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Faculty of Tropical AgriSciences

Storage of Olive Oil

Bachelor thesis

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Declaration

I hereby declare that I have done this thesis entitled Storage of Olive Oil independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 19th April 2019

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Anastasia Mitrusi

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Abstract

For more than 6000 years, the virgin olive oil has been essential for population living alongside Mediterranean basin. Nowadays, the olive oil is expanded and appreciated worldwide. In this literature review, the olive tree, whose fruits are cultivated for olive oil, is characterized. Secondly, the harvest and the processing of olive oil are described. Subsequently, the classification of olive oil is delineated by its quality. Further, the nutritional parameters of virgin olive oil and its health effects are mentioned together with the organoleptic properties of the oil. The aim of this thesis was to summarize the data from literature on the changes of quality parameters (free fatty acidity, peroxide value and UV absorbance for K_{232} and K_{270}) in different storage conditions. According to available data, the documented storage conditions and their effect on selected quality parameters of virgin olive oil were summarized and compared with standard prescribed in the Regulation of European Commission. All monitored parameters have been increasing during the storage period. Some of them overstep EU standards and their excesses depend on the light, time of the storage, packaging and the temperature. The degradation of virgin olive oil can be retarded by keeping the temperature lower than the room temperature is. The quality of olive oil can be extended by not exposing it to light, high temperatures and by keeping the headspace in the bottle as reduced as possible. Surprisingly, packaging material did not show as strong effect on the quality parameters as temperature and light; nevertheless, PET (polyethylene terephthalate) is the least suitable and Tetra-Brik® seems to be an optimal packaging material for virgin olive oil.

Key words: shelf-life, *Olea europaea,* stability, degradation, Tetra Pack

Abstrakt

Skladování olivového oleje

Po více než 6000 let je olivový olej součástí každodenní stravy obyvatel žijících v oblasti Středozemního moře. V dnešní době je rozšířen do všech koutů světa. V této literární rešerši je popsán jednak olivovník, jehož plody jsou pěstovány právě pro olivový olej, ale také jeho sklizeň a zpracování. Dále jsou popsány typy olivového oleje dle kvality, jeho nutriční hodnoty, organoleptické vlastnosti, a především účinky na lidské zdraví. Cílem této práce bylo shrnout informace z vědecké literatury tykající se změn kvalitativních parametrů (volné mastné kyseliny, peroxidové číslo, UV absorbance pro K_{232} a K_{270}) v různých skladovacích podmínkách. Z dostupných článků byly seskupeny a porovnány kvalitativní parametry podle norem Evropské komise. Všechny sledované parametry se dobou skladování změnily, některé z nich překročily normy v závislosti na světle, typu obalu, délce skladování a teplotě. Degradace kvality olivového oleje může být zpomalena uskladněním olivového oleje za nižších teplot, než je teplota pokojová. Kvalita oleje se dá prodloužit tím, že se nevystavuje světlu a vysokým teplotám a také tím, že v láhvi bude co nejméně prázdného prostoru nad olejem. Ukázalo se, že obalový materiál nemá až tak velký vliv na kvalitativní parametry jako světlo a teplo, nicméně PET (Polyethylentereftalát) je nejméně vhodným obalovým materiálem na uchovávání olivových olejů, optimálním obalovým materiálem se zdá být Tetra-Brik®.

Klíčová slova: trvanlivost, *Olea europaea,* stabilita, degradace, Tetra Pak

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List of the abbreviations used in the thesis

EVOO	extra virgin olive oil
FFA	free fatty acidity
mEq	milliequivalent
MEVOO	monovarietal extra virgin olive oil
N/A	not available
PET	polyethylene terephthalate
PP	polypropylene
PV	peroxide value
RT	room temperature
UV	ultraviolet
VOO	virgin olive oil

1. Introduction

For more than 6000 years, the virgin olive oil is essential for population living alongside Mediterranean basin. Nowadays the olive oil is worldwide expanded and appreciated for its health effect and sensory properties. It is one of relatively few edible oils which can be consume in raw state (El-Gharbi et al. 2018). Nevertheless, the olive oil contains substances which are not stable and therefore the quality can be degraded. Unfortunately, any European regulation for maximum expiration does not exist and that happens partly because its durability depends on the storage conditions (Serrano et al. 2016). The European Union has established only regulations on marketing standards for olive oil and its characteristics (European Commission 2012).

In the first part of this thesis olive tree, olive harvesting and olive oil processing are described in more details. Nutritional parameters, organoleptic characteristics and benefits on human health are addressed as well.

The second part deals with shelf-life of olive oil and its qualitative parameters. The effect of oxidation causes that the free fatty acidity and peroxide value are increasing during the storage period and phenolic compounds (and its antioxidants) are decreasing which causes decline the quality of olive oil.

Lastly, Morales et al. (2005) listed the factors affecting virgin olive oil quality, which can be divided into four groups: environment (climate, soil), agronomic (fertilisation, irrigation), cultivation (harvest, ripeness) and technological facilities (extraction method, storage). This work is primarily focused on storage conditions and deals with olive oil qualitative parameters and compare them together.

2. Aim of the thesis

The aim of this work was to summarize the data from literature on the changes of quality parameters of virgin olive oil in different storage conditions. The main objectives of this study were to introduce olive oil (its production and types) and to compare the influence of the different storage conditions on selected characteristic of olive oil: free fatty acidity, peroxide value and UV absorbance values. This literature research was focused on summarizing the facts about virgin olive oil. Secondary objective was to identify optimal storage conditions of virgin olive oil in small-scale (household) based on scientific data.

3. Methods

In this literature research, the citation style of Conservation Biology was used. The articles included in this work come mainly from the Web of Science, there were also used databases as Scopus, ScienceDirect and SpringerLink. Key words for searching articles were: shelf-life, extra virgin olive oil, *Olea europaea*, stability, degradation. There were adduced articles aimed at virgin olive oil and its production, health benefits, organoleptic properties, chemical parameters and others. This bachelor thesis was elaborated with the citation manager of Mendeley. The author has collected and compared more than 50 sources for this research.

4. Literature Review

4.1. Basic characteristics

4.1.1. *Olea europaea*

Olea europaea L. is a grey-green shrub or tree of the family *Oleaceae* which consists of 30 genera and 600 species (Uylaşer & Yildiz 2014). The true origin of *O. europaea* is not known (Vossen 2007). Archaeologists found clay tables which evidence the trade of olive oil at the Palace of Knossos, Crete. They are about 3000 years old. Other records were found in Turkey about 600 Before the Common Era. They discovered an ancient facility for processing olive oil (Uylaşer & Yildiz 2014).

This very undemanding plant can grow up to 15 metres (Guo et al. 2018) and has a very deep root system and a short thick trunk. It can grow in all types of soil. However, it does better off in calcareous soils; the drought is tolerated very well by olive tree, which likes sunny weather without shadows and a warm climate (Growers 2019). In order to survive in hot and dry climates of Mediterranean region, olive tree has a protective coat in the form of trichomes on the underside of the leave. The protection consist in slowing down the transpiration process (Plants & Flowers 2017). Olive tree grows extremely slowly but it lives for over a hundred years (Guo et al. 2018).

O. europaea produces hermaphrodite flowers. Small white flowers with a four-lobed corolla and a four-lobed calyx, two stamens and bifid stigma are borne generally on the wood from the previous year. Olive trees blooms in spring and the flowers produce pollen. Even though most olive varieties are self-pollinating, the flowers are pollinated by the wind. At the beginning of the spring during 12-15 weeks of temperature fluctuation, when the temperature occurs below 10 °C, there is a jarovization associated with the production of flowers. If the temperature drops under - 7 °C, the fruit production can be inhibited. On the other hand, when the tree is strongly pruned, higher production is being supported. After the process of pollination, the flower is fertilized and subsequently the fruit is created. The stone fruit is about 1- 2.5 cm long (Plants & Flowers 2017). The fruit of olive tree is a drupe. Olive consists of a lignified endocarp with seed, a massive mesocarp that holds the oil and the top layer is a thin epicarp. The total weight of the olives ranges from 0.5 to 20 grams (Guo et al. 2018).

The beginning of fruiting depends on type of cultivar. Some of them begin fruiting at an early age which is about 3 months. Nevertheless, most olive cultivars will not create fruit without a pollinator tree of another cultivar. Olives which grow from seeds do not produce fruit and if they do they will not probably have the same feature as the parent tree (Growers 2019).

Figure 1 Fruit of olive tree (Vajdić 2016)

Nowadays olives and olive oil are part of every European household especially in Mediterranean basin. From which it follows that Spain is the biggest producer of olive oil in the world (Mchugh 2015). In 2014, the virgin olive oil production was 1,738,600 tonnes (FAO 2019). So the olive oil is mainly produced in Europe (Mchugh 2015). Nevertheless, olive trees are also currently planted in Chile, Argentina, California and in Australia as well (Vossen 2007).

