Chapter

Cooking with Extra Virgin Olive Oil

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Abstract

Mediterranean cultures have used Extra Virgin Olive Oil (EVOO) as the only source of cooking oil for centuries, with their diet showing the highest amount of scientifically proven health benefits. However, there is a common misconception that EVOO is not suitable for cooking given its relatively lower smoke point, despite no scientific evidence that support this. This chapter aims to provide an overview of how EVOO is healthier, safer, and more stable to cook with than other common edible oils. Furthermore, this chapter aims to present EVOO's suitability for use on Teflon coated pans, which is another common myth.

Keywords: extra virgin olive oil, cooking oils, smoke point, nutrient content, key minor components, bioactives

1. Introduction

Olive oil occupied a key role in ancient Roman cooking and its culinary use expanded along with the Roman Empire, laying the foundation for what we now refer to as the Mediterranean diet. The culinary use of olive oil takes four basics forms: as a preservative, as a cooking medium, as an ingredient and as a condiment [1]. This chapter has a central focus on EVOO as a cooking medium.

As a cooking medium EVOO has a many functions, such as transferring heat from the heat source to the food, acting as a lubricant to prevent food from sticking to the cooking surface, adding flavour, crust and creating a more visually appealing look to the food [1]. It is an extremely healthy oil to use for all types of cooking and there is a lot of existing and emerging research related to the health benefits due to high levels of antioxidants (some of which are unique to EVOO) and the ability of the oil to enhance the health attributes of some ingredients once cooked [2–4].

However, myths related to cooking with EVOO have been prevalent from time to time, creating a lot of confusion for consumers.

2. Debunking the myths

Some of the prevalent myths related to cooking with EVOO are listed in **Table 1**.

Myth	Assumptions based on the myth	Truth/reality based on scientific evidence
Smoke point is a relevant factor in determining how suitable an oil is to cook with.	EVOO is not suitable for cooking at high temperatures given its lower smoke point.	The utilisation of smoke point as an indicator of the ability of an oil to withstand heat, and to determine suitability for cooking is technically incorrect, and is not supported by scientific evidence. Recent evidence [5] shows that EVOO is the most stable oil when heated when compared to other edible oils with higher smoke points. Mediterranean cultures have used EVOO as their only source of cooking oil for centuries and their diet has the highest amount of scientifically proven health benefits [2, 6, 7].
Cooking with EVOO can ruin cookware, such as non-stick pans (e.g., Teflon coated pans).	EVOO could be damaging to cookware coating.	Although there is no published scientific evidence to support this, these beliefs are specifically supported by some cookware manufacturers' specifications that oils with higher smoke points are more suitable for cooking with Teflon coated cookware [8, 9]. On the contrary, EVOO, like any other oil, acts as a lubricant, preventing the food from sticking to the pan [1]. Cooking with EVOO does not ruin non-stick Teflon coated pans at a different rate than other cooking oils.
Heating olive oil will increase the amount of saturated or trans fats.	You cannot heat olive oil.	All oils will oxidise and hydrogenate to a minor degree when heated several times using high temperatures, such as those used in industrial frying processes [10]. It has been documented that olive oil is less prone to oxidation and hydrogenation when heated than other oils when heated because it is rich in monounsaturated fat [11, 12]. Cooking with EVOO does not produce significant traces of trans fatty acids. In fact, EVOO is less prone to hydrogenation than other vegetable oils.
When you cook vegetables with EVOO, the vegetables lose antioxidants.	EVOO is not suitable to use when cooking vegetables.	This is incorrect. Recent evidence shows that when cooking with EVOO (including deep frying and sautéing), there is a resultant increase in total phenols (antioxidants) in the cooked food (particularly when cooking raw vegetables) [13]. Cooking with EVOO may in fact improve the nutritional properties of the food.

Table 1.
Myths related to cooking with EVOO.

2.1 Performance of edible oils when heated

Chemical reactions such as hydrolysis, oxidation, and polymerisation are prone to occur when edible oils are heated. Heating oils at high temperatures or for long periods of time can generate decomposition products such as free fatty acids (FFAs), alcohols, cyclic compounds, and polymers. Several factors can affect or influence these reactions, such as the type and quality of the oil, the kind of food used in cooking, the time and temperature of cooking and the food/oil ratio. These chemical reactions can affect both the nutritional value and the organoleptic properties of the oil. In addition, some of the products formed through oil decomposition may have adverse effects on human health. Physical changes in oil occur during heating and include increased viscosity, darkening in colour, and increased foaming. At the same time, the smoke point of the oil decreases [14–18].

