Report

Filter or not?
A Review of the Influence of Filtration on Extra Virgin Olive Oil

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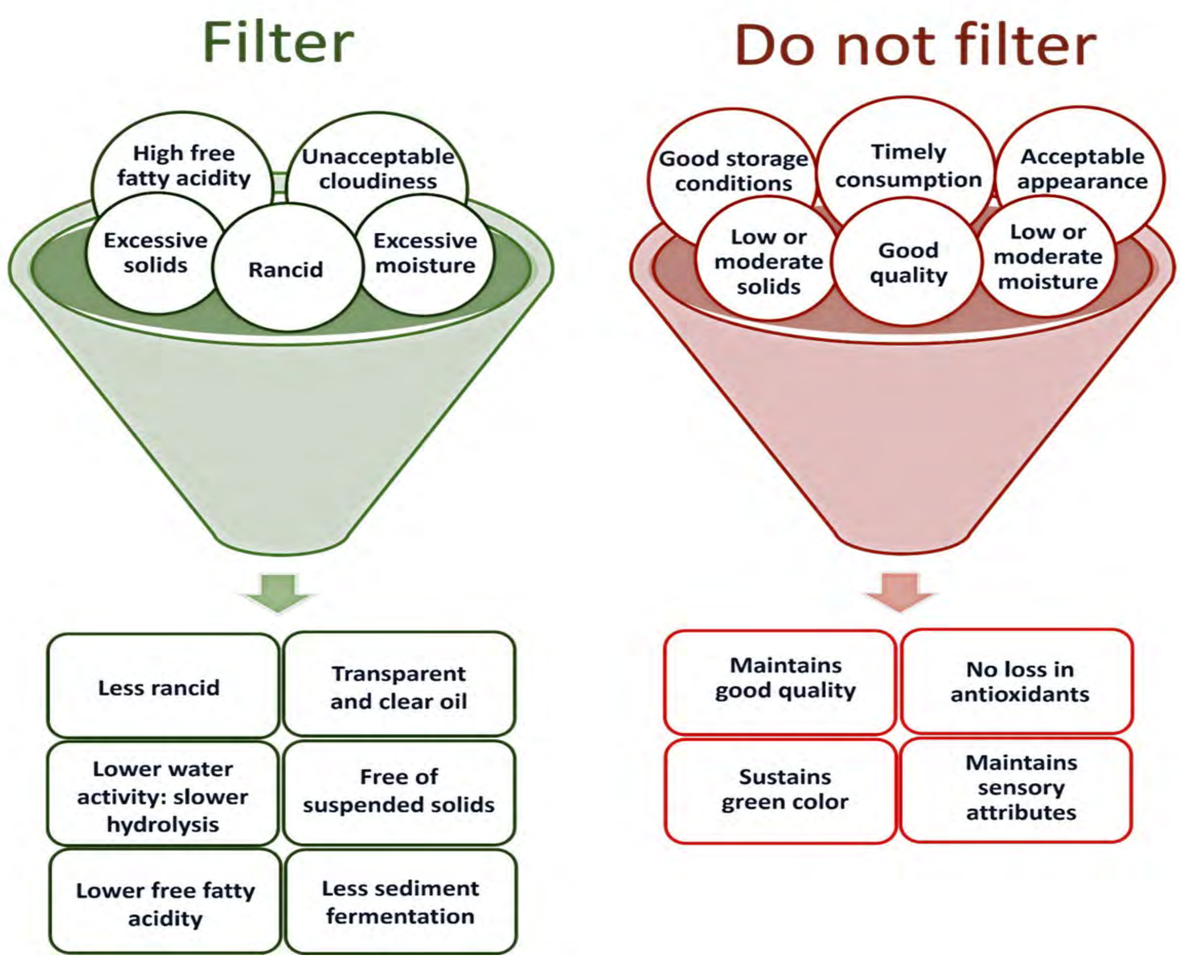
Executive Summary

Filtration removes suspended solids and moisture in olive oil before storage and can produce positive, negative or neutral effects on the parameters of stability, phenolics, volatiles, sensory, appearance, pigments and shelf life. The impact of filtration on the oil depends on the initial chemical and sensory profile, varietal of the oil, filtration system and storage conditions. Regardless of method, filtration will require additional expenses for equipment, labor, and processing time. After reviewing the current literature on filtration research, we found that there is no simple answer to the question of whether to filter or not. While the research lacks consensus regarding many of the effects of filtration as summarized in Figure 1, there are some general areas of agreement as summarized in Figure 2.

