DOI: 10.29050/harranziraat. 1514855
Harran Tarım ve Gıda Bilimleri Derg. 2024, 28(4):700-710

Research Article/Araştırma Makalesi

The Effects of Laurus nobilis L. and Lavandula stoechas L. Essential Oils on Oxidative Stabilities of Sunflower and Olive Oils during Accelerated Storage

Laurus nobilis L. ve Lavandula stoechas L. Esansiyel Yağlarının Hızlandırılmış Depolama Sırasında Ayçiçeği ve Zeytinyağlarının Oksidatif Stabiliteleri Üzerine Etkileri

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To cite this article:
Yüzereroğlu, Ö. & Yorulmaz, A. (2024). The Effects of Laurus nobilis L. and Lavandula stoechas L. Essential Oils on Oxidative Stabilities of Sunflower and Olive Oils during Accelerated Storage. Harran Tarım ve Gıda Bilimleri Dergisi, 28(4): 700-710

DOI: 10.29050/harranziraat.1514855

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Received Date:
11.07.2024
Accepted Date:
06.12.2024

ABSTRACT

The study aimed to investigate the effects of *Laurus nobilis* L (Laurel) and *Lavandula stoechas* L. (French lavender) essential oils on the oxidative stabilities of sunflower oil and olive oils. For this purpose, 500 and 1000 ppm of laurel and French lavender essential oils were incorporated into sunflower and olive oil samples. The oil samples were stored at 60°C for 12 days and analyzed every four days. During the storage period, free acidity and peroxide values, K232 and K270 values, and fatty acid profiles of the samples were monitored. The results showed that free fatty acids, peroxide and K232 values increased during storage. It was determined that the essential oils used in the study did not have an effect on free fatty acid formation for either type of oil. However, the enrichment with essential oils had slight positive effects on the stability of sunflower oil. Additionally, laurel and French lavender essential oils were determined to suppress the peroxide formation on the 4th and 8th days of storage of olive oil. A similar pattern was also observed for K232 values. K270 values of the oil samples enriched with essential oils generally showed a decreasing trend and this decreasing tendency was found to be clearer for olive oil. The major fatty acid in sunflower oil was linoleic acid, which ranged from 61.99 and 62.65%. Oleic acid, the main fatty acid of olive oil samples, covered 67.31-69.37% of the fatty acids. Statistically significant changes were observed in the fatty acid composition of oils during accelerated storage.

Key Words: *Laurus nobilis* L., *Lavandula stoechas* L., French Lavender Essential Oil, Laurel Essential Oil, Olive Oil

ÖZ

Bu çalışmanın amacı *Laurus nobilis* L. (Defne) ve *Lavandula stoechas* L. (Karabaş otu) esansiyel yağlarının ayçiçek yağı ve zeytinyağının oksidatif stabiliteleri üzerindeki etkilerini araştırmaktır. Bu amaçla ayçiçeği ve zeytinyağı örneklerine 500 ve 1000 ppm defne ve Karabaş otu esansiyel yağları eklenmiştir. Yağ örnekleri 60°C'de 12 gün saklanmış ve her dört günde bir analiz edilmiştir. Depolama süresince örneklerin serbest asitlik ve peroksit değerleri, K232 ve K270 değerleri ile yağ asidi profilleri izlenmiştir. Sonuçlar depolama süresince serbest yağ asitleri miktarının, peroksit ve K232 değerlerinin arttığını göstermiştir. Esansiyel yağ ilavesinin, her iki yağ türü için de serbest yağ asitliği oluşumunu baskılamadığı bulgulanmıştır. Ancak esansiyel yağlarla zenginleştirmenin ayçiçek yağının stabilitesi üzerinde hafif olumlu etkileri olmuştur.

Ayrıca Defne ve Karabaş otu esansiyel yağlarının zeytinyağında depolamanın 4. ve 8. günlerinde peroksit oluşumunu baskıladığı belirlenmiştir. Benzer durum K232 değerlerinde de gözlenmiştir. Esansiyel yağlarla zenginleştirilen yağ örneklerinin K270 değerleri genel olarak azalma eğilimi göstermiş ve bu azalma eğiliminin zeytinyağında daha belirgin olduğu görülmüştür. Ayçiçeği yağında temel yağ asidi %61,99-62,65 arasında değişen linoleik asit olarak belirlenmiştir. Zeytinyağı örneklerinin temel yağ asidi olan oleik asit, yağ asitlerinin %67,31-69,37'sini kapsamaktadır. Hızlandırılmış depolama sırasında yağların yağ asidi bileşiminde istatistiki olarak önemli değişiklikler gözlenmiştir.

