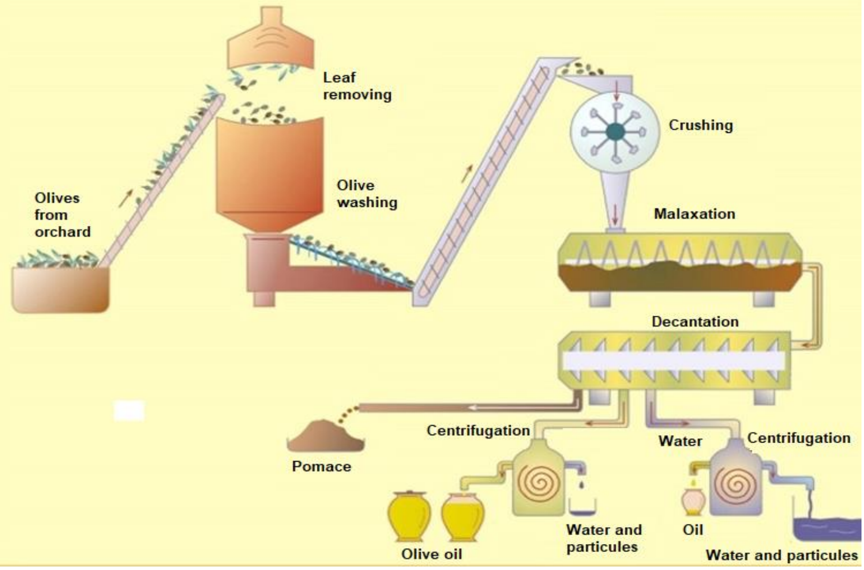


Figure 61. Continuous system olive oil production scheme

(1: Feeding chamber of the selected, leaf removed and washed olives, 2: crusher, 3: malaxers, 4: temperature board of malaxer, 5: decanter, 6: separator)

Figure 62. Fabrication layout of continuous system olive oil production

Today, almost all of the olive oil is produced in continuous system. Continues system is defined as 2 phase or 3 phase according to the used decantor working model. In the 3–phase production process, 3 phases are formed as waste–water, olive pomace and oil while in the 2–phase production process, 2 phases are formed as aqueous pomace and oil. In 3–phase production, water is added to the decanter and this water takes some of the olive juice and leaves to the system as waste water. In 2–phase production, there is no water added to the decanter and the olive juice remains in the pomace (Hocaoglu, 2015). The products and waste–water amounts formed according to the production processes are shown schematically in Figure 63.

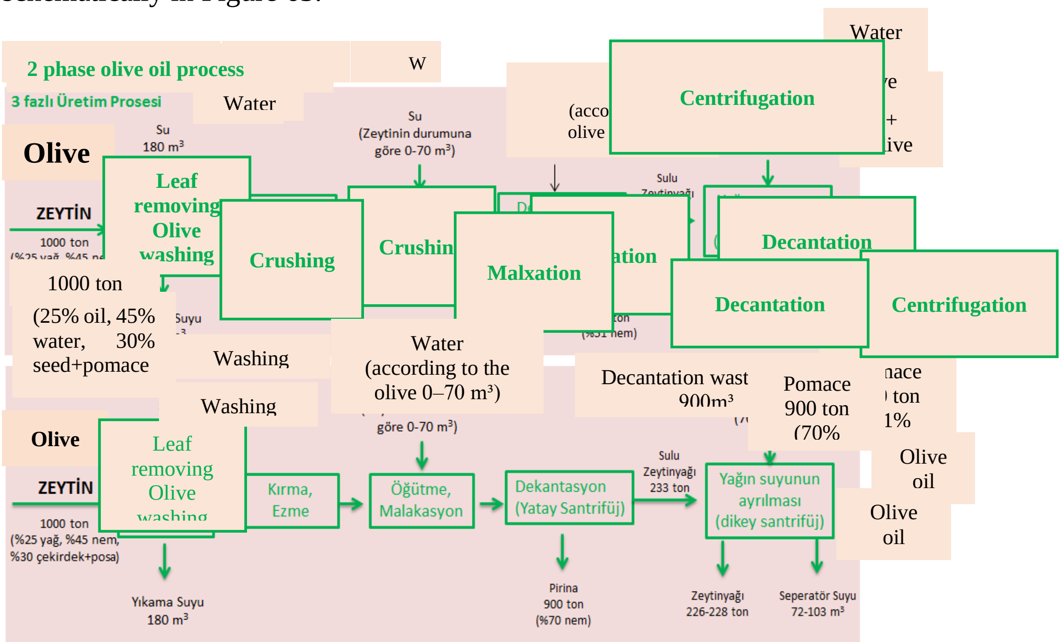


Figure 63. Olive production according to the production process (Hocaoglu, 2015)

Removal of Foreign Material and Unhealthily Olives

It is necessary to remove all rotten, diseased or damaged olives to increase the olive oil quality at high level. In addition, removal of stone, wood and similar foreign materials other than olives is necessary both to ensure hygiene conditions and to prevent damages to the machines.

Leaf Removal

Leaf removal can be carried out with a simple fan system. Effective removal of leaves can prevent the bitterness of olive oil and deterioration reactions in storage. For this reason, the leaves must be removed effectively.

Washing

Washing process is important for both to obtain high quality olive oil and hygiene. After washing, the cleaning efficiency should be controlled. Secondly, sorting process can be done to remove unhealthy olives. With washing, possible pesticides, dirties, dusts, soil and similar undesirable substances on the olive surface can be removed. It is necessary to change the washing water frequently to keep it clear. It was essential to use sufficient amount of water and to ensure sufficient contact time of water with olives for ensuring effective washing. In washing step olives are shaken into a washing basin by help of blower and finally rinsed with clean water (Peri, 2014).

Crushing

Olives are break down to small sizes in the crushing process. Crushers with rotating shaft or hammer are generally used for this process. Olives are fed to the crusher from above and are crushed by hitting the crusher equipment and the inner walls of the crusher in rotation (Figure 64). In this process, since the crusher rotates at high speed, olive seeds hit with a high force. Even the core is disintegrated with the effect of this impact. Olives coming out of the crusher have a pulp appearance with coarse particles. It is aimed to reduce the olives to a certain size by crushing and to ensure that the cell walls are damaged and the oil can come out more easily.

Figure 64. Internal view of olive crusher

Malaxation

The olives coming out of the crusher are mixed in the malaxation unit and become a uniform olive dough. Traditionally, the malaxing step consists of a low and continuous kneading of olive paste at a carefully monitored temperature. This step is especially useful for achieving high and satisfactory yields of extraction. In fact, this essential technological operation helps the small droplets of the oil formed during the milling to merge into large drops that can be easily separated through a centrifugal system (Clodoveo & Amirante, 2017). By means of malaxation, it is desired to combine the oil, which is scattered in small drops in the olive paste, to be present in larger clusters. This makes it easier to separate the oil in the decantation stage. The representation of the clustering of oil molecules during malaxation is given in Figure 65.