Figure 1. Filtration can have positive and negative effects on key parameters of extra virgin olive oil quality

Parameter	+ Positive Effects	– Negative Effects
Stability	Increases oil stability by reducing moisture and free fatty acidity.	Decreases oil stability due to the removal of suspended solids and exposure to oxygen during filtration.
Phenolics	Decreases the rate of secoiridoid hydrolysis that can affect shelf life over time.	Decreases water-soluble phenolic content and antioxidants that help prevent oxidation.
Volatiles	Eliminates undesired volatile compounds that affect the aroma of the oil.	Eliminates desired volatile compounds that affect the aroma of the oil.
Sensory	Reduces rancidity of the oil and removes the muddy sediment defect.	Decreases positive attributes (fruitiness, bitterness, and pungency).
Appearance	Contributes to transparent and clear appearance.	Contributes to lighter appearance and lower intensity of the green color.
Pigments	Decreases pigment concentration and reduces susceptibility to oxidative reactions when exposed to light.	Decreases pigment concentration and limits the ability to capture free radicals in the dark.
Shelf life	Prolongs shelf life by lowering free fatty acidity, water activity, hydrolysis and sediment fermentation, especially if the oil is stored in a higher than ideal temperature.	Reduces shelf life due to decrease in phenolic content.

Figure 2. Areas of general agreement on extra virgin olive oil filtration



Background

Extra virgin olive oil (EVOO) is produced solely through mechanical means, which includes washing of the olives, malaxing (or kneading) of the olive paste, centrifuging to separate the oil from the olive paste, and decanting of the oil before storage. While EVOO can be consumed without further treatment, some processors filter the oil to remove suspended solids or moisture that can promote oil deterioration. However, quantitative and qualitative changes occur during and after filtration, especially on the minor components that are very important for the oil quality and its health benefits.

More than 98 percent of olive oil (by weight) is triacylglycerols while the remainder, known as minor components, is made of phenols, pigments, volatiles and other non-glyceride chemical compounds. There are many agronomic and technological factors that affect the composition and concentration of these minor components, including olive fruit ripeness, fruit quality, milling conditions, malaxation (time, temperature, and oxygen exposure), centrifugation, and storage conditions.

There are several types of filter aids for removing suspended solids and moisture, and within the same filter aids, there are often additional options (e.g., paper filtering with or without Na_2SO_4). The different filtering systems are briefly described below:

Filters to remove moisture. In olive oil with a high moisture content, traditional filter presses such as cotton, paper or anhydrous Na_2SO_4 are used. The process is carried out after the filtration process to remove suspended solids, prior to storage. The system is pressurized by a hydraulic closure, and the oil is passed through each chamber of the filter as water is removed. Cotton filters removed water more consistently than paper filters, and filters with Na_2SO_4 dehydrated more efficiently than filters without it.[15,20]

Filters to remove suspended solids. In olive oil with a high amount of suspended solids, cellulose fibers can be used. Cellulose fibers have a rough surface, large porosity and elastic behavior providing a stable structure with higher flow rates and longer cycle times in comparison with mineral filter aids.[13,20,21]

Membrane filtration. Membrane filtration is often appropriate for filtering large volumes of olive oil, or oils with high levels of solids. The continuous flow over the membrane reduces impurities. Filtration is done with a perpendicular-flow through the filter, and the process is mild with little change to oil composition. The fluid is directed at high speed to the membrane surface allowing for high-filtrate fluxes.[20]