Table 1 The biggest producers of olive oil, data from 2014 (FAO 2019)

Country	Production in tonnes
Spain	1,738,600
Italy	294,914
Greece	208,900
Tunisia	179,700
Morocco	137,400
Syrian Arab Republic	100,638
Turkey	73,915
Portugal	66,532
Algeria	52,400

In Table 1, there are the top 10 greatest olive oil producers in the world. Even though data are from 2014, they are recent from the Food and Agriculture Organization database. As mentioned, Spain occupies the first place. Italy is on the second place and the third place belongs to Greece with 208,900 tonnes per year. Table 1 shows all the states that surround the Mediterranean Sea which confirms that olive trees come from this area (Guo et al. 2018) except for Syrian Arab Republic (FAO 2019).

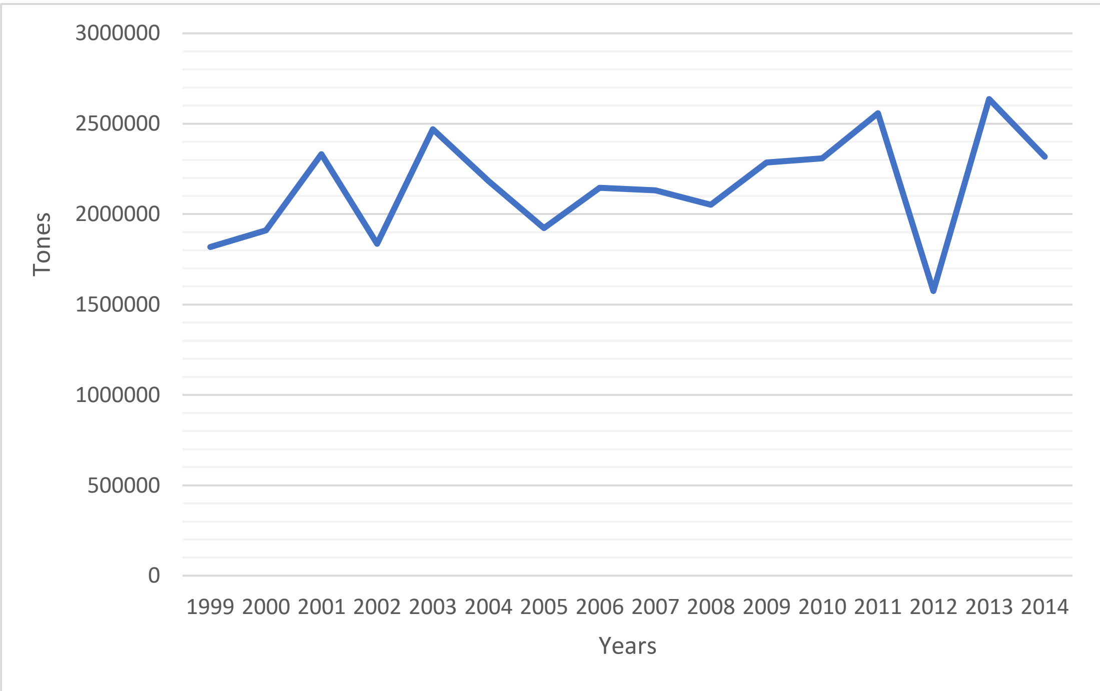

Figure 2 Summary of production quantity (FAO 2019)

The Figure 2 shows the total European production of virgin olive oil from 1999 to 2014. The lowest production was in 2012 and it was 1,574,543 tonnes. By contrast, the largest annual olive oil production 2,636,411 tonnes in the following year 2013 (FAO 2019).

4.1.2. Harvesting

The first step of producing olive oil is harvesting. Harvesting method has a significant effect on oil quality as well as the irrigation. It has been found that when olives are picked carefully by hand with no injury caused, the value of free fatty acidity and the peroxide value decreases and, on the other hand, the total polyphenol content increases. The effect of irrigation on the quality of oil obtained by mechanical and manual methods has been studied. Hence the degradation of olive oil is also linked to irrigation (Saglam et al. 2014). As well as the choice of harvesting method and the intensity of irrigation, the choice of harvesting time is necessary for obtaining the highest quality and quantity of olive oil (Camposeo et al. 2013). Olives are harvested in the fall and in the winter. Olives are harvested in the green to purple degree of maturity (Plants & Flowers 2017). Mechanical harvest is used to a limited extent in more intensive orchards (Saglam et al. 2014). For mechanical harvesting are using machines such as trunk shakers, overhead straddle-type harvesters and canopy contact shakers (Zipori et al. 2014). If olives are picked manually, better quality of oil is guaranteed. Hand harvest is realized by these techniques:

- Collecting fallen olives from the ground
- Whipping limbs with large rods to release the fruit and collecting olives on the nets below the tree
- Removing fruits with half open hands from branches that gall into picking bags or nets under the tree (Saglam et al. 2014).

The right choice of optimal harvesting time is important for achieving the highest quantity and quality of olive oil (Camposeo et al. 2013). Also the variety and maturation affect the final taste and quality of the olive oil (Mchugh 2015).

After the harvest, it is necessary to remove dirt, twigs and unripe olives and leaves that is why olives must be washed. If the olive fruit is processed within 24 hours after harvesting, the highest quality of the oil is achieved (Mchugh 2015).

4.1.3. Classification of olive oil

As well as coffee, wine, tea or chocolate, the olive oil is graded according to quality. This quality is reduced depending on storage conditions. The standards define the quality and the purity of olive oil according to its chemical parameters including free fatty acid content, peroxide values, UV absorbency, insoluble impurities and volatiles (Vossen 2005; Ciafardini & Zullo 2018).

What is important to notice is that olive oils must comply with the standards depending on where they are traded. In this chapter, the quality of olive oil will be determined according to the Codex Alimentarius (Conte et al. 2019).

In Figure 3 there is a description of different types of olive oils which are elaborately described below.

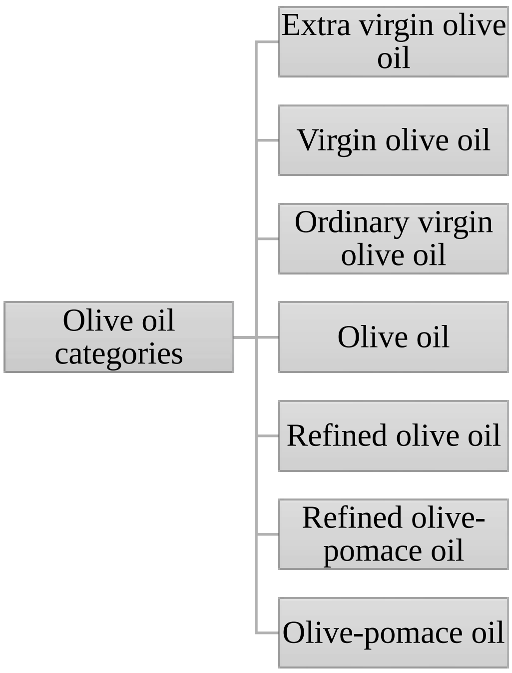

Figure 3 Distribution of olive oil (Codex Alimentarius Council 2017)

- Extra virgin olive oil (EVOO) – the type of highest-rated olive oil which is obtained only mechanically under thermal conditions. These thermal conditions do not produce any change in the oil. The EVOO goes only through the process such as washing, decantation, centrifugation and filtration (Codex Alimentarius Council 2017). The interesting fact is that EVOO is produced only during a restricted period of the year (Tena et al. 2017). The free acidity cannot exceed 0.8 grams per 100 grams (Codex Alimentarius Council 2017) and the peroxide value cannot exceed 20 mEq/ kg (Vossen 2005).

- Virgin olive oil (VOO) – the type of olive oil processed similarly to EVOO, but it has a slightly lower quality (Codex Alimentarius Council 2017). It consists of not more than 2 grams per 100 grams of free acidity and the peroxide value is less than 20 mEq/ kg (Vossen 2005).
- Ordinary virgin olive oil – the type of oil with a little bit lower organoleptic rating (Codex Alimentarius Council 2017). The free acidity is at most 3.3 grams per 100 grams and the peroxide value is up to 20 mEq/ kg (Vossen 2005).
- Olive oil – a blend of virgin and refined oil suitable for human consumption (Codex Alimentarius Council 2017). The free acidity is at most 1 gram per 100 grams (Vossen 2005).
- Refined olive oil – the type of oil obtained from virgin oils by refining. The oil is modified but its glyceride structure remains the same(Codex Alimentarius Council 2017). The free acidity is at most 3.3 grams per 100 grams (Vossen 2005).
- Refined olive-pomace oil – the type of olive oil obtained from crude pomace oil by refining (Codex Alimentarius Council 2017). The free acidity is at most 3.3 grams per 100 grams (Vossen 2005).
- Olive-pomace oil – a blend of virgin olive oil and refined olive-pomace oil for human consumption (Codex Alimentarius Council 2017). The free acidity is at most 1 gram per 100 grams (Vossen 2005).