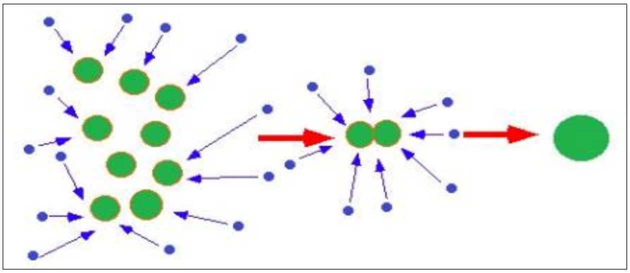


Figure 65. Schematic view of aggregation of oil molecules during malaxation (Clodoveo & Amirante, 2017)

Figure 66. Internal view of malaxer and temperature measurement (batch system)

Malaxation process, which is applied in 15–30 minutes depending on the condition of the olive paste, constitutes the bottleneck of the continuous production method. Thus, in the continuous system, the raw material enters from one side and leaves from the other in the other process steps. In other words, production is provided with a continuous flow. However, during the malaxation phase, all the crushed olives are filled into the malaxation and then it is waited until the malaxation process is completed. This creates a waste of time in the system. The schematic representation of the continuous and batch working steps in olive oil production and the bottleneck caused by the malaxation process is given in Figures 67 and 68.

Businesses connect several malaxers in parallel to the system to minimize the time loss. In this way, when the work of the first full malaxer is finished, the decantation process is started, while the other malaxers are operated and time is saved. Although it is aimed to facilitate the separation of the desired fat molecules by combining with malaxation, if this process is done too long and/or if the average temperature rises, oxidation and similar degradation reactions and quality losses may occur. The results of a study showing the effect of malaxation time on the total phenol content of olive oil are given in Figure 69.

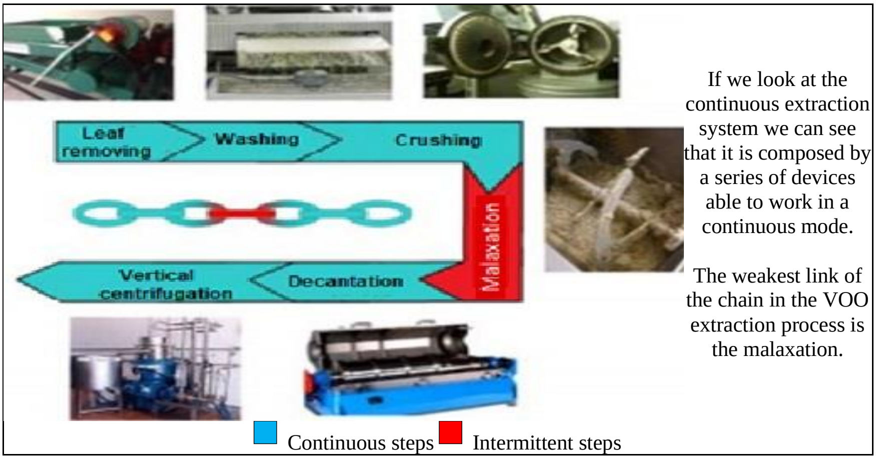


Figure 67. The display of continuous and intermittent steps in olive oil production (modified from Clodoveo & Amirante, 2017)

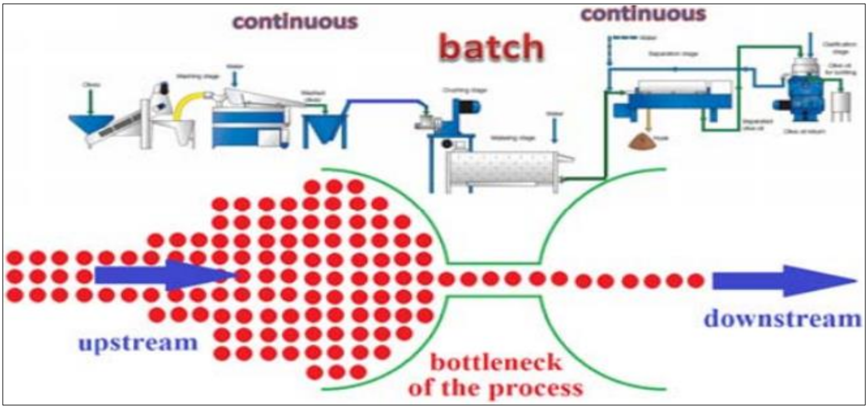


Figure 68. The bottleneck in olive oil production caused by malaxer (Clodoveo, 2015)

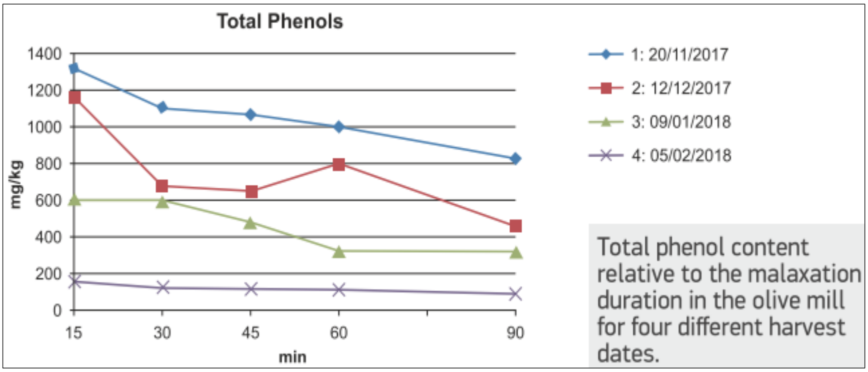


Figure 69. The effect of malaxation time on the total phenol content of olive oil

Increased temperature results in lowering of the viscosity of the oil droplets, but accelerates oxidation processes and enzymatic breakdown of the paste. During this process, also called as malaxing, enzymatic processes take place resulting in the formation of the typical flavor of olive oil. The longer the mixing time, the higher the chance of the oil taking up minor components that can improve the flavor. On the other hand, it has to be taken into consideration that oxidation processes occur which impair the oxidative stability of the oil and decrease the shelf life. With increasing mixing temperature and constant mixing time, the content of polyphenols increases while longer mixing time with constant mixing temperature results in a decrease of the total polyphenol content in the oil (Gupta, 2012).

Decantation

The decanter is a horizontal centrifuge machine that applies centrifugal force. These machines, which are widely used in plants producing olive oil in a continuous system, can divide the olive paste into three parts by taking advantage of the different densities of solid matter, non–oil liquid (waste–water) and oil. This process is called as decantation. Decanters that separate the olive paste into three parts as solid, waste–water and oil are called three–phase, and decanters that separate non–oil substances (solid matter and waste water) and oil are called two–phase decanters.