Inert gas filtration. The flow of inert gas (nitrogen or argon) generates a circular movement of the oil mass that facilitates the separation of the suspended solids. The process prevents organic materials from coming into contact with the oil and is considered by Italian and Spanish researchers to be an effective filtration system for water removal.[20] Moreover, at the end of the filtration step, the EVOO is already under inert gas providing suitable conditions to prolong the shelf life of the oil.[18,20]

Filter-Bag System. This filtration system contains two compartments, a cylindrical tube and a filter bag made of polypropylene. The filter bag is introduced into the cylindrical tube, and the system is pressurized by a hydraulic closure. Olive oil is taken directly from storage tanks to filtration equipment. The fluid passes across the filter bag, and suspended solids are removed. On occasion, similar to the other filtration systems described, various materials selected by the manufacturer may be used as filter aids to improve the filtration process. The main advantages of this system are its wide versatility and easy maintenance, which permits an optimal level of clear and transparent oil.[20]

Effects of Filtration

Research has shown that olive oil filtration can produce both positive and negative outcomes on olive oil's stability, phenolics, volatiles, sensory, appearance, pigments and shelf life. The published literature has mixed results and recommendations largely due to the use of the different types of filtering systems and the variable initial quality of the oils. Summarized below are the overall effects of olive oil filtration described in the current literature that focus specifically on stability, phenolics, volatiles, sensory, appearance, pigments and shelf life. Our summary also provides explanations and reasons relating to whether or not to filter the oil. More detailed descriptions of each study are shown in Tables 1 - 7.

Stability. By removing the suspended solids, the oil is at reduced risk of enzymatic spoilage and development of anaerobic microorganisms that can cause sensory defects and, subsequently, cause the oil to no longer meet extra virgin grade standards.[22] By removing the moisture, the rate of hydrolysis is reduced, which can help lower the free fatty acidity level.[26] However, some research suggested that the suspended solids and particles are important for stabilizing the oil and protecting it from both oxidative and hydrolytic degenerations.[11] These mixed results are mostly due to the difference in initial quality and characteristics of the oil (e.g., varietal, ripeness, robustness) and the filtration system used. For most oils, filtration does not cause significant changes to basic chemical parameters such as free fatty acidity, peroxide value and UV absorbance,[25] although, some studies have shown that a slight increase (with cotton, ultrafiltration) or decrease (with inert gas, filter bag) may take place.[6,18] Rancimat, an accelerated aging test, is commonly used to measure the oxidative stability of an oil. It provides quick information on the relative stability of oils, though it does not always resonate with real-time studies. Most research found that filtered oils have lower oxidative stability than unfiltered oils do. Studies tend to evaluate the commonly used chemical parameters of free fatty acidity, peroxide value, and ultraviolet absorbance and have not addressed how other useful parameters such as diacylglycerols (DAGs) and pyropheophytins (PPP) change after filtration.

Phenolics. After filtration, the concentration of total phenols drops due to the amphiphilic nature of phenolic compounds near the water droplets in olive oil. The percentage of loss is dependent on the type of filtration system and the oil. Filtration can not only reduce the total phenolic content but also change the phenolic profile.[21] Some research shows that there is sometimes an increase in total phenolics in filtered oils, however, this is most likely due to an effect of the analytical method used. Before filtration, the hydrophilic phenols are in a more polar matrix, and their affinity to the extraction solvent is low. After filtration, these compounds are more available to the extraction solvent. This results in an apparent increase in their concentration in filtered oils.[2,3,15]

In addition, the concentration of individual phenols changes during storage; some increase (i.e., hydroxytyrosol, tyrosol, from the hydrolysis of secoiridoid aglycones) and others decrease. A number of research papers have shown that in filtered oils, the levels of hydroxytyrosol and tyrosol had decreased and these oils showed a more rapid loss in total phenolic compounds compared to unfiltered oils.[7,12,15,25]

Volatiles. In EVOO, the most important volatiles, C_5 and C_6, consist of aldehydes, alcohols, ketones and esters. Knowledge about influence of filtration on volatiles is very limited and the pathways are not well understood. The changes in volatile profile are highly dependent on the characteristics of the oil and the filtration system used.