Anahtar Kelimeler: Laurus nobilis L., Lavandula stoechas L., Karabaş Otu Esansiyel Yağı, Defne Esansiyel Yağı, Zeytinyağı

Introduction

Lipid oxidation is a critical reaction affecting the quality and shelf-life of oils during processing and storage (Maszewska et al., 2018). It both causes undesirable changes in smell, appearance as well as texture of oil containing foods and it causes the loss of fat-soluble vitamins and bioactive components. Lipid oxidation may even play a role in forming compounds potentially toxic to humans (Yang et al., 2016; Shahidi and Zhong, 2010). Heat, light, heavy metal ions and oxygen play a role in the occurrence of oxidation. The primary products of lipid oxidation are hydroperoxides, whereas the secondary products are aldehydes, ketones, alcohols, hydrocarbons, furans and acids. Among these volatile compound groups, especially aldehydes cause the formation of undesirable taste and aroma. Several attempts were carried out to completely prevent or retard lipid oxidation reactions. Among these methods, a huge number of them focused on minimizing oxygen levels and light exposure, preventing metal contamination and using different natural and synthetic antioxidants (Çalık, 2017; Ulaş, 2015).

Synthetic antioxidants are generally used to prevent oxidation. The most preferred synthetic antioxidants are butylated hydroxyanisole (BHA), butylated hydroxy toluene (BHT) and tertiary butyl hydroquinone (TBHQ) (Shahidi, 2000; Frankel, 2007). Concerns about the possible adverse effects of synthetic antioxidants on human health have pushed manufacturers to use alternative natural antioxidant sources. Some studies have reported that natural antioxidants are more effective than synthetic antioxidants (Carvalho et al., 2005). Lately, different extracts originating from various parts of plants, especially herbs and spices (rosemary extracts, tea, sage, lavender, thyme, carob, barley seeds, etc.) have become popular in preventing lipid oxidation reactions (Marmesat et al., 2010).

Essential oils are aromatic, volatile substances extracted from plant materials including leaves, buds, fruits, flowers, herbs, branches, bark, roots and seeds with different methods. Essential oils consist of approximately 20-60 aromatic compounds, which give the oil a characteristic odour and aroma (Arora et al., 2015). Essential oils are generally liquid at room temperature and have a lower density than water. They have limited solubility in water and are highly soluble in organic solvents (Chahal et al., 2017). Essential oil content may vary depending on the source from which the plant is obtained, and the fraction obtained from the plant. In addition, the yield of the essential oil varies depending on genetic characteristics, environmental conditions, maturation status and applied extraction conditions such as steam distillation, hydro distillation and Soxhlet extraction (Woolf, 1999). Lipid oxidation-preventive properties of essential oils were well-documented in a few studies in the literature (Causevic et al., 2023; Meng et al., 2021; Wang et al., 2019; Tohma and Turan, 2015; Asensio et al., 2011).

The laurel plant (*Laurus nobilis* L.) is one of the plants of which essential oil can be used as an antioxidant source. Laurel, a plant from the Lauralee family, is an evergreen shrub native to the Mediterranean region. The antioxidant property of the laurel plant was attributed to its eugenol and methyl eugenol content. The essential oil obtained from the bay plant is used as a flavoring in the food industry. The dominant components of laurel essential oil were determined as 1,8-cineol, α-terpinene and sabinene (Turhan and Tural, 2017).

French Lavender (*Lavandula stoechas* L.) is an

evergreen shrub that can grow up to one meter high, often with violet flowers. The essential oil extracted from Lavandula stoechas represents 0.1-3% of the dry weight and contains monoterpenoids and sesquiterpenoids (Hassiotis, 2010). Essential oil is extracted from the above-ground parts of the plant (stems, leaves and flowers) by steam distillation (Carrasco et al., 2015; Angioni et al., 2006; Dob et al., 2006). Monoterpenes, fencon (33-37%) and camphor (16-24%) were reported to be the main components of Lavandula stoechas L. essential oil (Carrasco et al., 2015; Kırmızıbekmez et al., 2009; Angioni et al., 2006).

Different food processing stages may reduce the resistance of edible oils against oxidation, and this situation brings the necessity of taking precautions to protect the stability of the oils. Within the scope of the current study, Laurus nobilis L. and Lavandula stoechas L. essential oils were incorporated into sunflower and olive oils at two concentrations (500 and 1000 ppm) and stored at 60°C. The concentrations of the essential oils were decided based on a similar former work (Ataei and Solemanpour, 2019). The changes in quality parameters and fatty acid profiles were monitored throughout the accelerated storage, to observe the potential of these essential oils as natural antioxidants.

Materials and Methods

Material

The sunflower and olive oils used in the study were purchased from local markets; *Laurus nobilis* L. and *Lavandula stoechas* L. essential oils were obtained from Tabia Pure Nature Company, Turkey. Essential oils were produced using the supercritical carbon dioxide extraction technique.