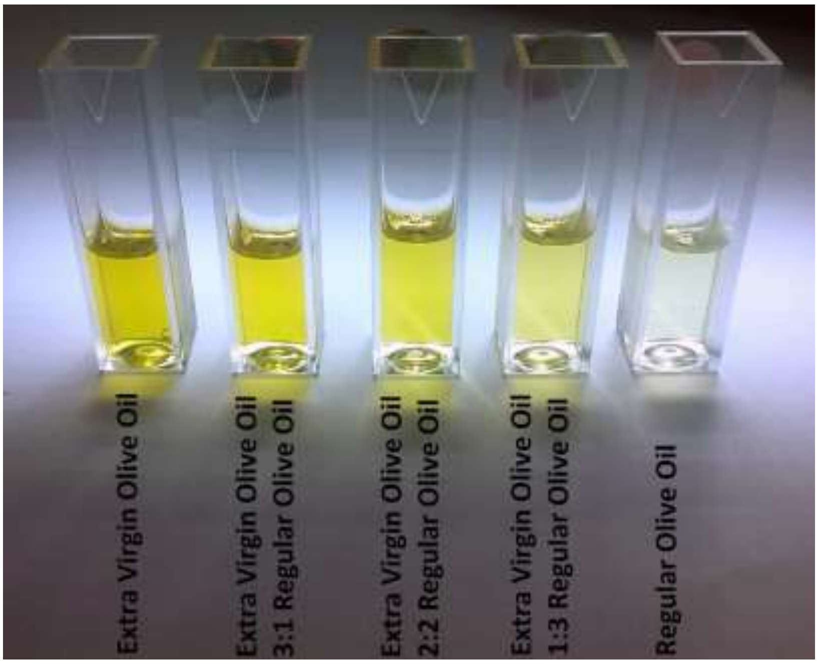

Figure 4 Comparison of olive oils and their mixtures (Mowatt 2015)

The equivalent is the amount of substance that can react with one mole of counter-ion carrying and unit charge. The milliequivalent (mEq) is 1 / 1,000 equivalent. Because of the amounts found in chemical terms, the unit mEq is more common (Nelson 2018).

4.1.4. Processing of olive oil

On the basis of the type of processing, the quality of olive oil is classified into individual categories such as EVOO, VOO and so forth. Processing is closely related to the initial qualitative parameters.

The olive fruit contains roughly 1/3 solid material, 1/3 oil, and 1/3 water, which is also known as olive juice. Traditional olive oil processing begins with grinding the olives into a paste. The intention of the grinding is to simplify the release of the oil from the vacuoles (Mchugh 2015). The process continues with mixing the paste which helps to separate the oil from the pomace (Vossen 2005). The amount of oil extracted through the formation is optimized by the mixing process, also known as malaxation. Small droplets form into larger droplets which make oil extractability better. During the malaxation it is essential to control the temperature, which cannot exceed 28 °C, because higher temperature can cause a loss of fruit flavours or increasing the bitterness of acridity (Vossen 2005). This process lasts from 20 to 45 minutes and it allows the fruit enzymes to generate desirable flavours and aromas. Longer process can decrease a quality and a shelf-life (Mchugh 2015). Subsequently, the oil is extracted from the fruit water and the paste (Vossen 2005). There are several extraction methods: pressing, percolation and centrifugation (Kapellakis et al. 2008). In Table 2 there are presented pressure methods like traditional press, 3-phase system decanter and 2-phase system decanter (Vossen 2005). The first one is the most familiar method for processing olive fruit and is described in more details below.

Decanters belong to centrifugation method. It is built on separation the oil from the oil paste. This process is based on different densities of olive paste ingredients. It is separated by decanter. After crushing and mixing, the oil is either completely free, which is separated by a centrifuge, or the oil is in the form of microgels. The oil locked in the microgel is released by the addition of water (Kapellakis et al. 2008).

In Table 2, there is an overview of the volume of waste materials generated during extraction. Most solid waste produces 2-phase decantation. However most water waste produces 3-phase decantation, even twice as much as the traditional method (Vossen 2005).

Table 2 Methods of extraction (Vossen 2005)

	Solid waste [kilos/ton olives]	Waste moisture [%]	Waste water [kilos/ton olives]	Fruit water moisture [%]
Traditional press	330	25	600	94
Decanter – 3-phase	500	48	1,200	90
Decanter – 2-phase	800	55	250	99

The traditional press method is the oldest procedure of oil extraction. This method is built for using high pressure to get filter mats compacted in a hydraulic press. During this process solid phase is compacted and subsequently the liquid phase is percolated (Vossen 2005). Olive juice has the ability to run down the sides of the discs to accelerate the percolation. After this process the liquids are detached by centrifugation or decantation (Mchugh 2015). Nevertheless, the machinery is cumbersome, the process needs more labour than other methods because the filter mats can easily be contaminated. The purity of the mats is very important. One problem with traditional press method arises when mats start to ferment which can cause a loss of the quality of oil. It starts when mats are not used continuously or if they are not cleaned regularly. The solution is to use machine frequently until the end of harvest or to wash the mats after each use. Oils from presses can produce the best oil if everything works great. The oil tends to have better flavour and higher polyphenol capacity. The other way around, if it is not properly operated many defects arise. In particular the fermentation of mats can degrade the olive oil (Vossen 2005). Nowadays the modern olive mills are partially or fully automated. They consist of a stainless steel crusher which rotated a high speed (Mchugh 2015).

Besides these methods, selective filtration process, also called sinolea process is used but this method is different from others because it does not need the pressure. The principle is that the oil adheres to the stainless steel blades and drips into a separate container while the solids and water remain together (Vossen 2005).

After the processing, the oil is put into large stainless steel tanks which contain a protective coating with nitrogen to protect the oil from oxygen (Mchugh 2015). Newly produced virgin olive oil contains some solid particles at the bottom of the containers which are undesirable. It can be eliminated by sedimentation or filtration (Ciafardini & Zullo 2018).

4.1.5. Nutritional parameters

From the ancient times, people from the Mediterranean countries consume extra virgin olive oil (Ghanbari Shendi et al. 2018), which contain a cocktail of chemical components (Di Serio et al. 2018).

Virgin olive oil is a complex mixture of more than 200 compounds containing major, and minor but indispensable, components (Aiello et al. 2015). Different environments, olive variety, agronomy and processing systems have a significant impact on the nutritional content of olive oil. When olive oils are properly stored, they retain its nutritional values which are higher than other edible oils (Guo et al. 2018). Monounsaturated fatty acids, polyunsaturated fatty acids and saturated fatty acids are the major constituents of its chemical composition (Guo et al. 2018). Olive oil contains more monounsaturated than polyunsaturated fatty acids than other vegetable oils (Foscolou et al. 2018). Besides the fact that olive oil is rich in lipids, it also contains large amounts of minerals and vitamins, namely: calcium, sodium, potassium, iron, and vitamin E and K (Guo et al. 2018).

Vitamin E, known as tocopherol, is present in olive oil. Tocopherol is a very important antioxidant and it has regulatory cellular and molecular roles. A daily consumption of 25 grams of VOO would provide about 30 % of the recommended intake of this vitamin (Cayuela & García 2017).

From the perspective of Foscolou et al. (2018), one tablespoon of olive oil contains 119 kcal, 13.5 g of fat, 10 g monosaturated fat, 1.9 mg of vitamin E and 8.1 μg of vitamin K.

4.1.6. Potential health effects

Besides the positive qualities of olive oil such as taste and nutrition value, olive oil also affects the human body in a positive way (Tsimidou et al. 2003). In the long-term storage of olive oils, phenolic compounds which have a beneficial impact on human health can be lost. This effect is related with high content of oleic acid and various antioxidants which are essential for human organism (Samaniego-Sánchez et al. 2012).

The most important fact is that the olive oil has the highest percentage of monounsaturated fat of all edible oils. In addition, olive oil contains pigments, flavonoids and phenolic compounds that include oleuropein and hydroxytyrosol (Yada et al. 2007). These minor components include antioxidants which have abundant cardiovascular health benefits (Foscolou et al. 2018).

One group of scientists established studies about potential health benefits of the Mediterranean diet. People there live verifiably longer and there is lower occurrence of cancer, neurodegeneration and also cardiovascular diseases (Visioli et al. 2018). In these countries, saturated fat replaces healthier monounsaturated fats. These fats can also be found in avocados, peanut butter or sesame oil.

Consumption of extra virgin olive oil restricts developing cardiovascular diseases such as coronary artery disease and hypertension (Foscolou et al. 2018). It is also proved there is 40 % lower incidence of Alzheimer's disease, dementia, mild cognitive decline or age-related decline. In addition, postmenopausal women who consume EVOO are 62 % less likely to experience breast cancer (Visioli et al. 2018). Other benefits include the fact that olive oil contributes to weight control. For instance, obesity is the true risk factor for type 2 diabetes. Olive oil reduces this risk due to high quantity of polyphenols (Salas-Salvado et al. 2014).

Virgin olive oil is rich in hydroxytyrosol, as mentioned above. It has very beneficial effects on human health. It captures free radicals and reactive oxygen or nitrogen in the body (Kuban-Jankowska et al. 2018). The ability to capture free radicals with hydroxytyrosol has been confirmed in studies on rats (Jemai et al. 2009). Studies have shown that hydroxytyrosol stimulates mitochondrial biosynthesis, which is reduced in diabetes mellitus. This unique property of hydroxytyrosol scales down the potential risks for developing type 2 diabetes mellitus (Kuban-Jankowska et al. 2018).