Sensory. Filtration can remove unwanted particles that cause hydrolysis, lipid oxidation and microbial fermentation, which would end up producing sensory defects during storage.[1,4] However, positive attributes such as pungency, fruitiness and bitterness may also be affected depending on the filtration system. Research results are very mixed on the sensory impacts of filtration, which are highly dependent on the sensorial attributes of the unfiltered oil, the type of filtration used, and the time in storage.

Appearance. Filtration increases the transparency of the oil and reduces the intensity of green color.[20]

Pigments. The reduction of suspended solids decreases pigment concentration leading to lower chlorophyll and carotenoid concentration in filtered oils. Chlorophyll is a pro-oxidant in the light and an antioxidant in the dark; therefore, its effect on the oxidative stability of the oil depends on the storage conditions.[14]

Shelf life. Filtration helps to reduce the rate of hydrolysis of the triacylglycerol matrix, especially in oils with higher initial free fatty acidity. A study showed that the effect of filtration on shelf life is dependent on the oil varietals and storage temperature (25 °C vs. 40 °C).[12] Some research showed that individual phenols such as the hydroxytyrosol and tyrosol[25] decreased while some showed that they increased[7,12] in both filtered and unfiltered oils during storage, using paper filtration. The rancid defect appears in filtered and unfiltered oils of Arbequina after a ten-month period.[12] Unfortunately, research on shelf life using newer filtration systems is lacking. (Note: Table 7 omits a study that examined the effect of cellulose fiber on shelf life after a nine-month storage period – the study found no significant differences in free fatty acidity, peroxide value and UV absorbance after nine months.[23])

Conclusion

The literature shows mixed results on the effects of filtration on parameters of stability, phenolics, volatiles, sensory, appearance, pigments and shelf life that can affect the oil positively, negatively, or not at all. Some studies show that filtration can achieve specific goals such as prolonging shelf life, reducing moisture and removing suspended solids. The suspended solids contain water and enzymes that impair oil stability, increase fermentation and degrade the oil's sensory quality; by removing these solids, filtered oil has less water activity, clearer appearance, less green color, and no deposits in the storage container. On the other hand, the literature also shows that filtration can have negative impacts on a variety of parameters. Ultimately, the effect of filtration depends on the chemical and sensory profiles, quality of the initial oil, the type of filter aid and system, and storage conditions. Research does not show consistent results using the same filtration system due to variance in factors such as olive variety, ripeness, water and solid contents, and the initial chemical and sensory parameters of the oils after milling.

Thus, currently, the literature does not provide simple answers on whether to filter or not. While there have been some carefully designed research on olive oil filtration, many studies did not characterize the complete chemical and sensory profiles of the initial oil before filtration and during storage after filtration. In addition, a large number of studies relied on lab-scale equipment that may or may not correlate with results from industrial-sized systems.

To provide additional clarity on the question of whether to filter or not, future studies should seek to include all of the following features:

- collection of chemical and sensory data of the oils, both prior to and after filtration;
- inclusion of oils made from a variety of cultivars and maturity levels;
- evaluation of oil shelf life, particularly using newer filtration systems;
- examination of how filtration affects olive oil volatiles and sensory attributes over time; and
- use of industrial-scale filtration systems to complement the existing body of data on lab-scale systems.

Regardless of method, filtration will require additional expenses for equipment, labor, and processing time.

Table 1. + Positive, ▬ negative, and O neutral effects of different oil filtration systems on olive oil stability.