Olive oil and waste–water, two liquids with different densities that cannot be mixed in a 3–phase decanter, are separated from the solid phase. Waste–water has a higher density than olive oil. Inside the machine, waste–water is collected in the middle between oil and solid layer. Thus, two liquids separated from each other can be drawn from the 3–phase decanter (Hiller GmbH, 2020). Schematic representation of the internal structure of two and three phase centrifuges is given in Figure 70.

Since water is added to the decanter in the 3–phase production system, most of the phenolic compounds pass into the decanter wastewater. However, in the 2–phase production system, most of the phenolic compounds remain in olive oil, since there is no water intake from outside. When both production processes are compared in terms of product quality, many studies have shown that olive oil produced in a 2–phase system is richer in polyphenols (Hocaoglu, 2015). The comparison of 2 phase and 3 phase olive oil production in Table 7.

Table 7. The comparison of 2 phase and 3 phase olive oil production (Hocaoglu, 2015)

Production Process	Advantages	Disadvantages
3 phase	•Since water is used in the decanter, it is easier to operate. •The cost of storage, transportation and drying of the resulting pomace is low. •Pomace is easier to dry. •Selling price of pomace to solvent extraction facilities is higher.	•More wastewater is generated. •The pollution load of the wastewater generated is very high. •Wastewater can cause pollution; it is difficult to control (insufficient evaporation cannot be achieved and there may be discharges into the receiving environment). •Since the moisture content of pomace is lower, water should be added for seed separation.
2 phase	•Less wastewater is generated. •The pollution load of the waste–water generated is low. •It saves water. •Since most of the natural antioxidant and water–soluble polyphenols remain in the oil, more durable olive oil is formed. •Since the pomace is juicy, the bean is easily separated (technology available). •The potential of the resulting pomace to be utilized as an animal feed item is higher. •Easier to control in terms of wastewater disposal.	•The amount of pomace is higher than the 3–phase production and the pomace is more moist, •The unit sales price of pomace to solvent extraction facilities is lower. •In olive oil enterprises, the collection of pomace should be well organized so that the production is not interrupted. •Since no water is used in the decanter, its operation requires a little more expertise than the 3–phase decanter.

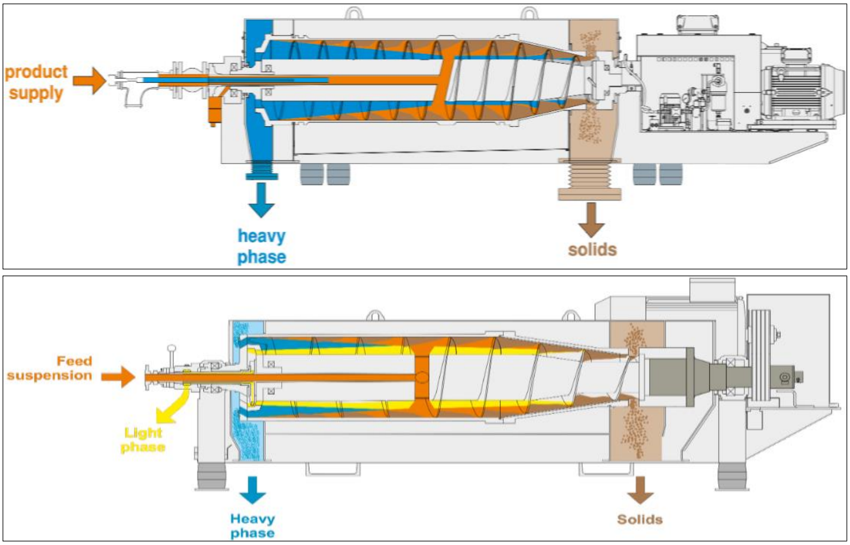


Figure 70. Schematic representation of the internal structure of two and three phase decanter (Hiller GmbH, 2020)

Centrifugation

Centrifuge is applied to oil coming out of the decanter to remove suspended particles and water that may remain in the oil. If the suspended particles are not removed, they slowly precipitate on the bottom of storage containers. This step produces clear olive oil, prevent precipitation and quality loss during storage. Unlike the decanter, these centrifuges apply centrifugal force vertically. It is also named as finishing centrifuge.

Filtration

The filtering process aims to keep solid particles that may remain suspended in oil, similar to centrifuge. Thanks to the removal of these particles, degradation reactions that may cause quality losses during future storage are prevented. Generally, the filtering process is carried out by passing olive oil through plate filters with the help of a pump.

Storage/Filling

Olive oils must be stored because they are produced intensively within two month following the olive harvest and are consumed gradually throughout the year. There is an olive oil filling tap at the top of the cone–shaped part under the tank and a sediment drain tap at the bottom in storage tanks olive oil. During the storage of olive oil, the residue that may precipitate can be removed from the oil by opening the residue drain cock at appropriate intervals. Head space of storage tanks can be filled with inert gasses (N_2) or floating cover may be used for small capacity storage tanks for preventing from oxidation of olive oils.

Filling of olive oi in packages such as bottles or cans can be done by volume–adjusted filling machines. It is preferable to leave as little head space as possible in the filling process. In this way, oxidations that may occur in the presence of oxygen can be prevented.

STORAGE OF OLIVE OIL AND POSSIBLE SPOILAGE REACTIONS DURING STORAGE

Fluctuating physical conditions that virgin olive oil is subjected to during its journey from the manufacturing plant until it reaches the consumers, such as changes in temperature, oxygen and light, cause oxidative and hydrolytic deterioration of the olive oil. These chemical changes shorten the shelf life of virgin olive oil as they not only decrease the phenolic content olive oil but also affect the sensory quality of olive oil resulting in loss of taste and flavor (Batra, 2016).

Storage and packaging of the olive oil should be planned to prevent quality losses. This will increase the attraction of consumer who interest on taste and beneficial effect of olive oils. Otherwise, economic losses may occur due to quality losses in olive oil and even making it unavailable for sale. Temperature, light and air cause quality losses in olive oil (Figure 71). Therefore, precautions should be taken during storage.