There are two major properties of cooking oils commonly believed to dictate the behaviour of that oil, and subsequent safety when exposed to high cooking temperatures: smoke point and oxidative stability. While oxidative stability is a reasonable predictor of an oils' ability to withstand heat, initial smoke point has proven to have very little correlation with the oils' stability under heat while cooking, and the formation of polar compounds [5].

2.2 What is smoke point and why is it an unreliable measure of oil performance when heated?

The smoke point is defined as the temperature at which a visible and continuous bluish smoke appears. At this point sufficient volatile compounds, such as FFAs and short chain oxidation products are emerging and evaporating from the oil.

The smoke point of an oil generally increases as the FFA content decreases, and the degree of refinement increases [19, 20].

The smoke point should not be considered a reliable measure of an oil's stability and suitability for cooking for the following reasons:

- The smoke point changes when an oil is heated, therefore it is not the same during the whole cooking process. The smoke point decreases faster when heating oils with a higher polyunsaturated fat content, such as in seed oils, than when heating oils with less poly-unsaturation and greater monounsaturated fat levels such as in EVOO [21].

- The chemical fraction that mostly determines the smoke point of an oil is the FFA fraction which is under 1% of the total oil composition. This means that when the oil reaches the smoke point, only a minor part of it is evaporating and does not indicate the deterioration of the fat itself. In fact, studies have shown that the levels of FFA are not a reliable indication of deterioration of cooking fat [14].

- When determining the smoke point, a small volume of oil is heated using a little brass cup in a confined and dark environment (**Figure 1**). Studies have shown that the smoke point rises when using a bigger container or a larger volume of oil in the presence of air. As a result, when cooking in a kitchen, smoke point temperatures could be greater than the ones that have been reported in the literature [22–24]. Thus, exact smoke point temperatures cannot be given [21, 24].

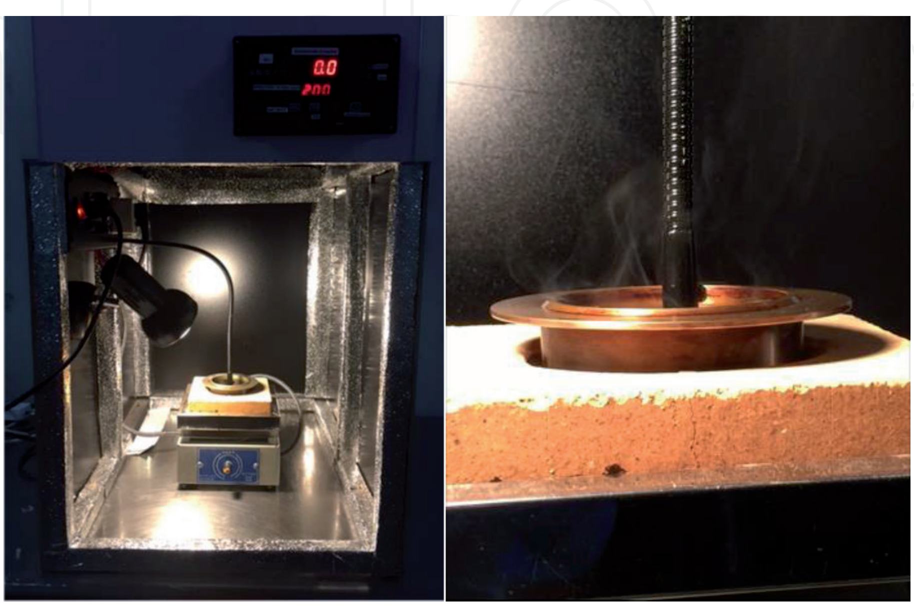

Figure 1.
Smoke point determination equipment.

- The standard procedure used to establish the smoke point relies heavily on the ability of the worker to determine visually the point at which the oil begins to smoke. This means that there can be analyst subjectivity when using this test procedure [19, 24].

- The refining process used to produce other vegetable oils such as canola, peanut and rice bran oils involves high temperatures to neutralise FFAs. This gives the oils a higher smoke point but also produces secondary oxidation products which have been shown to have a detrimental effect on human health.

2.2.1 What measurements we should use instead to determine oil suitability for cooking

When heating oils, the process of fat oxidation is accelerated. Fat oxidation is where fat molecules interact with oxygen, leading to the potential formation of harmful compounds. Many authors agree that oxidative stability is the best predictor of the behaviour of oil during cooking [5, 16, 25].

Industrially and technically, the ability of an oil to withstand heat is measured by its resistance to the formation of polar compounds.