Other important polyphenol of olive oil is oleuropein which is effective against various bacteria, fungi, viruses, molds and even parasites. Oleuropein inhibits platelet aggregation and results in a reduction of the number of blood vessels exhibiting strong antiangiogenic properties. One of other positive effect of oleuropein is the fact it includes anti-cancer activity observed in: melanoma, bladder carcinoma, prostate cancer, lung carcinoma and more. Oleuropein has been shown to exhibit the ability to reduce tumour cell viability. Its anti-angiogenic properties prevent or slow down the development of tumours (Kuban-Jankowska et al. 2018).

In conclusion, the aggregated evidence corroborates that consumption of olive oil has beneficial effects on a human body, especially against developing cardiovascular diseases, diabetes mellitus and cancer (Foscolou et al. 2018).

4.1.7. Organoleptic properties

Apart from the fact that olive oil has positive health effects it is also popular because of its aroma and taste. Poor storage of olive oil can release these sensory properties. It could be said that the consumers are more interested in its taste rather than in potential health effects. The freshness is one of the most important features of olive oil and it is very often considered to be the main indicator of quality among people (Li & Wang 2018).

Volatile aroma compounds create the pleasant fragrance (Aparicio et al. 1996). The concentration of these compounds depends on variety of olive trees, growing conditions and post-harvest treatments, specially transport and storage conditions (Reiners & Grosch 1998; Escudero et al. 2016).

The flavour and the aroma are hard to determinate in the laboratory. Saliva components are able to integrate with aromatic compounds and release the aroma from the olive oil (Ployon et al. 2017; Genovese et al. 2018). For the sensory evaluation it is essential to use the tongue which can discover texture differences (Vossen 2005). The classification of olive oils is based on the detection of negative properties (Ciafardini & Zullo 2018). The first one is fusty flavour of oil obtained from olives in a stage of fermentation. The second characteristic is mustiness-humidity which is attained from olives heaped under humid conditions where several species of fungi were developed. Another sensory note is winey-vinegary due to the high concentration of ethyl acetate, ethanol and acetic acid. The last one is a rancid attribute which is characteristic for all oils and fats that have undergone an auto-oxidation caused by a contact with the air for a long time (Morales et al. 2005).

The virgin olive oil must be free from the taste of vinegar or fermentation. Bitter taste is not a defect it is mostly found in newly made oils. As the oils age the bitterness will dissipate. Actually, the bitterness is positive because of a higher amount of polyphenols. Bitter oils preserve polyphenols longer than oils of sweet taste (Vossen 2005).

4.2. Storage conditions of virgin olive oils

As it is generally known, olive oils are not stable. They tend to go rancid and this is how the substances are degraded. Their quality decrease because of bad storage conditions (Tsimidou et al. 2003). During oxidative and hydrolytic reactions the shelf-life of olive oil is decreased by temperature, oxygen and light (Lanza et al. 2015). Other factors include fertilization, cultivation, pedoclimatic conditions, handling of olives between harvesting and processing (El-Gharbi et al. 2018; Liberatore et al. 2018). However, the packaging material and conditions have key impact on shelf-life of olive oils (Sanmartin et al. 2018). Therefore, it is necessary to avoid contact with inadequate materials such as metal containers that may cause oxidation reactions. However, metal containers exist and are still used because they provide complete protection from light, oxygen and water vapor. Hence special tin-free sheets are made (Sanmartin et al. 2018). For a better protection the interior of the container is coated with resin (Silva et al. 2015). Besides the metal packaging, glass bottles of olive oil are also made and used on the market. These glass bottles are made from special glass with low light permeability in the UV range (Limbo et al. 2014).

It should not be neglected that decanting, which is done for separating out the dregs, is essential for the final product. If possible, decanting should be performed twice or three times a year. In factories, oil containers are carefully cleaned and maintained at the stable temperature (Tsimidou et al. 2003).

The study of chemical and physicochemical attributes of the EVOO is useful in order to determine the shelf-life to maintain the nutritional and organoleptic quality as long as possible within the limits of the virgin olive oil category declared by the European Union Commission Regulation (Lanza et al. 2015). The European commission has set marketing standards for olive oil (European Commission 2012). These standards for EVOO and VOO are shown in Table 3. These values in the Table 3 are compared with the values of following studies. The conclusions are drawn as how to the qualitative parameters have changed over the time and what are the ideal conditions and time period of the storage.

Table 3 Characteristics of virgin olive oil (European Commission 2012)

Category	**FFA [%]** *	**PV [mEq O_2/ kg]**	**K_{232}**	**K_{270}**
EVOO	≤ 0.8	≤ 20	≤ 2.50	≤ 0.22
VOO	≤ 2.0	≤ 20	≤ 2.60	≤ 0.25

* Values for FFA are given in g/100 g, which corresponds to a percentage value

Several studies monitor the chemical parameters of olive oil under various storage conditions. These studies lead to different conclusions, which are discussed in more details in the following subchapters. The most monitored parameters include free fatty acidity (FFA), peroxide value (PV), ultraviolet absorbance (UV) (Li & Wang 2018), diglycerides (Ayyad et al. 2015), chlorophyll content, iodine value, phenolic compounds (Serrano et al. 2016) and volatile compounds (Lanza et al. 2015).

In this study four qualitative parameters are described in detail. These parameters are FAA, PV, UV absorbance for K_{232} and K_{270}.

Free fatty acids are created by the hydrolysis of triglycerides during ripening, processing and storage. An elevated level of FFA signifies poor quality oil made from defective fruit, improperly processed oil or stored oil. The concentration of FFA is determined by analytical titration (Li & Wang 2018). The ideal value for FFA in extra-virgin olive oil is below 0.8 % by the EU standards (European Commission 2012).

Peroxide value, also known as peroxide index, is a method of determining peroxides. The maximum value of PV is 20 milliequivalents of active oxygen per kilogram (Serrano et al. 2016) in categories of EVOO and also VOO. Peroxides are primarily oxidized products which are formed when oils are exposed to oxygen, generating undesirable flavours and aromas. An elevated level of peroxides indicates oxidized or poor-quality oil. As well as FFA, the PV is also determined by analytical titration (Li & Wang 2018).

Ultraviolet absorbance provides information about the degree of olive oil oxidation and hence its quality (Escudero et al. 2016). Conjugated double bonds are formed from natural nonconjugated unsaturation in oils upon oxidation. The K_{232} measures primary oxidation products (Li & Wang 2018). The K_{232} indicates the formation of conjugated hydroperoxides (Kiritsakis 1998). The K_{270} measures secondary oxidation products. An elevated degree of UV absorbance detects poor quality or oxidized oil (Li & Wang 2018). According to EU standards, ideal value for the K_{232} is smaller or equal to 2.5 for the EVOO and for the VOO is smaller or equal to 2.6. For K_{270} the value should be smaller or equal to 0.22 for the category of EVOO and for the VOO is smaller or equal to 0.25 (European Commission 2012). The method for determining UV absorbency is called UV spectrophotometry (Li & Wang 2018).

The following chapter delineate articles where chemical parameters are observed during storage of olive oils for different times and in different surroundings.

4.2.1. Storage experiments with virgin olive oil

- **Effect of shelf conditions by Lanza et al. (2015)**

In their study one type of olive oil was observed – Monovarietal extra virgin olive oil (MEVOO) acquired from *Olea europaea* L. cv 'Taggiasca'. This oil was extracted in mill by 3-phase continuous system and stored in dark-green bottles at room temperature from 18 °C to 25 °C under artificial light and away from heat source. It was being monitored for 12 months. After one year of storage the rancid defects were observed. To give an example, the organoleptic properties got worse as well as fruitiness and bitterness were reduced. Furthermore, phenolic substances and tocopherols were also reduced. The acidity shows a very small increase because fatty acids from lipids have been released by hydrolysis. The oil has abundant content of natural antioxidants before storage. For instance, α-tocopherol shows the value of 168 mg/ kg. At the end of the 12 months of storage the value was only 64 mg/ kg. The PV has risen to a maximum value of 19 mEq O_2/ kg at the third months of storage and then started to decrease to 12.8 mEq O_2/ kg. This phenomenon can be explained by the initial increase in hydroperoxides, which are compounds formed during the primary oxidation step.

Interesting fact is that the dark green glass protects chlorophylls from oxidation. This glass absorbs a portion of the radiation at wavelengths corresponding to their absorption. Therefore, the coefficient K_{232} remained almost constant or a little increased after 9 months of storage. The coefficient K_{270} remained unchanged throughout the storage period. Likewise, the content of chlorophyll and carotenoid remained constant through the observation period.

They followed also the evolution of phenolic compounds. During storage, the phenolic compounds are modified by endogenous enzymatic activities that occur in the cloudy phase. Oil filtration partially removes water and the enzymes, that cause this modification, to stabilize the olive oil. Biophenols such as oleuropein increase after three months of storage due to aglycone degradation.

- **Effect of shelf conditions by Ayyad et al. (2015)**

This type of olive oil was examined by the group of scientists from the University of Bologna in Italy and the University of the Balearic Islands in Spain. They investigated the effects of storage conditions of EVOO.