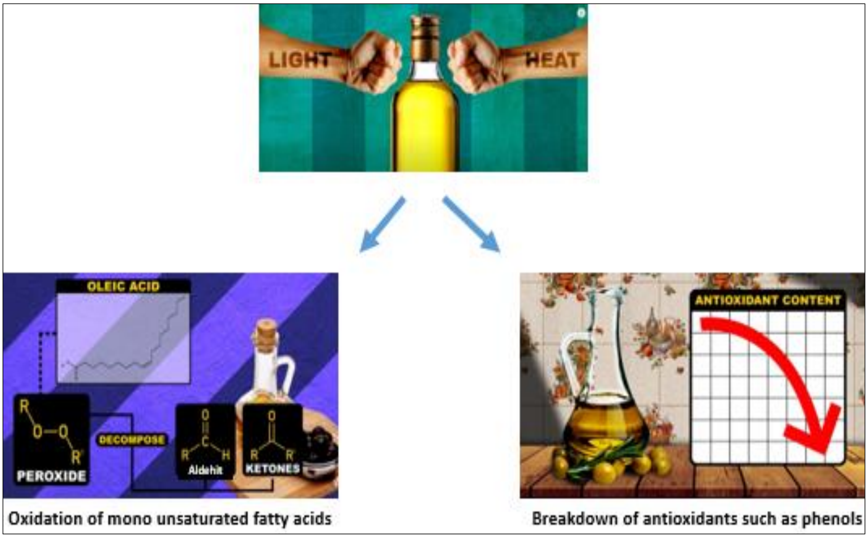


Figure 71. Schematic representation of the effects of temperature and light during packaging and storage

Auto–oxidation and photo–oxidation may occur in olive oils when they are not protected from light and air. The degradation reaction that starts with photooxidation continues with auto oxidation and finally hydroperoxide is formed. Photooxidation acts on the double bond and performs a fast reaction. Antioxidant compounds such as the polyphenolic substances that olive oil has, partially protect the fatty acids against oxidation. Photo–oxidation and autoxidation of oleic acid and formation of peroxide are given in Figure 72.

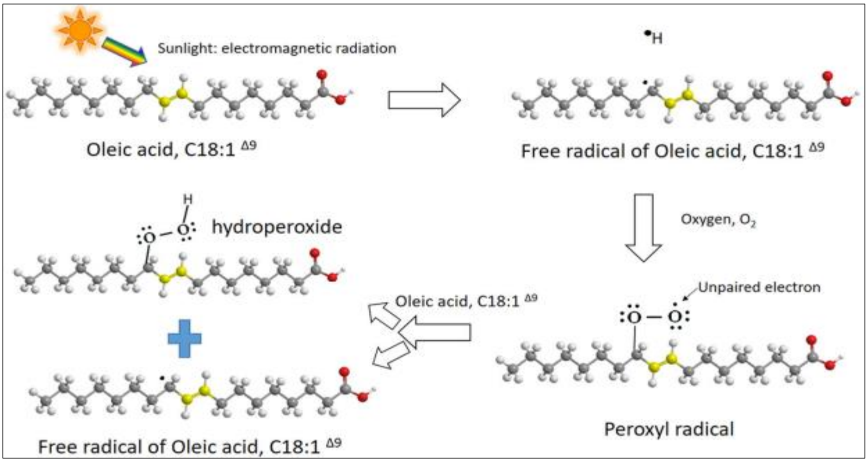


Figure 72. Photo–oxidation and autoxidation of oleic acid and formation of peroxide (Mailer et al., 2005)

As occurs with other fats, olive oil becomes oxidized when it comes into contact with the air. This is due to the fact that the unsaturated fatty acids (monounsaturated and polyunsaturated) have one or more double links that take oxygen and give rise to the formation of peroxides, one of the main products of oxidation. On reacting with another unsaturated fatty acid, these peroxides transform into hydroperoxides, which, in turn, oxidated form and give rise to the formation of aldehydes and ketones that are responsible in this case for the rancidity of olive oils. The peroxide index indicates the quality of life attributed to a virgin olive oil from the moment it is produced to when it is packaged (Olivarama, 2013)

The free acidity (or percent acidity) is defined as the amount of free fatty oleic acid per 100 g of oil, as specified by International Standard ISO 660. Free acidity is expressed as a percentage by mass. Acidity level is a degree of the free fatty acids present in the oil, and how decomposed the oil is before it was bottled or during shelf life. Figure 73 shows that the free acidity (Free acidity expressed in % w/w oleic acid) influenced tremendously by the exposure to sunlight and air.

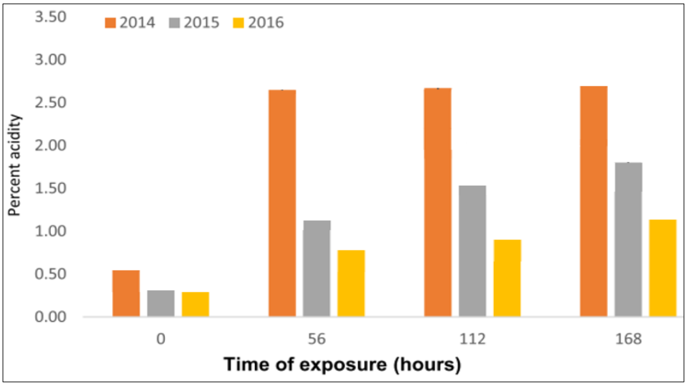


Figure 73. Increase of free acidity as time interval to air and sunlight increased (Houshia et al., 2019)

Olive oils should be based on storage low temperature, protect from sun and air to prevent olive oil quality loss which includes phenolic content until expiry date. Currently, olive oil is commercially stored at 20°C to 25°C and the storage period of virgin olive oil from bottling to consumption is up to 24 months. This storage period could be increased and providing customers with high–quality olive oils that meets the requirements of the health claim may be as simple as decreasing storage temperatures to 15°C during its storages (Olivarama, 2013). Changes of phenolics during storage for different monovarietal olive oils at different temperature were given in Figure 74.

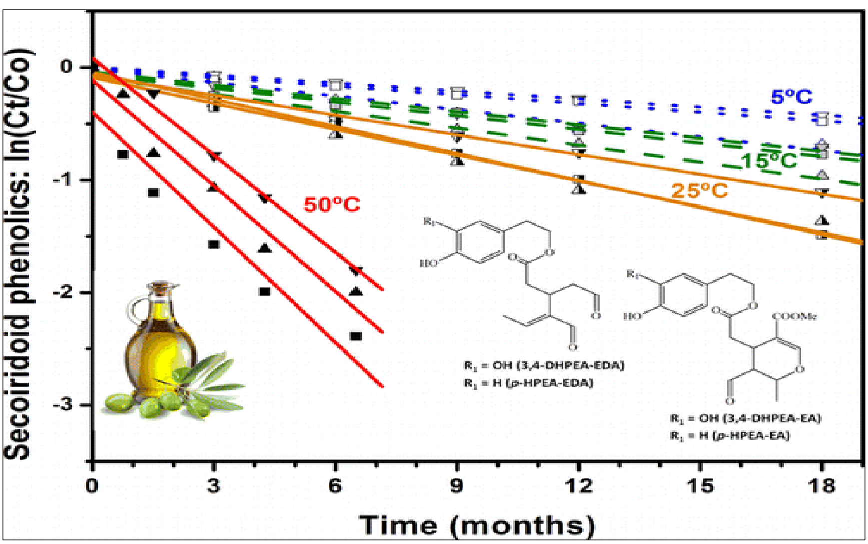


Figure 74. Changes of phenolics during storage for different monovarietal VOOs at different temperature (Krichene et al., 2015)

While the health claim is justified due to the presence of polyphenols in high–quality virgin olive oil, one of the biggest hurdles to the implementation of this claim is that olive oil polyphenol content decreases over time (Batra, 2016). The total phenolic content of olive oils decreased during exposure to air and sun because oxidation of polyphenols. Figure 75 illustrates the changes in the total polyphenols as a function of sequential increase of time of exposure to sunlight.