Non-volatile polar compounds, triacylglycerol (TAG) dimers and polymers are the main deterioration products of cooking oils. Several studies have associated these substances with certain types of cancer and neurodegenerative diseases including Alzheimer's and Parkinson's disease [26, 27]. However, this negative effect on health is related to the dose of these components. National and International legislation has identified that no more than 24–27% of polar materials in the final oil is a safe limit for human consumption [27]. These limits are made to ensure the oils used in cooking operations are safe for human consumption. When storing food after being cooked is required, then the recommended end point of polar compounds in the oil is <10% [14, 27].

Laboratory research is extremely important to understand the frying process and what the toxicological limits are to establish guidelines for consumers. However, it is important to highlight that sometimes the research completed with cooking oils has been pushed to the point of abusing the oils. These are extreme heating conditions and the results obtained do not always represent real-life situations, especially during home cooking. Therefore, proper judgement when drawing conclusions needs to be made. When cooking at home, normally one does not reach excessive temperatures for prolonged periods of time that deteriorate either the food or the oil in a way that makes them inedible or unsafe [27].

2.3 Why should we cook with EVOO?

2.3.1 EVOO composition

Edible oils are composed of triacylglycerols (> 96%) and endogenous minor components. It is generally agreed that the inherent composition of edible oils exerts considerable influence on their heating stability [15, 18]. In the interest of understanding better why we can, and we should cook with EVOO, it is important to review first its chemical composition. EVOO has a high level of oxidative stability when compared to other types of cooking oil and is less likely to undergo oxidation. This is primarily attributed to the following factors:

1. EVOO contains high levels of oleic acid, a monounsaturated fatty acid (MUFA) with just one double bond and low levels of linoleic and linolenic acids, which

are polyunsaturated fatty acids (PUFAs) with multiple double bonds. This high MUFA/PUFA ratio confers good oxidative stability making it highly resistant to the production of harmful substances (such as polar compounds). The high levels of double bonds in PUFAs in seed oils make them sensitive to damage by heat [28–30].

2. The presence of natural antioxidants in EVOO, such as biophenols and Vitamin E, enhance the oil's stability and resistance to oxidative degradation. Besides adding health benefits to the oil, these minor constituents boost EVOO's stability reducing oxidative processes when the oil is heated [31, 32].

3. The phytosterols are a significant fraction of the unsaponifiable matter in EVOO. These substances add to the oil's health profile. Some sterols have been shown to provide higher protection against lipid thermal deterioration by decreasing the production of TAG polymers [33]. These sterols are sometimes lost during oil refining and because EVOO does not require this manufacturing step, it retains high concentrations of phytosterols. It has been documented that phytosterols can be transferred to food while cooking, which could have a nutritionally positive impact on consumers [34].

2.3.2 EVOO performance when heated in comparison with other edible oils

In a comprehensive trial in Australia [5] conducted by an ISO 17025 accredited laboratory in 2018, ten of the most used cooking oils were selected from the supermarket to test their performance when heated. The oils tested were EVOO, virgin olive oil (VOO), olive, canola, rice bran, grapeseed, coconut, peanut, sunflower, and avocado oils.

Two different volumes of oils were heated in open pans (250 mL) for 20 minutes from 25–240°C and in deep fryers (3000 mL) at 180°C for 6 hours. Samples were collected at different intervals and then tested.

Authors specifically assessed the correlation between smoke point and other key chemical parameters related to an oils stability and likelihood to break down and form harmful compounds.

From this study, it was concluded that under different heating conditions, the generation of polar compounds with temperature and time was more pronounced for refined seed oils with higher initial values of smoke point, PUFAs, K232 and K270 (oxidative by-products). Reasonable predictors of how an oil will perform when heated have been oxidative stability, secondary products of oxidation, total level of PUFAs. EVOO was the most stable oil of those tested when heated, followed closely by coconut oil and other virgin oils such as avocado and high oleic acid seed oils. EVOO yielded lower levels of polar compounds and TFAs when compared with other oils.

This research also showed that an oil's smoke point is not a relevant parameter to explain the oil's behaviour when heated. Smoke point does not correlate with the stability of the oil during heating, as it showed a positive correlation with the increase in polar compounds (**Table 2**). That is to say that the higher the smoke point, the more polar compounds that are produced. PUFAs, K232 and K270 showed a positive correlation with polar compounds. Oxidative stability was negatively correlated with final content of polar compounds, demonstrating that a non-stable oil in terms of thermal degradation, will produce more polar compounds when heated (**Table 2**).