STABILITY						
Paper	Paper with Na_2SO_4	Cotton	Cellulose fiber	Membrane	Inert gas	Filter bag
O Showed no effect on peroxide values and UV absorbance in most oils.[25]	▬ Decreased the oxidative stability index (OSI) using the Rancimat method and were lower in OSI than using cotton filters.[15]	▬ Decreased the oxidative stability index (OSI) using the Rancimat method but were higher in OSI than using paper with Na_2SO_4 filters.[15] ▬ O Increased slightly in free fatty acidity, peroxide value and UV absorbance in Coratina and Salentina oils made from ripe fruits, but no significant difference in both oils from less ripe fruits.[10]	O Produced no significant difference between filtered and unfiltered oils in free fatty acidity, peroxide value and UV absorbance except for the oil filtered with the Tami T50 membrane showed a higher peroxide value.[6] O Showed no significant difference in free fatty acidity, peroxide value and UV absorbance for the filtered oils.[5]	O Produced no significant difference between filtered and unfiltered oils in free fatty acidity, peroxide value and UV absorbance except for the oil filtered with the Tami T50 membrane showed a higher peroxide value.[6] O Showed no significant difference in free fatty acidity, peroxide value and UV absorbance for the filtered oils.[5]	+ Decreased the peroxide value to half of the initial value in unfiltered oils.[18] ▬ Decreased slightly the oxidative stability index using the Rancimat method due to the reduction in water content and were more pronounced in effect using argon gas than nitrogen gas filters.[18] ▬ Obtained high concentration of ortho-diphenols (e.g. hydroxytyrosol and oleuropein) using the Rancimat method but had the lowest oxidative stability index compared to unfiltered oils due to reduction in water content where these compounds are more protective against oxidation in water-in-oil emulsion.[18]	+ Decreased the peroxide value to half of the initial value in unfiltered oils.[18] ▬ Decreased slightly the oxidative stability index using the Rancimat method due to the reduction in water content and were more pronounced in effect than using nitrogen gas filters.[18] ▬ Obtained high concentration of ortho-diphenols (e.g. hydroxytyrosol and oleuropein) using the Rancimat method but had the lowest oxidative stability index compared to unfiltered oils due to reduction in water content where these compounds are more protective against oxidation in water-in-oil emulsion.[18] O Produced no effect on the fatty acid composition.[18]

Table 2. + Positive, – negative, and ○ neutral effects of different oil filtration systems on olive oil phenolics.

PHENOLICS						
Paper	Paper with Na_2SO_4	Cotton	Cellulose fiber	Membrane	Inert gas	Filter bag
+ Decreased the degradation rate of secoiridoid phenolics.[7] – Reduced the total phenolic content.[17] ○ Showed no effect on alpha tocopherol content.[7,12]	+ Increased the hydroxytyrosol content.[15] – Decreased the total phenolic content for most of the oils.[25] ○ Decreased the tyrosol content in some filtered oils while showed an increase in others.[15]	+ Increased the hydroxytyrosol and tyrosol content in oils made from riper olives.[10] – Decrease the total phenolic and tocopherol content as ripening proceeded.[10] – Decreased significantly the hydroxytyrosol content.[15]	– Decreased the phenolic alcohols and flavones compounds using a 100% cellulose and 70% cellulose/30% ligand filters and were less affected when using the 70% cellulose/30% ligand filter.[3] – Removed humidity and reduced water content along with a portion of phenolic compounds.[15] – Lowered significantly the hydroxytyrosol and 3,4-DHPEA-EA content.[23] ○ Showed no significant change in total phenolic compounds.[23]	– Decreased significantly the hydroxytyrosol content.[5,6,7] – Decreased the total phenolic content after cross-flow microfiltration and ultrafiltration treatments.[6]	+ Increased significantly the total phenolic content using argon gas.[18] + Increased the quinic acid content (responsible for astringency) using argon and nitrogen gas.[18] ○ Showed no effect on lipophilic phenolic compounds (e.g. tocopherols).[18]	+ Increased significantly the total phenolic content.[18] – Showed a decrease in phenyl alcohols, lignans and flavones compounds.[18] – Removed quinic acid (responsible for astringency).[18] ○ Showed no effect on lipophilic phenolics (e.g. tocopherols).[18]

Table 3. + Positive, – negative, and O neutral effects of different oil filtration systems on olive oil volatiles.