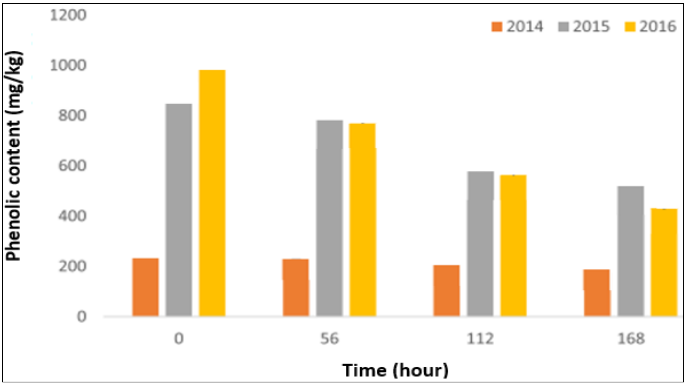
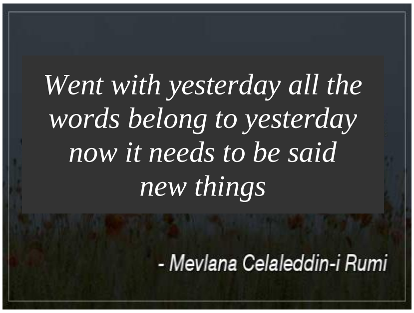


Figure 75. Changes in the total polyphenols as a function of sequential increase of time of exposure to sunlight and air (Houshia et al., 2019)

The most common test that are routinely carried to study chemical composition of olive oil are: acid value; peroxide value, and DK (difference in absorbance at specific wavelength, where $\Delta K = K_{270}$ [(K_{266} + K_{274})/2]). Both K and ΔK are altered when oxidation products are present. The absorbance at 232 nm is caused by hydroperoxides (primary stage of oxidation) and conjugated dienes (intermediate stage of oxidation). The absorbency at 270 nm is caused by carbonylic compounds (secondary stage of oxidation) and conjugated trienes (technological treatments) (Bajoub et al., 2018).

THE USE OF NEW TECHNOLOGIES IN OLIVE OIL PRODUCTION

Although olive oil production is a traditional activity, it has developed itself every year by adding new technologies and has made more modern production possible. This development will continue in the future, faster than in the past. In this context, those who are educated in olive oil have greater duties. It is an important task to develop new technologies in this regard, to realize lower cost and/or high quality production, and to follow newly developed technologies and make them used in production. In addition, it is extremely important to develop environmentally friendly technologies and to make them available in the olive oil industry.



In traditional production, it is often more difficult for personnel who are trained from the core or who have not received technical training on the subject, to grasp the new technology and to integrate it into the current production method or to switch to a new one by changing the old method. For this reason, factories with personnel trained in this subject are more advantageous. They are more likely to implement new technologies in their production lines more quickly and effectively.

It has always been the focus of attention to develop new technologies that increase oil yield and/or shorten the production time without damaging the oil quality. Ultrasound, electric field and microwave applications, which are among the new technologies frequently used in this field, have found more space for themselves as they show more potential benefits. Below, two visuals of olive oil production made with ultrasound application are given in Figure 76.

The breakdown of olive cell walls by pulsed electric field before malaxation can increase oil yield and shorten the time required for malaxation. Olive oil production begins with the shredding of the olives after the selection and washing of the olives. After the crushing process here, the pulsed electric field application makes it possible to make more effective extraction. The application of pulsed electric field to olives after the shredder is shown in Figure 77.

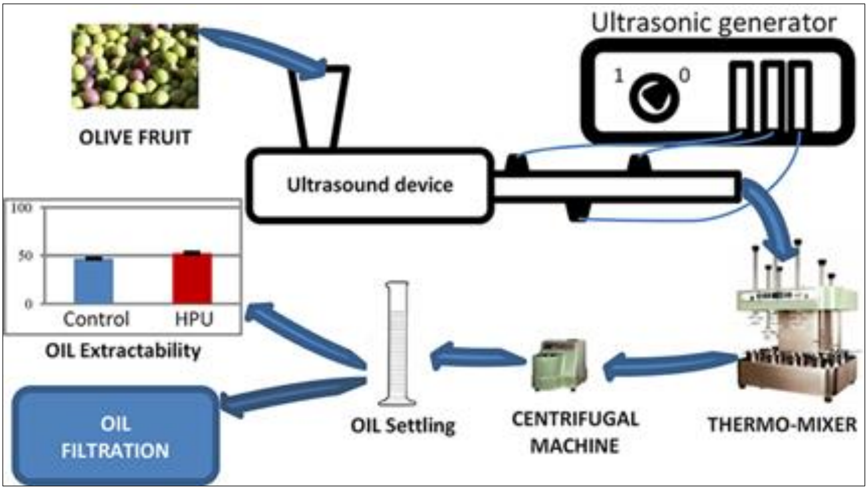
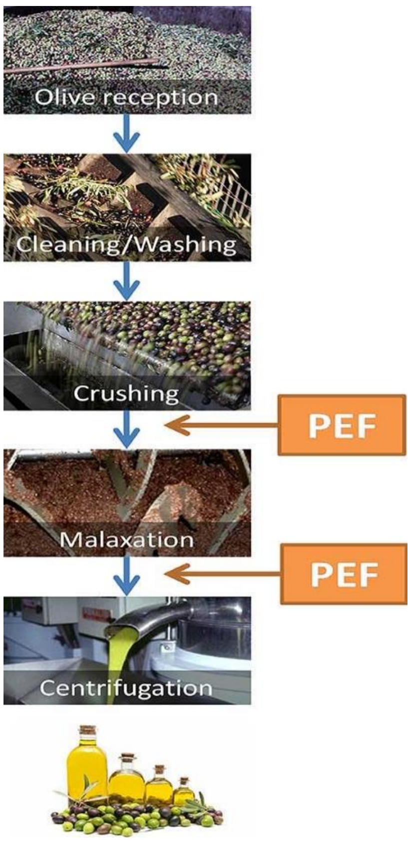


Figure 76. Image of olive oil production made with ultrasound application (Bejaoui et al., 2016)



Pulsed electric field treatment chamber

Figure 77. PEF treatment after crusher (4 tons/hour capacity) (Raso, 2018)

Disruption of the cell envelopes of the olive pulp that act as a physical barrier is required to facilitate the oil release during malaxation. Although the crushing step is a very effective process, in the current extraction process a percentage of the oil remains inside olive pulp cells. Pulsed electric field (PEF) is a physical non–thermal processing method that may complement the crushing step by the formation of pores in cell membranes that were not disrupted by the crusher. PEF treatment has reported as improving the extraction rate of olive oil and phenolic content (Raso, 2018).