These results are also supported by recent research carried out in New Zealand in 2019 [25]. The authors concluded that quality EVOO, in accordance with relevant

Initial Parameter	Correlation with final polar compounds levels (%)
Smoke Point	83
Oxidative Stability	−65
FFA	−34
PUFAs	74
UV Coefficient K232	80
UV Coefficient K270	54

Note: A negative, or inverse correlation, between two variables, indicates that one variable increases while the other decreases, and vice-versa. i.e. the less oxidative stability, the more polar compounds produced.
Table Reference [5].

Table 2.
Correlation between final polar compounds and initial oil's chemical parameters.

olive oil standards, is the best cooking oil for use in the home from a stability and health viewpoint. These authors also recommended criteria to indicate an EVOO is stable for cooking:

- Initial % free fatty acids (FFA) <0.2% (w/w as oleic acid)
- Peroxide Value (PV) < 5.0 mEq/kg
- Induction time in Rancimat >15 hours.
- Total polar compounds after 8 hours heating at 180°C < 25%
- p-Anisidine value after 8 hours at 180°C < 70

2.3.3 What are trans fat and why does cooking with EVOO not produce significant TFAs?

TFAs are formed during partial hydrogenation of oils. The interconversion from cis to trans requires a lot of energy (~65 kcal/mole), however the use of a high temperature or a catalyst can enhance the reaction [35]. Consumption of diets high in hydrogenated fat and/or TFAs has been shown to have an adverse effect on lipoprotein profiles with respect to cardiovascular disease risk [36, 37].

The formation of TFAs while cooking food using oil is closely related to the temperature and how many times oil is reused [38, 39]. Several European countries have determined that the frying oil temperature must not exceed 180°C. These measures not only contribute to decreased degradation of unsaturated fatty acids but also result in a lower formation of monounsaturated trans fatty acid (MTFAs) and polyunsaturated trans fatty acids (PTFAs) during frying.

Much research has been done to determine how typical cooking procedures used in food preparation affect TFAs formation in edible oils. Research suggests even applying normal and/or extreme temperatures when cooking does not significantly affect the amounts of TFAs in edible oils [40, 41]. Formation of minor amounts of trans-oleic acid, inferior to 0.2 g/100 g fatty acids was observed by [11, 12] for all the olive oil grades, which is lower than the trans amounts in other refined vegetable oils.

Recent research presented at the World Congress of Oils and Fats in 2020 [42] demonstrated that initially EVOO does not contain TFA and that the food TFA content decreased by approx. 70% or remained stable when using EVOO. The same behaviour was observed with oils: the lowest TFAs production was in EVOO in comparison with other vegetable oils.

2.3.4 Cooking with EVOO

Cooking with edible oils, such as deep frying, usually involves two phenomena. Firstly, when the oil, that acts as a heating medium to the food, reaches 100°C water starts to evaporate from the food. This in turn gives way to the oil being absorbed into the food which modifies the fatty acid composition of the food as it cooks. It has been proven that the fat content of the food after deep frying is more like the fat profile of the oil used to cook than the raw food itself [14]. In addition, although the antioxidant content is reduced somewhat during cooking many healthy substances still remain in EVOO and are absorbed by the food. The absorption of these antioxidants into the food gives the food a better nutritional profile. For this reason, the use of EVOO is a healthier option than using other oils with less bioactive components [13, 42, 43].

2.3.4.1 Frying

Frying is one of the oldest methods of food preparation. It improves the sensory quality of food by formation of aromatic compounds, attractive colour, crust and texture, which are all highly appreciated by consumers [44, 45]. The most common frying methods are deep-frying, being the food totally immersed in hot oil, and pan-frying, when the food is cooked in a pan with a little amount of oil [46, 47].

There is a higher degradation under pan-frying conditions for olive oil and other vegetable oils, that can be explained by the higher contact surface between the food and the oil, higher exposure to atmospheric oxygen, and lower temperature control under processing [46].

Frying with EVOO using a lower food:oil ratio presents lower total polar compound amounts than more unsaturated vegetable oils, and with apparently no interference by the presence of food [32, 48, 49]. Within olive oils, the higher the degree of polyunsaturation the higher the tendency for the formation of total polar compounds [50].

The volatile fraction formed during the heating process, apart from being important from the sensorial point of view, is rich in degradation compounds. The formation of low molecular weight volatile aldehydes has a clear dependence on the temperatures used, rather than frying time [51]. The high oleic acid content in olive oil, together with the presence of chlorophylls, pheophytins and carotenoids, seems to contribute to a reduced acrolein formation and lower amounts of toxic monoaromatic hydrocarbons, alkylbenzenes and alkenylbenzenes, in comparison with other vegetable oils with higher polyunsaturated acyl groups [51–53].