For this experiment they used EVOO samples from olives of the Arbequina cultivar which is located in Soller, Majorca, Spain. A three-phase decanter was used to produce this olive oil. This type of oil was put into four 250 mL transparent glass bottle with the headspace about 2 mL in each bottle. The first sample was stored in the darkness inside a thermostatic chamber at 20 °C. The second one was stored in diffuse light simulating the conditions of supermarket shelfs at 20 °C. The third sample was stored in a refrigerated chamber under diffuse light at 4-6 °C. The fourth sample, which is the last one, was stored in diffuse light at 20 °C and the headspace contained added argon.

Ayyad et al. (2015) were also interested in the content of diglycerols in EVOO during the storage. The results confirm that the isomerisation of diglycerides in EVOO depends not only on the length of storage but on the storage temperature as well. After 10-14 months of storage it was found that the diglyceride ratio remained higher for the samples stored in the lower storage temperature. Further, the sample with argon gas in the headspace of the bottle was insufficient to prevent isomerization of diglycerides under light conditions.

As can been seen in Table 4 all the monitored parameters are in the EU standards at the end of storage observation.

- **Effect of shelf conditions by Serrano et al. (2016)**

Picual virgin olive oil from Portugal was monitored for 12 months in five different conditions. The first one was stored in amber bottle of 250 mL in the dark at 4 °C. The second sample was in artificial light in amber bottle of 1 L at 20-28 °C. The third sample was in artificial light in colourless bottle of 0.75 mL at 20-28 °C. The fourth sample was the same as the third one with added *Catostylus tagi* which is a large hemispherical jellyfish with a massive bell (Boltovskoy 2018). The last one was in colourless bottle of 0.75 L under natural light without controlled temperature. All samples had the same constant air in the headspace.

In this work, FFA was determined after 12 months of storage at 4 °C and at uncontrolled temperature. Both samples remained below 0.6 g oleic acid/ 100 g which shows no statistical difference between them. It can be said that the most unfavourable storage conditions have not changed this parameter in a significant range.

During the monitoring, the peroxide value remained the same. In the twelfth month of monitoring the values were either at maximum levels according to EU standards or exceeded the standard. A colourless bottle in natural light and an amber bottle in artificial light exceed it.

Due to EU standards, all samples comply with K_{232} after a storage period of 12 months. Unfortunately, for K_{270} all values did not meet the standards. The value of samples in uncontrolled temperature in natural light has number of 0.27 which is shown in Table 4. It exceeds the specified standard of the category VOO with the value 0.25 by 0.02.

Regarding the sample with added *C. tagi*, there was no clear effect on the increase or decrease in the UV absorbance values. However, the presence of *C. tagi* reduce the evolution of oxidation for the peroxide value. Nevertheless, the sample in the amber bottle in dark has still lower peroxide value than the sample with algae in the artificial light in colourless bottle.

- **Effect of shelf conditions by Sanchez et al. (2012)**

In this research article, samples were taken from three Picual variety EVOOs. Each sample was stored in a different commercial format – polyethylene terephthalate (PET), glass and Tetra-Brik®. Tetra-Brik® is a carton package better known as Tetra Pak which is the official name of the company that makes Tetra-Brik®. The oils were stored for 9 months in the dark without headspace. All oils were packaged in four different materials and were stored in refrigerated temperature 4 °C and at normal household temperature 20 °C.

During storage, the acidity in all samples increased. The oils in the Tetra-Brik® have the smallest increment because the Tetra-Brik® contains a metal lining, thereby protecting the oil from penetrating light and oxygen. The biggest increase was in oils stored in PET plastic whereas it has the highest permeability of all these materials. The acid value was not affected by temperatures.

To evaluate the PV values, it could be said that after 9 months, the values for all samples stored at room temperature (20 °C) increased to more than twice the original value. None of the oils has exceeded EU standards yet. However, the largest increase in PV was observed for the sample stored in PET plastic, again because of the highest permeability.

Another parameter was the ultraviolet absorbance. It was found that after 9 months the value of coefficient K_{232} exceeded the standards in samples stored in PET plastic in both measured temperatures. Furthermore, it was showed after 9 months of the storage that the sample in the glass exposed to 20 °C does not comply with the EU standards as it can be seen in Table 5. The next one was the coefficient K_{270} which should have a maximum of the value 0.22 in the EVOO category according to EU standards. Unfortunately, all samples do not meet this standard after 9 months of storage. However, the sample in glass in 20 °C and 4 °C and Tetra-Brik® in 4 °C can be classified as VOO by EU standards. Even with these parameters, it was confirmed that the PET plastic is the worst of all storage containers.

- **Effect of shelf conditions by Di Serio et al. (2018)**

In the article by Di Serio et al. seven EVOO cultivars were studied. They were stored in dark-green containers of 1 L in room temperature. This temperature was 15 °C during winter and 18 °C during summer. All bottles were exposed to diffuse light in the same air conditions.

The fatty acids in EVOOs contain large amounts of monounsaturated fatty acids that protect the oil from oxidation processes. However, there were no major changes during the 12 months storage period.

The peroxide value shows the processes of degradation and aging. The primary oxidation process was observed during the trial. The Figure 5 shows increasing peroxide value of the variety 'Biancolilla'. After 12 months it was 21.5 mEq O_2 per kg. The maximum value 20 mEq O_2 per kg permitted by law was exceeded after 10 months of storage. However, other varieties exceeded the limit after 12 months of the storage. EVOOs 'Nocellara del Belice' and 'Carolea' are the only ones remaining within the standards.

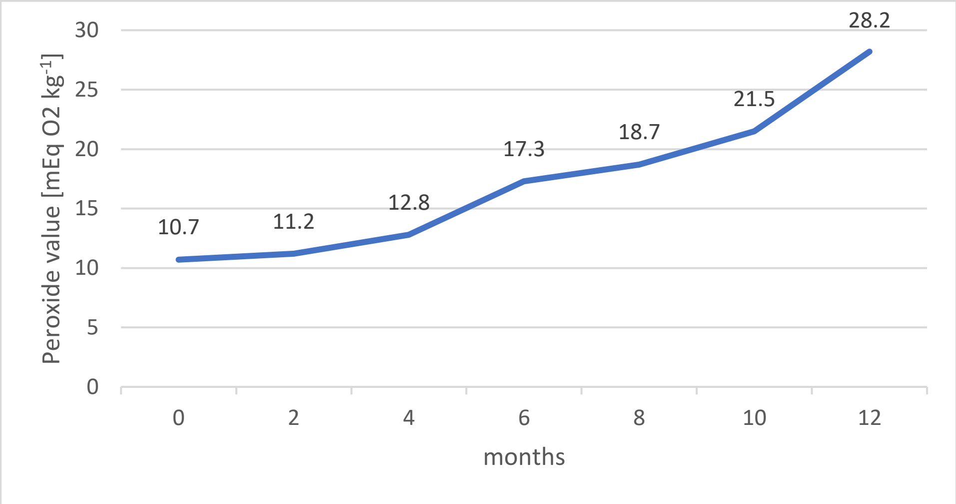

Figure 5 PV during 12 months (Di Serio et al. 2018)

After 10 months, the UV parameter absorption K_{232} met the requirements of EU except of the variety 'Biancolilla' which overstepped the standards with value of 2.578 which can be seen in Figure 6. However, after 12 months of storage, the limit was overstepped for all varieties except for 'Nocellara del Belice' and 'Nocellara Etnea' EVOOs. Di Serio et al. also studied the absorption parameter K_{270}. This value was not exceeded within the EU standards for EVOO. All varieties were below the limit 0.22.

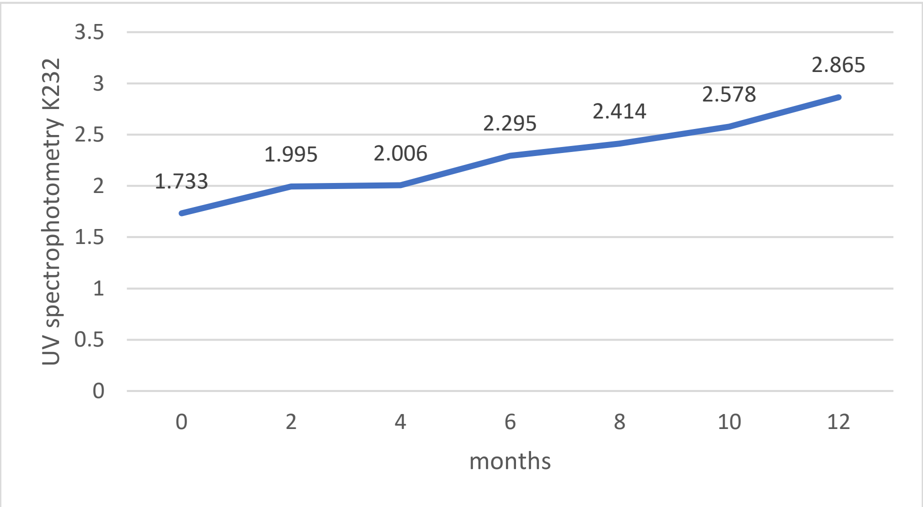

Figure 6 K_{232} during 12 months (Di Serio et al. 2018)

- **Effect of shelf conditions by Pristouri et al. (2010)**

In the article by group of scientists from the university of Ioannina, Greece studied the packaging material, its light, oxygen transmission and the effect of storage temperature. The samples were from the olive variety "Koroneiki" grown in Greece.