REFINING

In order to find the deserved value of the farmer and the olive oil producer, they give attention to the production to obtain extra virgin olive oil or at least virgin olive oil. However, as a result of some undesirable situations, producers may have to refine their olive oil. The display of olive oils obtained by physical and chemical methods is given in Figure 78.

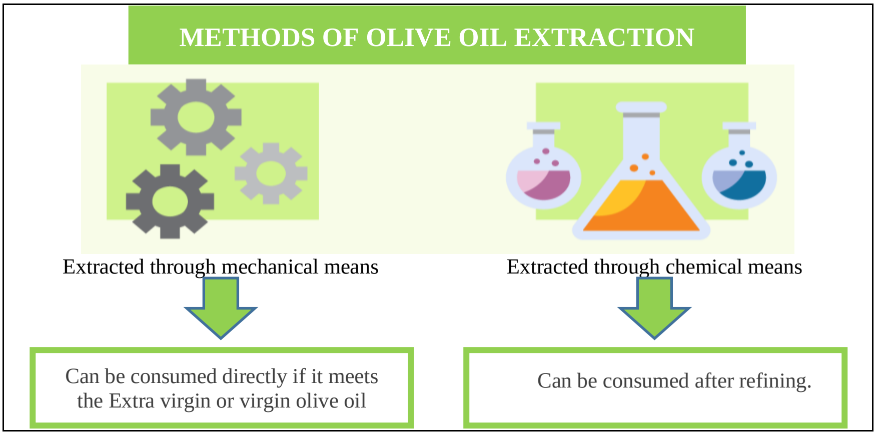
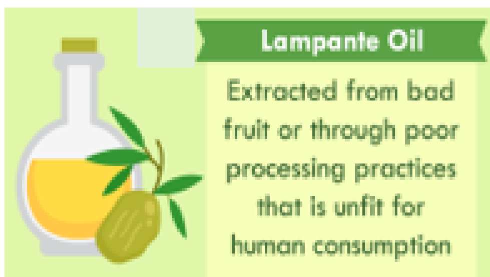


Figure 78. The display of olive oils obtained by physical and chemical methods



Although the first thing that comes to mind when it comes to the classification of olive oil is its free fatty acid content, there are many features that prevent olive oil consumption or prevent it from entering extra virgin or virgin olive oil groups. As a result, refining ensures that olive oils, which are not suitable for consumption, are brought into the economy. Refined olive oil never named as “pure” and “light” olive oil.

The purpose of refining is to remove unwanted components by preserving beneficial components as much as possible, minimizing oil loss and avoiding environmental pollution. The purpose of refining is summarized below.

Aim of refining;

Removing unwanted compounds from crude oils Free fatty acids (FFA), Phospholipids (gums), Oxidized products, Metals and contaminants, Color pigments
Preserving useful ingredients as much as possible (vitamin E or tocopherol–natural antioxidants)
Protection of oil against spoilage

In chemical refining, free fatty acids, in some applications most of the phosphatides and other impurities are removed from the oil using an alkali solution (usually NaOH). In physical refining, the removal of free fatty acids and deodorization process is carried out simultaneously with steam distillation. However, in the physical refining process, before steam distillation, phosphatides and other impurities must be carefully removed from the environment. The steps used in chemical and physical refining processes are given below. One of the chemical or physical refining can be applied, considering the free fatty acid amount, impurity level, quality and sensitivity of the crude oil to thermal degradation.

Table 8. Chemical and physical refining process steps

Refining Process	
Chemical Refining Process Steps	***Physical Refining Process Steps***
•Removal of sticky substances (degumming) •Acidity removal (neutralization) •Lightening color (bleaching) •Odor removal (deodorization)	•Removal of sticky substances •Lightening color •Neutralization and deodorization with steam distillation

Although it is obtained from olives some oils cannot be consumed directly and sent to refining. Oil obtained from pomace or oils that cannot be sold in although they are of naturel virgin olive oil and extra virgin olive oil class due to poor storage conditions are used after refining. The composition of the pomace and the refining process steps are given in Figure 79.

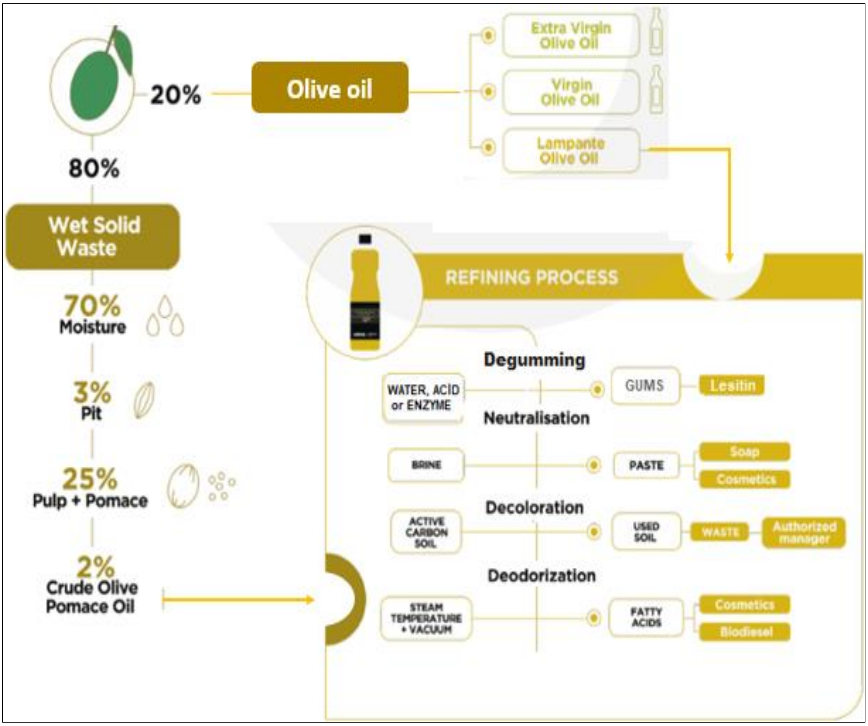


Figure 79. Composition of pomace and refining process steps (modified from Oriva, 2020)

Chemical Refining

Degumming

Depending on the structure of the phospholipids olive oil has, water, acid or enzyme application can be used for the degumming process. Unfortunately, polyphenols are also removed from the oil at this step. This process is generally separated from the oil by treating the crude oil with a low amount of water in order to hydrate the phospholipids and then centrifuge.

Neutralization

The neutralization process constitutes the most basic part of refining facilities. With the application of alkali (such as NaOH), free fatty acids are removed and the acidity of the oil is reduced to the targeted values. Free fatty acids are then separated by centrifugation as soap raw material.

Bleaching

The bleaching earth provides the bleaching process with the solid liquid adsorption it provides. This process is not just the removal of coloring matter. Phospholipids, oxidation products, trace metals and soap residues remaining in the oil from neutralization are held by bleaching soil. In this process, generally the oil is heated to about 100°C and mixed with an acid activated bleaching earth. Then, the bleaching earth and the components it holds are removed from the oil by filtering. The views of the bleaching soil and the oil bleaching experiment are given in the Figure 80.