Furthermore, as mentioned previously, in comparison with other vegetable oils, the fried food is enriched with olive oil antioxidants, which improves the nutritional profile of the food [54].

2.3.4.2 Roasting

Roasting with olive oil is common in both domestic and industrial food preparation in Mediterranean countries [55]. This procedure is highly prone to oxidation due to the higher surface area exposed to convention hot air and processing times. When comparing with other vegetable oils with a higher degree of unsaturation, olive oil is also more resistant to oxidation under these heating conditions [11, 56].

In opposition, the total polar compounds clearly increase with vegetable oils with higher unsaturation degrees such as sunflower and corn oil [57].

2.3.4.3 Microwave

In general, heating olive oil using a microwave demonstrates an apparent higher oxidation when compared with conventional heating, despite being probably lower than those achieved with other vegetable oils [58]. Researchers have compared microwave and conventional heating (in an electric oven) in several vegetable oils including sunflower, high oleic sunflower and olive oil. Among the studied oils, the EVOO exhibited better performance against oxidation with both heating methods. This is mainly due to its composition, including minor compounds with antioxidant properties (phenolic compounds and tocopherols) and a lower percentage of linoleic acid [59]. Still, all studies were performed without the presence of food, meaning further studies using real processing conditions are required for correct inferences [15].

2.3.5 EVOO and cookware interaction

In 2019, Modern Olives Laboratory, an Australian oil specialist laboratory, conducted research to assess the suitability of various cooking oils, including EVOO, for use on Teflon coated (TC) pans.

To investigate the hypothesis of whether cooking with EVOO ruins pans, the researchers measured the release of elements and metals from the pans when separately heated with different oils. They used three different brands of TC pans. These pans were heated with an acidic solution of water vinegar (WV) both prior to and after 6 cycles of heating with different oils (EVOO, olive oil, canola oil, rice bran oil and grapeseed oil). The WV solutions were tested to study the release of various metals.

Combining all TC pans, the authors found no significant differences in the chemical elements content between the final WV solutions from TC pans treated with the different oils. This indicates there is no significant difference between the volume of metals released from the cookware when various cooking oils were used. Hence, the various cooking oils had no effect on the pans' integrity and quality when cooking. However, differences of statistical significance for Ca, Cu, Fe, P, Zn and SiO2 were observed between the different TC pan types. Higher values of these metals were detected in the most expensive pan compared with the cheapest TC pan. For example, Ca average values (including initial and final treatment) in the most expensive pan were ~ 2.92 mg/L vs. ~1.75 mg/L in the cheapest pan and ~ 2.42 mg/L in the average price pan. When considering each brand of TC pan, phosphorus levels were significantly higher between treatments when using rice bran oil in the average priced TC pan (4.7 mg/L vs. 2.5 mg/L) versus a low- or high-priced TC pan. Silicon dioxide was not detected before treatment and significantly increased using olive (1.1 mg/L) and grapeseed (1.03 mg/L) oils only in the lowest priced TC pan.

After all treatments, no visual deterioration of any of the TC pans was observed. This investigation indicates that higher differences in metal leaching were between pans quality, rather than between the treatments with the different oils. In no case the use of EVOO lead to the release of significantly higher levels of metallic substances from the pan than when using any other oil.

Even though these results are limited considering the lifetime of the TC pan, they indicate no initial impact of the oils' smoke point on the performance of the TC pan and that EVOO performs similarly to other oils under normal cooking conditions when it comes to TC pan degradation.

3. Conclusion

Sufficient research has been done to demonstrate that an oil's smoke point is not a reliable measurement as an indicator of the ability of an oil to withstand heat, and to determine suitability for cooking. Reasonable predictors of how an oil will perform when heated are oxidative stability, secondary products of oxidation, and total level of PUFAs. EVOO has been demonstrated to be the most stable oil when heated given its unique chemical composition, which is rich in monounsaturated fatty acid and antioxidant content.

Experts have agreed that one of the most versatile and healthy oils to cook with is EVOO and many studies have linked it to better heart and overall health.

Food cooked with EVOO also had lower levels of undesirable products of degradation such as TFAs and polar compounds when compared with other vegetable oils such as canola, grapeseed, peanut, sunflower and rice bran oils, while deep-frying under normal cooking conditions.

Furthermore, based on scientific evidence EVOO does not deteriorate the coating when using Teflon cookware. On the contrary it acts as a lubricant to prevent food from sticking to the pans.

Selecting a true high quality EVOO, that is certified to meet EVOO grade and quality requirements is important to ensure high oxidative stability and safety while cooking.

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Conflict of interest

The authors declare no conflict of interest.

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