VOLATILES						
Paper	Paper with Na_2SO_4	Cotton	Cellulose fiber	Membrane	Inert gas	Filter bag
O Changed the initial flavor of the oil through the formation of volatile products caused by oxidation.[4,24]			+ Increased volatile 2-methylbutanal described as sweet and malty.[23] – Decreased volatiles *trans* -2-hexen-1-ol and *cis* -2-penten-1-ol described respectively as green grass, leaves and sweet and banana.[23] O Showed no significant change in a majority of the 38 volatile compounds analysed.[23]	+ Eliminated some undesired volatile compounds.[6] O Reduced significantly the short and medium-chain carbonyl compounds (C_{5-13}) which contributes to its flavor and fruity taste using cross-flow filtration.[5] – Reduced the concentration of short and medium-chain carbonyl compounds (C_{5-13}) which contribute to oil flavor and fruitiness when using cross-flow micro- and ultrafiltration and produced less effect on the loss of volatiles when using microfiltration.[6]		

Table 4. Positive, negative, and neutral effects of different oil filtration systems on olive oil sensory attributes.

SENSORY						
Paper	Paper with Na_2SO_4	Cotton	Cellulose fiber	Membrane	Inert gas	Filter bag
+ Increased mildly the fruity attribute of Cornicabra and Arbequina oils.[12] − Decreased significantly the fruity, pungent and bitter attributes after removal of suspended solids and moisture.[12] − Decreased mildly the intensity of pungency.[9] O Showed no change in the fruity, bitter and sweet attributes.[9]	+ Increased mildly the fruity attribute of Cornicabra and Arbequina oils.[12] − Decreased significantly the fruity, pungent and bitter attributes after removal of suspended solids and moisture.[12] − Decreased mildly the intensity of pungency.[9]	+ Increased the apple and grass attributes while fruity, bitter and sweet attributes showed no change.[9] + Decreased significantly the rancid defect.[12] − Decreased bitter and pungent attributes in oils made from more ripe olives.[10]	− Decreased mildly the pungent attribute in Picual oils due to the removal of phenolic compounds.[21] + Increased the pungent and fatty attributes.[23]	+ Retained the pleasant aroma in filtered oils.[5] O Obtained similar aroma values for filtered and unfiltered oils.[5,6]	+ Enhanced bitter and pleasant flavors.[18] + Produced a greater intensity of pungency in filtered than unfiltered oils using nitrogen and argon gas.[18] + Produced a higher intensity of apple and sweet attributes in filtered than unfiltered oils using argon gas.[18]	+ Enhanced bitter and pleasant flavors.[18] + Produced a higher intensity of apple and sweet attributes in filtered than unfiltered oils.[18] O Showed the same intensity of fruitiness in filtered and unfiltered oils.[18]

Table 5. + Positive, − negative, and o neutral effects of different oil filtration systems on olive oil appearance.

APPEARANCE						
Paper	Paper with Na_2SO_4	Cotton	Cellulose fiber	Membrane	Inert gas	Filter bag
− Increased the lightness and minimized the green color.[15]	− Increased the lightness.[9]	− Increased the lightness and minimized the green color.[15]		+ Removed all absorbing visible light spectrum substances but retained the finer particles and color.[5]	− Showed that filtered oils were richest in yellow and poorest in green color.[18]	− Showed that filtered oils were richest in yellow and poorest in green color.[18]
		− Increased the lightness.[9]		o Showed no significant differences in color between filtered and unfiltered oil.[6]		

Table 6. Positive, negative, and neutral effects of different oil filtration systems on olive oil pigments.

PIGMENTS						
Paper	Paper with Na_2SO_4	Cotton	Cellulose fiber	Membrane	Inert gas	Filter bag
Neutral: Produced no significant changes in chlorophyll and carotenoid concentration in dark laboratory conditions.[25]		Neutral: Decreased significantly the chlorophyll and carotenoid concentrations in filtered oils.[9]		Neutral: Decreased total chlorophyll concentration after cross-flow microfiltration.[6] Neutral: Showed no effect on carotenoids and chlorophyll.[5]	Positive: Reduced the chlorophyll content and oxidative susceptibility when exposed to light.[18] Negative: Lowered the chlorophyll content by 3-fold in filtered oils suggesting that the oxidative stability would be lower in darkness.[18]	Positive: Reduced the chlorophyll content and oxidative susceptibility when exposed to light.[18] Negative: Lowered the chlorophyll content by 3-fold in filtered oils suggesting that the oxidative stability would be lower in darkness.[18]