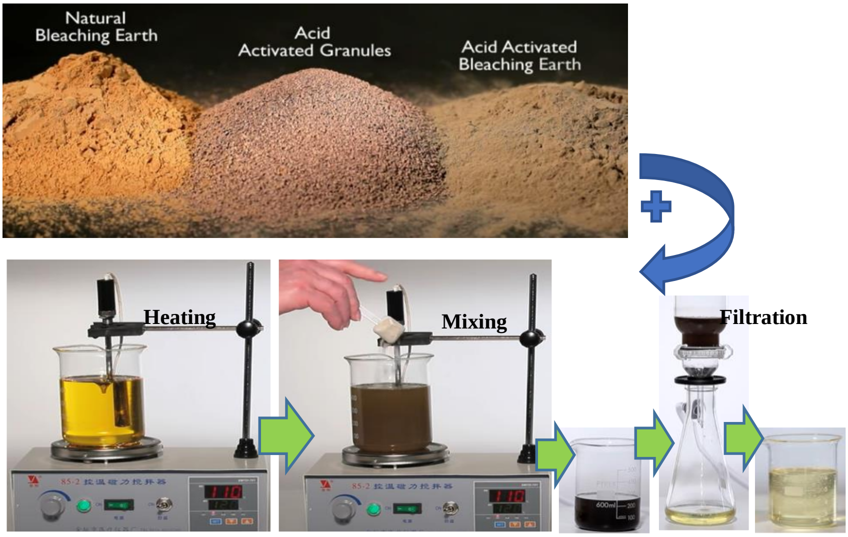


Figure 80. Views of bleaching soil and oil bleaching experiment (AMC, 2013)

Deodorization

It is an important process to remove volatile compounds which create unwanted flavor and odor. For this process, deodorization is provided by the permanent feature of water vapor under vacuum. It is used as a steam scavenger at high temperatures up to 260°C under vacuum (6 mmHg). The appearance of oils before and after refining is given in Figure 81.

Figure 81. View of crude oil (a) and refined oil (b)

Physical Refining

Physical refining begins with the removal of adhesive materials, followed by the bleaching process. These two steps are carried out in the same as chemical refining. The last step in physical refining is steam distillation. In this step, de–acidification and deodorization are carried out together using water vapor. This step differs from the chemical refining process.

Refining Plant

It is possible to divide refining systems into three groups according to their capacities which are large–scale refining system, small–scale refining system and refining machine. They use similar methods. It is possible to refine olive oils with a lower investment amount and space requirement with small scale refining systems or refining machines. There are machines with 500–2500 kg/day oil refining capacity. However, in cases where high capacity is required, large–scale refining systems should be established. Images of the small capacity refining system and refining machine are given in Figure 82 and Figure 83.

(1: refinery tank, 2: de-acidification tank, 3: bleaching tank, 4: leaf filter, 5: deodorization tank, 6: steam generator, 7: bay type filter, 8: vacuum, 9: hot water and alkaline tank, 10: bleaching earth tank, 11: oil pump, 12: vacuum pump, 13: electric control system)

Figure 82. Small–scale oil refining system

Figure 83. Oil refining machine

OLIVE POMACE OIL PRODUCTION

After the production of olive oil produced by physical systems, pomace, which is a by–product, is still a valuable product and oil can be obtained from it. Similar to the oil obtained from crops such as sunflower and corn, the oil remaining in the pomace can be recovered using the solvent. In addition, oil can be obtained from pomace by physical methods such as press. This product, which can also be named as crude pomace oil, is later refined and named as refined olive pomace oil. Refined pomace oil is mixed with extra virgin or virgin olive oil and sold under the name of olive pomace oil. The scheme showing the production flow of olive pomace oil from pomace is given in Figure 84.

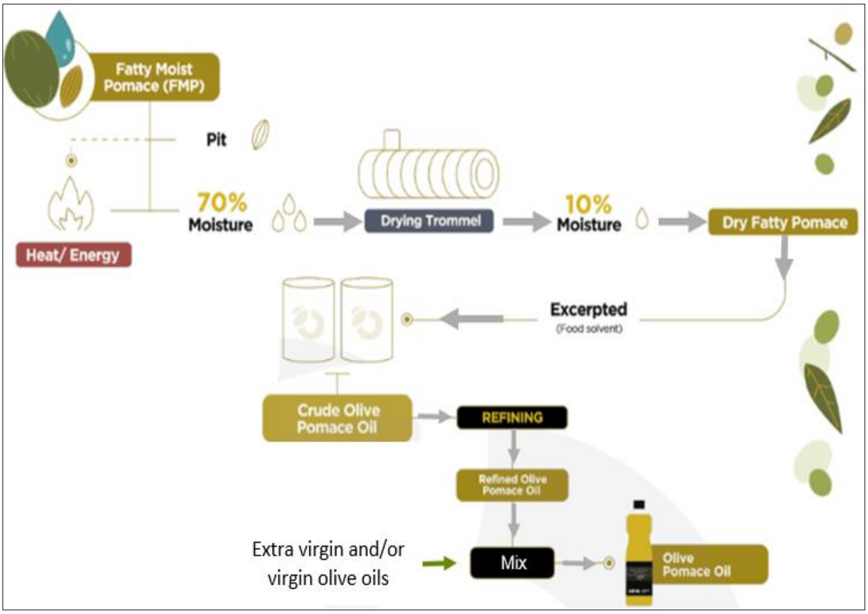


Figure 84. Scheme showing the production flow of pomace oil (modified from Oriva, 2020)

Unlike extra virgin or virgin olive oil, although it is produced by refining process, olive pomace oil still has a special place among other refined oils. Sensory properties may vary depending on its mixing ratio with extra virgin or virgin olive oil.

OLIVE OIL LEGISLATION AND SENSORY ANALYSIS

As mentioned in the previous sections, it refers to a product group that includes groups with different characteristics in olive oil in technical and commercial terms. If what are the components of olive oil, how olive oil is produced, what are the properties of olive oil or what is the price of olive oil asked, the answer should be “which olive oil” firstly. Although all of them are expressed as olive oil but there are 6 olive oil groups (oils obtained from pomace are included) and each of them have different characteristics. These groups are; extra virgin olive oil, virgin olive oil, blend olive oil, refined olive oil, oil pomace oil and refined olive pomace oil.

These groups have been created by national and international regulators in order to ensure that consumers know what they are buying and to protect the rights of honest producers. Thanks to these regulations, it also prevents frauds such as imitation and adulteration in olive oils or preventing the sale of olive oils with low quality values that are not suitable for the labelled group.

Why is there olive oil legislation?