Firstly, the olive oil was put into three types of bottle: clear PET, clear polypropylene (PP) and clear glass. These bottles were sealed with aluminium screw-type caps of negligible permeability to oxygen. These containers were stored in the dark at 22 °C which is temperature environmental chamber.

Secondly, PET, PET with UV blocker and PET covered with aluminium foil were filled with the EVOO and stored on the lab shelf exposed sporadically 12 hours to daylight. These samples were also stored in the dark at 22 °C.

Thirdly, the samples were all put into the PET bottles. Nevertheless, they were stored in various temperatures: 13 °C (cellar temperature), 22 °C (room temperature), 35 °C (summer temperature).

Regarding the acidity, the limits which firstly exceeded the standards were in the pure PET bottle in the ninth month. However, samples of PET with UV blocker, PP and PET in 35 °C exceeded the standard after 12 months too. After 12 months of storage the lowest FAA value was in the PET bottle in 13 °C.

Standards of peroxide value exceeded the sample in PP already in the ninth month. After 12 months, the standards exceeded PET in the dark and both sample in PET at 22 °C and 35 °C. The best value stayed in PET bottle in 13 °C.

Concerning the absorption coefficient K_{232}, majority of samples exceeded the EU standards after 3 months. However, the sample in PET at 13 °C was measured 2.30 after 3 months from which it follows that this storage space is most preferred for K_{232}. Unfortunately, all values had not met the standards after 12 months.

However, the coefficient K_{270} was similar to the coefficient K_{232}. Samples in PP, PET in 35 °C, clear PET and PET + UV blocker infringed the standards EU after 3 months. After 12 months none of studied samples complied with EU standards.

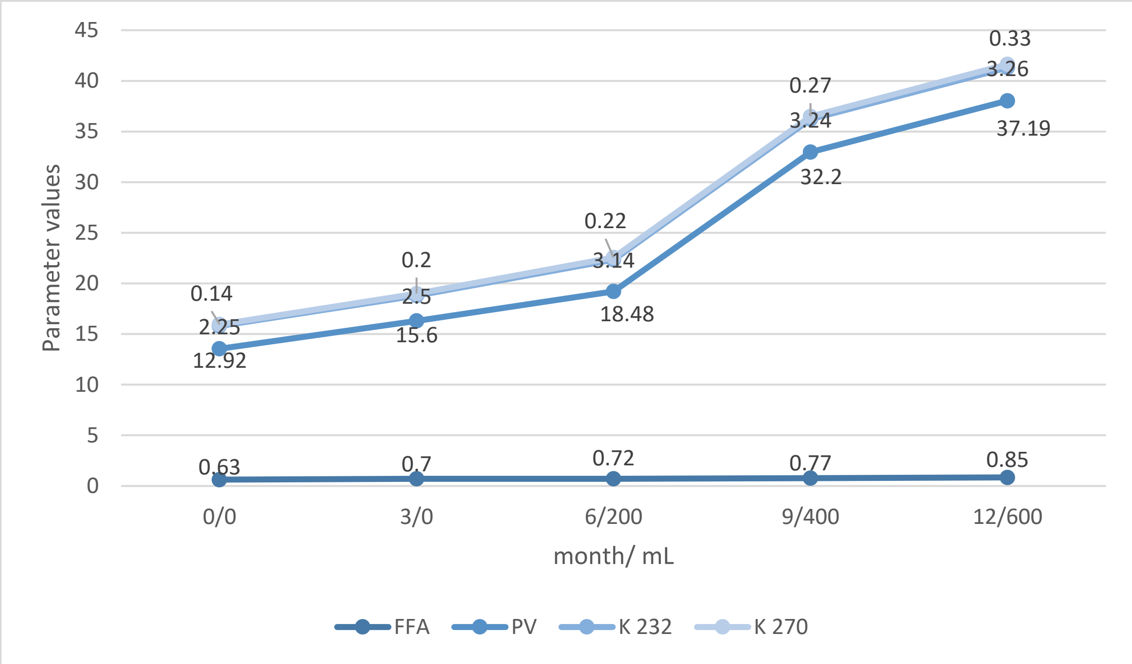

Figure 7 The effect of headspace on qualitative parameters (Pristouri et al. 2010)

This article is also interested in the impact of headspace on storage of olive oil. Figure 7 shows how the values of FFA, PV, K_{232} and K_{270} change according to the volume of the headspace. This sample was stored in a PET bottle in the dark at 22 °C.

- **Effect of shelf conditions by Shendi et al. (2018)**

Three scientists from three universities in Turkey studied the Turkish olive monocultivar VOO. This oil was made from the olives variety Saurani which is a domestic variety from the province of the south Turkey. This oil was putted into 250 mL amber glass bottles with the headspace containing 4 centimetres. These bottles were stored at 18 – 24 °C which is room temperature. This experiment lasted 12 months.

FAA increased during the year but did not exceed the EU standards.
In this case, the PV was remarkable. In the fifth month it reached the value of 21 mEq O_2/ kg, which exceeded the standard. This increase was continued until seventh month of monitoring. However, the value fell again in the eighth month. This effect occurs depending on the packaging material and storage conditions.

The value of K_{232} decreased up to four month. While in the eighth month the value increased. Further, this VOO had the highest and the lowest value of the K_{270} in the second and the first month.

4.2.2. Evaluation of storage experiments with virgin olive oil

All the monitored parameters increased during storage. Some of them exceeded EU standards in the twelfth month or other in the third month, it depended on the light, packaging and temperature. Table 4, 5 and 6 show all monitored parameters in the longest possible storage time. The quality parameter values that exceed the EU standards are highlighted in Table 4, 5 and 6. Qualitative changes that arise in olive oil can come from processing and are not necessarily a consequence of the storage (Samaniego-Sánchez et al. 2012).

The most fundamental finding is that the initial virgin olive oil composition influences the storage period (Di Serio et al. 2018). Another fact is that blended olive oils are more stable that monovarietal olive oils (Serrano et al. 2016).

The factors as temperature and light affect the storage period. A daylight causes the development of secondary oxidation thereby reducing the shelf-life (Serrano et al. 2016). Higher temperature can initiate degradation reactions and facilitate the production of volatile compounds (Samaniego-Sánchez et al. 2012). However, the shelf-life can be increased by reducing the ambient temperatures. At low temperatures (less than 4 °C), the possibility of extending shelf-life is significantly higher compared to higher temperatures (more than 20 °C) (Samaniego-Sánchez et al. 2012). Nevertheless, it is not recommended to store EVOO for more than 12 months, but when the oils are kept in the darkness and the temperatures are lower, the storage period can be extended (Di Serio et al. 2018). It should be noted that the experiment by Serrano et al. (2016) when *C.tagi* was put into colourless bottle in artificial light the development of peroxides in the olive oil slowed down.

The choice of container is important to ensure the longest stability of the virgin olive oil (Samaniego-Sánchez et al. 2012). Containers with high oxygen transmission rates, for example PP and PET are not suitable for packaging olive oils (Pristouri et al. 2010). PET is the least suitable material for this purpose (Samaniego-Sánchez et al. 2012). UV filters in PET bottles do not retain the quality of EVOOs (Pristouri et al. 2010). Glass, as packaging material for olive oils, seems also unsuitable, although it is better than PET material. The EVOO stored in a dark-green glass bottle at room temperature under artificial light away from a heat source remained EU standards for 9 months (Lanza et al. 2015). The most suitable packaging material seems to be Tetra-Brik®. It protects olive oil from light and oxygen as well, which is directly related to organoleptic features, nutritional properties and EVOO quality parameters. Tetra-Brik® is the least influenced by the environment from all of these materials (Samaniego-Sánchez et al. 2012).