Table 7. + Positive, − negative, and O neutral effects of different oil filtration systems on olive oil shelf life

SHELF LIFE	
Paper	Paper with Na_2SO_4
Tested shelf life of five different oils over an 8-month storage period:[12] + Exhibited low increase in free fatty acidity at 25°C in filtered and unfiltered oils, except Arbequina (which had the lowest initial free fatty acidity) produced no increase during storage at 25°C or at 40°C. Obtained a greater increase in free fatty acidity in Colombaia and Taggiasca than in Picual, Cornicabra and Arbequina oils due to having higher initial free fatty acidity. + Differed in oxidation rates between oil varieties at 40°C after 8 months of storage. Increased the peroxide value more slowly in Cornicabra and Picual than in Arbequina, Taggiasca, and Colombaia (had the highest initial free fatty acidity) oils. Showed that using a paper filter contributed to lower peroxide values than in the unfiltered oils of Picual and Arbequina. + Decreased linearly the oxidative stability of some oils during storage at 25°C and 40°C where at 40°C the decrease was faster at the beginning of storage after 2–3 months while Taggiasca and Colombaia oils showed no change in oxidative stability using the Rancimat method. + Increased linearly the hydroxytyrosol and tyrosol content in Picual, Cornicabra, Arbequina and oils after 8 months. Showed a higher hydroxytyrosol content after 3 months but decreased slightly after 8 months while the tyrosol content decreased after 3 months and increased again after 8 months in Colombaia oils. Showed an increase in hydroxytyrosol after 3 months and a decrease after 8 months while the tyrosol content increased after 3 months and decreased after 8 months in Taggiasca oils. − Produced the rancid defect in filtered and unfiltered oils of Arbequina after 10 months of storage and of Cornicabra oil after 14 months at 25°C and 40°C. **Tested shelf life of 3 different oils over a 340-day storage period:**[7] + Increased the hydroxytyrosol and tyrosol content in all 3 filtered and unfiltered oils during storage where both compounds showed a rapid increase after the first 200 days and equalized for the rest of the 340 day period. O Showed no significant change in peroxide value and UV absorbance in filtered and unfiltered oils of Arbequina, Hojiblanca and Picual. **Tested shelf life over a 9-month storage period:**[25] − Decreased significantly the tyrosol and hydroxytyrosol content where the loss was more rapid in filtered than unfiltered oils after 4 months. − Monitored oxidation by peroxide value, oxidative stability index, and phenolic content. Showed that filtered oils had a higher peroxide value than unfiltered oils after 4 months and had more loss in phenolic compounds than unfiltered oils throughout the 9 months.	**Tested shelf life of five different oils over an 8-month storage period:**[12] + Hydrolysis rate was lower in filtered than unfiltered oils of Arbequina, Picual, Colombaia, Taggiasca and Cornicabra after 8 months of storage. + − Differed in oxidation rates between oil varieties at 40°C after 8 months of storage. Increased the peroxide value more slowly in Cornicabra and Picual than in Arbequina, Taggiasca, and Colombaia (had the highest initial free fatty acidity) oils . Showed that using paper with Na_2SO_4 contributed to the highest peroxide value in all oils except for Colombaia compared to unfiltered oils. + Increased linearly the hydroxytyrosol and tyrosol content in Picual, Cornicabra, Arbequina and Taggiasca oils after 8 months. Showed a higher content after 3 months but decreased slightly after 8 months in hydroxytyrosol while the tyrosol content increased linearly in Colombaia oils. − Decreased linearly the oxidative stability of some oils during storage at 25°C and 40°C where at 40°C the decrease was faster at the beginning of storage after 2–3 months while Taggiasca and Colombaia oils showed no change in oxidative stability using the Rancimat method. − Produced the rancid defect in filtered and unfiltered oils of Arbequina after 12 months of storage at 25°C and 40°C.

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