•Protection of consumer and producer's rights

•The consumer receives the income he deserves

•The producer's return for the price paid

•Detection of cheats

•Classifying olive oils

Each of the olive producing countries has its own national legislation. Legislations issued by the European Union regulations, the International Olive Council, the Codex Alimentarius Committee, the United States Department of Agriculture and other relevant scientific organizations and food authorities are also international regulations used in grouping and defining the characteristics of olive oils and olive pomace oils.

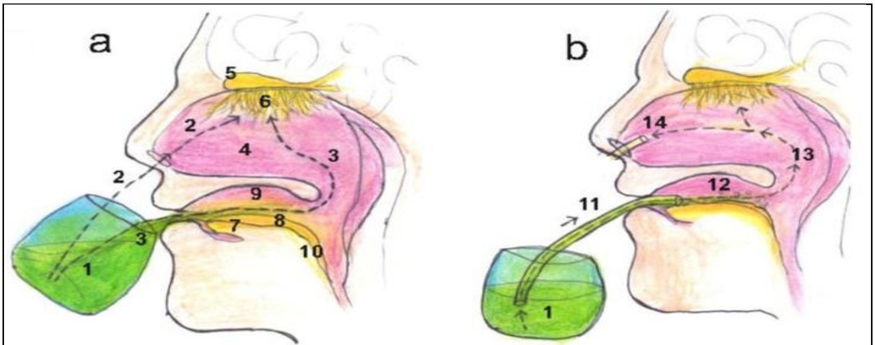
In olive oil regulations contain: free acid content, peroxide value, specific absorption in ultraviolet light, fatty acid composition, sterol composition, total sterol content, erythrodiol and uvaol ratio in total sterol, trans fatty acids, experimental and theoretical ECN 42 triglyceride content (determination presence of seed oils), amount of stigmastadiens (determination presence of refined vegetable oils), amount of waxy substance, sensory analysis evaluation, campesterol ratio, stigmasterol ratio and delta–7 stigmasterol ratio analysis. These values are used both for the grouping of olive oil or pomace oil and for the determination by the authorities in case of adulteration.

Table 8. Information on grades of olive oil (modified from About Olive Oil, 2015b)

Oils	**Extra virgin olive oil**	**Virgin olive oil**	**Olive oil blend**	**Olive pomace oil**
Health benefits				
Production methods	Naturally extracted without heat or chemicals retains antioxidants	Naturally extracted without heat or chemicals retains antioxidants	Naturally extracted & then refined. No solvent used. Blend of refined olive oil & extra virgin/virgin olive oil. Some antioxidants, increases with higher % of virgin olive oil	Solvent extracted & refined. Blend of refined olive pomace oil & extra virgin/virgin olive oil. Minimal antioxidants depending on the amount of virgin olive oil.
Flavor	IOC–certified panel of 8 to 12 tasters median scores Taste defects=0 Fruitness>0	IOC–certified panel of 8 to 12 tasters median scores Taste $0<defects<3,5$ Fruitness>0	Good flavor. Color ranges from light yellow to green	Good flavor. Color ranges from light yellow to green
Quality chemistry	Acidity $\leq$0.8%, peroxide$\leq$20 meq O_2/kg, UV measurement	Acidity $\leq$2%, peroxide$\leq$20 meq O_2/kg, UV measurement	Acidity $\leq$1%, peroxide$\leq$15 meq O_2/kg, UV measurement	Acidity $\leq$1%, peroxide$\leq$15 meq O_2/kg, UV measurement
Purity Chemistry	About 30 measures check for adulteration with other oils, refined olive oil or olive pomace oil	About 30 measures check for adulteration with other oils, refined olive oil or olive pomace oil	About 30 measures check for adulteration with other oils or olive pomace oil	About 25 measures check for adulteration with other oils

In the list of health claims approved by EFSA, there are four health claims related to the olive oil (Anonymous 2014). Phenolic substance, vitamin E, oleic acid and monounsaturated and/or polyunsaturated fatty acids content analyzes are performed to control the limits required to allow olive oils to be labeled with health claim. The health claim regarding polyphenols is unique to olive oil among all foods. 20 g of olive oils containing at least 5 mg of hydroxytyrosol and its derivatives (oleuropein complex and tyrosol etc.) can be labeled with the statement "Olive oil polyphenols contribute to the protection of blood lipids against oxidative stress". The consumer should inform that “the beneficial effect is achieved with a daily intake of 20 g olive oil” on label of this olive oil.

The popularity of extra virgin olive oil is linked both to its unique taste (pleasant sensory notes) and health properties. The sensory notes of EVOO are attributed to the presence of aroma compounds while bitterness and pungency are due to the quality–quantitative composition of phenolics which are well–known to be responsible also for several healthy properties. Schematic picture of sensory perception place of odour and aroma are given in Figure 85.



(a: generally accepted sensory perception places, b: perception places according to analysis results of APCI/MS
1: extra virgin olive oil, 2: odour (through orthonasal route), 3: aroma (through retronasal route), 4: nasal cavity, 5: olfactory bulb, 6: olfactory epithelium (sense of smell), 7: tongue (sense of taste), 8: taste buds (bitterness perception), 9: oral cavity, 10: trigeminal nerve (chemesthesis perception: pungency), 11: oil aspiration in mouth (without orthonasal route), 12: oil volatiles interaction with saliva in the oral cavity, 13: retronasal route (aroma after interaction with saliva), 14:aroma expulsion)

Figure 85. Schematic picture of perception places of odour and aroma for olive oil (Genovese & Sacchi, 2018)

It was mentioned that sensory analysis is one of the analyzes used in the classification of olive oil. However, olive oils with relatively high sensory values, even if they are in the same olive oil group, can be offered for sale at higher prices than others. In addition, it may not be possible to have total phenolic content analysis for each batch of olive oil production or small amount of olive oil batches of producers which have small number of olive trees. In such cases, sensory analysis can give an idea about the amount of phenolic components these olive oils. Basic information about the olive oil tasting is given in Figure 86.

Figure 86. Basic information about olive oil tasting (About Olive Oil, 2015)

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Dear reader, this book was written describes the fascinating journey of olive oil in the light of scientific data within the scope of Aristoil Capitalization project. In this way, it is hoped that growers, industrialists, packers and restaurants, hotels, etc. using olive oil will benefit those who want to pursue a career in this field and consumers. By providing clear and up–to–date information collectively, it is aimed to reach as many people as possible with correct information and to provide added value.

As in every field, it is hoped that idealist people will be a driving force in olive cultivation and olive oil and will do useful work by realizing efficient, quality and environmentally friendly productions. In this way, they will be able to ensure the implementation of new technologies as an example for the whole olive oil industry. As a result, olive oil, which is defined as both a traditional and a technological product, is likely to be brought to a better position by idealist students/producers/scientist working in this field.

We recommend that you continuously improve yourself by examining the written or visual documents such as books, articles about olive oil with this book or after you have finished this book and acquired the basic information.

We hope this book will be useful for all readers...