Table 4 Comparison of documented storage conditions

Type	Packaging	Temperature	Light	Storage period [1]	FFA[2]	PV[3]	K232[4]	K270[4]	Source
MEVOO, cv 'Taggiasca'	dark-green bottles	RT[5] (18–25 °C)	artificial light, away from heat source	12	0.35	12.8	2.145	0.132	Lanza et al.
EVOO, Arbequin cultivar	Diffuse light simulating the conditions of a supermarket shelf	20 °C	Diffuse light	14	0.20 ± 0.01	14.74 ± 1.02	2.19 ± 0.07	0.18 ± 0.01	Ayyad et al.
	Inside a thermostatic chamber	20 °C	Darkness	14	0.20 ± 0.01	12.74 ± 0.55	2.34 ± 0.02	0.15 ± 0.01	
	Refrigerated chamber	4–6 °C	Diffuse light	14	0.17 ± 0.01	15.47 ± 0.80	2.19 ± 0.06	0.14 ± 0.00	
	With argon in the headspace of bottles	20 °C	Diffuse light	14	0.20 ± 0.01	14.70 ± 0.40	2.24 ± 0.03	0.18 ± 0.01	
VOO, Picual variety	Amber bottles, 250 mL	4 °C	Darkness	12	0.15 ± 0.04	15.8 ± 1.1	1.64 ± 0.12	0.123 ± 0.004	Serrano et al.
	Amber bottles, 1 L	20–28 °C	Artificial light	12	N/A[6]	**20.2 ± 1.6**[7]	2.08 ± 0.1	0.150 ± 0.081	
	Colorless, 0.75 L	20–28 °C	Artificial light	12	N/A	**21.6 ± 1.7**	1.81 ± 0.11	0.191 ± 0.033	
	Colorless, 0.75 L with *C.tagi*	20–28 °C	Artificial light	12	N/A	17.5 ± 0.9	1.92 ± 0.08	0.157 ± 0.032	
	Colorless bottle 0,75 L	Uncontrolled temperature	Natural light	12	0.20 ± 0.06	**20.9 ± 2**	2.46 ± 0.13	**0.27 ± 0.023**	

Table 5 Comparison of documented storage conditions (continued)

Type	Packaging	Temperature	Light	Storage period [1]	FFA[2]	PV[3]	K232[4]	K270[4]	Source
EVOO, Picual variety	Glass	20 °C	Darkness	9	0.45 ± 0.0009	15.48 ± 0.09	**2.70 ± 0.003**[7]	**0.24 ± 0.002**	Samaniego-Sánchez et al.
	PET	20 °C	Darkness	9	0.57 ± 0.008	18.98 ± 0.12	**2.98 ± 0.002**	**0.40 ± 0.005**	
	Tetra-Brik®	20 °C	Darkness	9	0.42 ± 0.011	12.43 ± 0.09	1.8 ± 0.004	**0.27 ± 0.003**	
	Glass	4 °C	Darkness	9	0.47 ± 0,018	11.09 ± 0.1	2.23 ± 0.005	**0.25 ± 0.003**	
	PET	4 °C	Darkness	9	0.47 ± 0.012	13.21 ± 0.21	**2.78 ± 0.003**	**0.35 ± 0.004**	
	Tetra-Brik®	4 °C	Darkness	9	0.42 ± 0,012	11.54 ± 0.25	1.67 ± 0.003	**0.25 ± 0.002**	
EVOO, Biancolilla	Dark green bottles	RT[5]	Diffuse light	12	0.55	**28.2**	**2.865**	0.16	Di Serio et. al
EVOO, Carolea	Dark green bottles	RT	Diffuse light	12	0.33	19.5	**2.563**	0.143	
EVOO, Coratina	Dark green bottles	RT	Diffuse light	12	0.31	**20.7**	**2.691**	0.184	
EVOO, Dolce di Rossano	Dark green bottles	RT	Diffuse light	12	0.39	**26.8**	**2.799**	0.149	
EVOO, Frantoio	Dark green bottles	RT	Diffuse light	12	0.31	**24.4**	**2.862**	0.124	
EVOO, Nocellara del Belice	Dark green bottles	RT	Diffuse light	12	0.35	16	2.214	0.149	
EVOO, Nocellara Etnea	Dark green bottles	RT	Diffuse light	12	0.55	**21.7**	2.494	0.166	
EVOO, Koroneiki variety	clear PET	RT	intermittently 12 h to daylight	12	**0.85 ± 0.01**	**21.98 ± 0.31**	**3.18 ± 0.09**	**0.37 ± 0.02**	Pristouri et al.

Table 6 Comparison of documented storage conditions (continued)

Type	Packaging	Temperature	Light	Storage period [1]	FFA[2]	PV[3]	K232[4]	K270[4]	Source
EVOO, Koroneiki variety	PET + UV blocker	RT[5]	intermittently 12 h to daylight	12	0.80 ± 0.03	19.24 ± 0.30	**2.90 ± 0.06**[7]	**0.37 ± 0.02**	Pristouri et al.
	PET + Aluminium foil	RT	intermittently 12 h to daylight	12	0.75 ± 0.02	18.81 ± 0.59	**2.88 ± 0.01**	**0.24 ± 0.01**	
	clear PET	22 °C	Darkness	12	0.79 ± 0.01	**20.61 ± 0.20**	**2.98 ± 0.13**	**0.32 ± 0.02**	
	clear PP	22 °C	Darkness	12	**0.83 ± 0.01**	**22.54 ± 0.10**	**3.22 ± 0.09**	**0.35 ± 0.01**	
	clear glass	22 °C	Darkness	12	0.75 ± 0.01	18.86 ± 0.10	**2.82 ± 0.13**	**0.28 ± 0.02**	
	PET	13 °C	Darkness	12	0.73 ± 0.01	16.81 ± 0.50	**3.00 ± 0.11**	**0.25 ± 0.02**	
	PET	22 °C	Darkness	12	0.77 ± 0.02	**20.60 ± 0.20**	**3.10 ± 0.02**	**0.25 ± 0.02**	
	PET	35 °C	Darkness	12	**0.83 ± 0.01**	**23.61 ± 0.40**	**3.27 ± 0.01**	**0.32 ± 0.03**	
VOO, Saurani variety	Amber glass bottles, 250 mL	RT, (18–24 °C)	N/A[6]	12	0.6 ± 0.00	10.1 ± 0.01	2.2 ± 0.00	0.14 ± 0.00	Shendi et al.

[1] In months
[2] g oleic acid/100 g
[3] mEq O_2 / kg
[4] An unitless number
[5] Room temperature
[6] Not available
[7] **Bold** highlights the numbers that exceed the EU standards

In the end, the temperature and the light are the most important factors that influence the quality parameters and their degradation. Subsequently, on the second place is the packaging material. However, all these factors are related and thus all must be considered.

4.2.3. Recommendations for household virgin olive oil storage

For household conditions, storage of EVOO up to 9 months can be recommended. However, this recommendation is only indicative and depends on the conditions in which the olive oil is stored. The degradation of virgin olive oil can be retarded by keeping it lower than the room temperature. The quality of olive oil can be extended by not exposing it to light and high temperatures. Most home-based EVOOs are found in glass bottles, but glass material transmits light and thus it does not prevent oxidation. PET is the least suitable material for packaging of olive oils. Although Tetra-Brik® seems to be an optimal packaging material for virgin olive oil, packaging material does not have as strong effect on degradation as temperature and light, it is rather a large amount of headspace in the bottle that reduces the life of the olive oil. To maintain quality of virgin olive oil as long as possible, it is necessary to limit the headspace in the container and consider how much olive oil household consumes in nine months and accordingly buy a certain amount.

5. Conclusions

The content of this work concerns storage of virgin olive oils and their chemical compounds which are free fatty acidity, peroxide value and UV absorbance values (K_{232} and K_{270}). The types of storage conditions and the aforementioned values were compared and evaluated. Furthermore, the fundamental facts about virgin olive oils were summarized. Additionally, the optimal storage conditions of virgin olive oil in households were identified.

The initial composition of virgin olive oil influences the storage period. High temperatures and light affecting olive oil can cause an increase in undesirable substances (such as hydroperoxides), decrease desirable substances (such as α-tocopherol) and can hence degrade the quality of virgin olive oil. As it was shown the quality of the olive oil maintain when it is stored within 9 months. Nevertheless, this time can be extended by not exposing olive oil to light and high temperatures. Therefore, storing olive oil in transparent containers cannot be recommended for the reason that daylight causes the development of oxidation and thus olive oil loses its quality. Literature shows, that packaging material does not show as strong effect on the quality parameters as temperature and light; however, PET is the least suitable material for preservation of virgin olive oils and Tetra-Brik® seems to be an optimal packaging material for virgin olive oil.

To conclude, I would like to mention that I am interested in continuing to study this topic in my master thesis and as well as concluding my own research. I would like to focus on the impact of headspace and packaging material on qualitative parameters, also I would like to specify antioxidants and their stability and particularly to establish recommendation for the storage of virgin olive oils in the Czech Republic.

6. References

Aiello A, Guccione GD, Accardi G, Caruso C. 2015. What olive oil for healthy ageing? Maturitas.

Aparicio R, Morales MT, Alonso M V. 1996. Relationship between volatile compounds and sensory attributes of olive oils by the sensory wheel. JAOCS, Journal of the American Oil Chemists' Society **73**:1253–1264.

Ayyad Z, Valli E, Bendini A, Adrover-Obrador S, Femenia A, Gallina Toschi T. 2015. Extra virgin olive oil stored in different conditions: Focus on diglycerides. Italian Journal of Food Science **27**:166–172.

Blbost. 2015. How Olive Oil Is Made:1–4. Available from http://www.youtube.com/watch?v=aieNV3V4b_s.

Boltovskoy D. 2018. Zooplankton of the South Atlantic Ocean. Available from http://species-identification.org.

Camposeo S, Vivaldi GA, Gattullo CE. 2013. Ripening indices and harvesting times of different olive cultivars for continuous harvest. Scientia Horticulturae **151**:1–10.

Cayuela JA, García JF. 2017. Sorting olive oil based on alpha-tocopherol and total tocopherol content using near-infra-red spectroscopy (NIRS) analysis. Journal of Food Engineering **202**:79–88.

Ciafardini G, Zullo BA. 2018. Virgin olive oil yeasts : A review. Food Microbiology **70**:245–253. Elsevier Ltd. Available from https://doi.org/10.1016/j.fm.2017.10.010.

Codex Alimentarius Council. 2017. Standard for olive oils and olive pomace CODEX STAN 33-1981. Available from http://www.fao.org/fao-who-codexalimentarius/committees/committee-detail/es/?committee=CCFO.

Conte L et al. 2019. Olive oil quality and authenticity: A review of current EU legislation, standards, relevant methods of analyses, their drawbacks and recommendations for the future.

Di Serio MG, Giansante L, Di Loreto G, Di Giacinto L. 2018. Shelf life of extra-virgin olive oils: First efforts toward a prediction model. Journal of Food Processing and Preservation **42**:1–10.

El-Gharbi S, Tekaya M, Bendini A, Valli E, Palagano R, Gallina Toschi T, Hammami M, Mechri B. 2018. Effects of archaic olive and oil storage methods still used in

southern Tunisia on olive oil quality. Italian Journal of Food Science **30**:102–115.
Escudero A, Ramos N, La Rubia MD, Pacheco R. 2016. Influence of Extreme Storage Conditions on Extra Virgin Olive Oil Parameters: Traceability Study. Journal of Analytical Methods in Chemistry **2016**:10.
European Commission. 2012. COMMISSION IMPLEMENTING REGULATION (EU) No 29/2012 of 13 January 2012 on marketing standards for olive oil. Pages 9–14 Official Journal of the European Union. Available from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0481.
FAO. 2019. FAOSTAT. Available from http://www.fao.org/home/en/.
Foscolou A, Critselis E, Panagiotakos D. 2018. Olive oil consumption and human health: A narrative review. Maturitas **118**:60–66. Elsevier. Available from https://doi.org/10.1016/j.maturitas.2018.10.013.
Genovese A, Yang N, Linforth R, Sacchi R, Fisk I. 2018. The role of phenolic compounds on olive oil aroma release. Food Research International **112**:319–327.
Ghanbari Shendi E, Sivri Ozay D, Ozkaya MT, Ustunel NF. 2018. Changes occurring in chemical composition and oxidative stability of virgin olive oil during storage. Ocl **25**:A602.
Growers O tree. 2019. Frequently Asked Questions. Available from https://olivetreegrowers.com/faq.php.
Guo Z, Jia X, Zheng Z, Lu X, Zheng Y, Zheng B, Xiao J. 2018. Chemical composition and nutritional function of olive (Olea europaea L.): a review. Phytochemistry Reviews **17**:1091–1110.
Jemai H, Feki AEL, Sayadi S. 2009. Antidiabetic and antioxidant effects of hydroxytyrosol and oleuropein from olive leaves in alloxan-diabetic rats. Journal of Agricultural and Food Chemistry **57**:8798–8804.
Kapellakis IE, Tsagarakis KP, Crowther JC. 2008. Olive oil history, production and by-product management.
Kiritsakis AK. 1998. Flavor components of olive oil - A review.
Kuban-Jankowska A, Cappello F, Knap N, Gorzynik-Debicka M, Wozniak M, Przychodzen P, Marino Gammazza A, Gorska-Ponikowska M. 2018. Potential Health Benefits of Olive Oil and Plant Polyphenols. International Journal of Molecular Sciences **19**:686.
Lanza B, Di Serio MG, Giansante L, Di Loreto G, Di Giacinto L. 2015. Effect of shelf

conditions on the phenolic fraction and oxidation indices of monovarietal extra virgin olive oil from cv. 'Taggiasca'. Acta Alimentaria **44**:585–592. Available from http://www.akademiai.com/doi/abs/10.1556/066.2015.44.0031.

Li X, Wang SC. 2018. Shelf Life of Extra Virgin Olive Oil and Its Prediction Models. Journal of Food Quality **2018**:1–15.

Liberatore L, Casolani N, Murmura F. 2018. What's behind organic certification of extra-virgin olive oil? A response from Italian consumers. Journal of Food Products Marketing **24**:946–959. Routledge. Available from https://doi.org/10.1080/10454446.2018.1426513.

Limbo S, Peri C, Piergiovanni L. 2014. Extra-virgin olive oil packaging. Pages 179–199 The Extra-Virgin Olive Oil Handbook.

Mchugh T. 2015. How oil is made. Institute of Foog Technologists:1–4. Available from http://phys.org/news/2015-05-olive-oil.html.

Morales MT, Luna G, Aparicio R. 2005. Comparative study of virgin olive oil sensory defects. Food Chemistry **91**:293–301.

Mowatt M. 2015. Samples of extra virgin olive oil, diluted with increasing amounts of regular olive oil. Counterfeit Detection in Olive Oil. Available from https://oceanoptics.com/counterfeit-detection-in-olive-oil/.

Nelson D. 2018. How To Calculate A Percentage. Available from https://sciencing.com/.

Plants & Flowers. 2017. Olea europaea. Available from http://www.plantsrescue.com/olea-europaea/.

Ployon S, Morzel M, Canon F. 2017. The role of saliva in aroma release and perception. Food Chemistry **226**:212–220. Elsevier Ltd. Available from http://dx.doi.org/10.1016/j.foodchem.2017.01.055.

Pristouri G, Badeka A, Kontominas MG. 2010. Effect of packaging material headspace, oxygen and light transmission, temperature and storage time on quality characteristics of extra virgin olive oil. Food Control **21**:412–418. Elsevier Ltd. Available from http://dx.doi.org/10.1016/j.foodcont.2009.06.019.

Reiners J, Grosch W. 1998. Odorants of Virgin Olive Oils with Different Flavor Profiles. Journal of Agricultural and Food Chemistry **46**:2754–2763.

Saglam C, Tuna YT, Gecgel U, Atar ES. 2014. Effects of Olive Harvesting Methods on Oil Quality. APCBEE Procedia **8**:334–342. Elsevier B.V. Available from http://dx.doi.org/10.1016/j.apcbee.2014.03.050.

Salas-Salvado J et al. 2014. Original Research Prevention of Diabetes With Mediterranean Diets. Annals of internal medicine **160**:1–11.

Samaniego-Sánchez C, Oliveras-López MJ, Quesada-Granados JJ, Villalón-Mir M, Serrana HLG. 2012. Alterations in picual extra virgin olive oils under different storage conditions. European Journal of Lipid Science and Technology **114**:194–204.

Sanmartin C, Venturi F, Sgherri C, Nari A, Macaluso M, Flamini G, Quartacci MF, Taglieri I, Andrich G, Zinnai A. 2018. The effects of packaging and storage temperature on the shelf-life of extra virgin olive oil. Heliyon **4**:e00888. Elsevier Ltd. Available from https://doi.org/10.1016/j.heliyon.2018.e00888.

Serrano L, Cruz A, Sousa S, Morais Z. 2016. Alterations in monovarietal, blended and aromatized Portuguese virgin olive oils under four storage conditions for 12 months. European Food Research and Technology **242**:1041–1055. Springer Berlin Heidelberg.

Silva SF, Anjos CAR, Cavalcanti RN, Celeghini RMDS. 2015. Evaluation of extra virgin olive oil stability by artificial neural network. Food Chemistry **179**:35–43.

Tena N, Aparicio R, García-González DL. 2017. Virgin olive oil stability study by mesh cell-FTIR spectroscopy. Talanta **167**:453–461. Elsevier B.V. Available from http://dx.doi.org/10.1016/j.talanta.2017.02.042.

Tsimidou M, Blekas G, Boskou D. 2003. Olive oil. Page Olive oil.

Uylaşer V, Yildiz G. 2014. The Historical Development and Nutritional Importance of Olive and Olive Oil Constituted an Important Part of the Mediterranean Diet. Critical Reviews in Food Science and Nutrition **54**:1092–1101.

Vajdić M. 2016. OLIVES. Available from https://openphoto.net/gallery/image/view/30080.

Visioli F, Franco M, Toledo E, Luchsinger J, Willett WC, Hu FB, Martinez-Gonzalez MA. 2018. Olive oil and prevention of chronic diseases: Summary of an International conference. Nutrition, Metabolism and Cardiovascular Diseases **28**:649–656.

Vossen P. 2005. Olive Oil Production. Olive production manual. Sibbet, SG and Ferguson, L.(Eds.). University of California. Agriculture and Natural Resources. USA. Publication 3353:157–173. Available from https://www.amazon.com/Production-Publication-University-California-Agriculture/dp/1879906155.

Vossen P. 2007. Olive oil: History, production, and characteristics of the world's classic oils. Pages 1093–1100 HortScience.

Yada S, Harris LJ, York G, Vaughn R. 2007. Olives: safe methods for home pickling:1–26.

Zipori I, Dag A, Tugendhaft Y, Birger R. 2014. Mechanical harvesting of table olives: Harvest efficiency and fruit quality. HortScience **49**:55–58.