Among the standards and solvents used during the analyses; isooctane, diethyl ether, ethyl alcohol, hydrochloric acid, methanol, sodium hydroxide, and methyl orange were obtained from Sigma-Aldrich (St-Louis, USA). Acetic acid, *n*-hexane, chloroform, potassium iodide, starch, sodium thiosulfate, potassium hydroxide, and phenolphthalein were purchased from Merck (Darmstadt, Germany).

Methods

Accelerated Stability Test

Laurus nobilis L. and *Lavandula stoechas* L. essential oils were incorporated to sunflower and olive oils at two different concentrations (500 and 1000 ppm). The control samples did not contain any essential oils. For this test, 50 mL of each oil sample was kept in dark glass bottles with a volume of 150 ml, in the presence of air and without the presence of light in a laboratory scale oven (Memmert, Germany). The sunflower and olive oil samples were stored at 60°C for 12 days. All samples were analyzed every four days in terms of their free fatty acidity, peroxide, K_{232}, and K_{270} values, and fatty acid profiles.

Determination of Quality Parameters

Free fatty acidity, peroxide value, and UV spectrophotometric absorbances at 232 and 270 nm were determined according to AOCS Ca 5a-40, AOCS Cd 8-53 and AOCS Ch 5-91 Official Methods (AOCS, 2003) respectively.

Fatty Acid Composition

The fatty acid methyl esters were prepared according to the method offered by the International Union of Pure and Applied Chemistry (IUPAC, 1987). The methyl esters were analyzed using a gas chromatograph (GC 2010, Shimadzu, Kyoto, Japan) equipped with a flame ionization detector. DB-23 fused silica capillary column (60 m, 0,25 mm internal diameter and 0,25 µm film thickness, J&W Scientific, ABD) was utilized to elute the peaks. Injector, detector and column temperatures were set at 230, 240 and 190 °C in the same order. Nitrogen was the carrier gas with a flow rate of 0.8 ml/min. Split ratio was 80:1.

Statistical Evaluation

The data obtained were statistically evaluated using the SPSS 15.0 packaged software (SPSS Inc., Chicago, USA). All productions were replicated

twice and all the measurements were replicated twice. The difference between group averages was determined using the analysis of variance technique (ANOVA). The significance level of the difference was determined by the Duncan multiple comparison test. A *p*-value of less than 0.05 was considered as significant.

Results and Discussions

The free fatty acid level, which is an indicator of hydrolysis of triglycerides, was examined during the storage of sunflower and olive oil samples at 60°C and the obtained results were given in Table 1 and Table 2. The free acidity of control sunflower oil sample was 0.12% at the beginning and it gradually increased during storage and reached 0.18% at the end of the 12th day (p<0.05). Similar increases were also reported by Tan et al. (2017) for palm oil stored at 60°C. The increase in acidity is attributed to the degradation of triglycerides because of the high temperature (Choe ve Min, 2007). The inclusion of different essential oils at different levels was not found to suppress the formation of free fatty acids during storage. The comparable increasing trend in the free acidity was also determined for olive oil samples. While the free fatty acid content of the olive oil sample was initially 0.26%, the amount of the free fatty acids increased slightly and reached 0.32% at the end of the storage period. The enrichment of olive oil samples with *L. nobilis* L. and *L. stoechas* L. essential oils at different levels had not a vigorous effect on delaying the hydrolysis reaction.

Peroxide value (PV) is an index of hydroperoxide concentration in the oil and is affected by the factors that promote oxidation such as oxygen, light and temperature. The changes in peroxide values of sunflower and olive oils during accelerated storage conditions was also given in Table 1 and Table 2. The peroxide values of all oils increased gradually and significantly throughout the storage period, as was also shown in a previous similar study (Mulagić et al., 2020). The peroxide value of the control sunflower oil sample was 2.01 mEq O_2/kg oil at the beginning and reached 137.33 mEq O_2/kg oil at the end of 12 days of storage (p<0.05). The addition of laurel essential oil had slight and significant positive effects on PV of the sunflower oils. Nevertheless, different concentrations of laurel essential oil did not have an effect proportional to its concentration. The addition of French lavender essential oil at 1000-ppm level had slight positive effects on PV of sunflower oils during the storage period.

The peroxide value of the control olive oil sample was 4.71 mEq O_2/kg oil at the beginning and was found to rise to 77.50 mEq O_2/kg oil at the end of the period (p<0.05). Laurel and French lavender essential oils were determined to suppress the peroxide formation on the 4^{th} and 8^{th} days of storage; however, the same positive effect was not observed on the 12^{th} day. Essential oils are susceptible to degradation under heat (Mahanta et al., 2021), and Laurel and French lavender essential oils may had lost their efficiency at the last day of accelerated stability test.

Specific absorption values (K_{232} and K_{270}) in ultraviolet light are indicators of the oxidative stability of oils, and these parameters increase as the oxidation level of the oil increases. The changes in K_{232} values of sunflower and olive oils during accelerated storage are given in Table 1 and 2. The K_{232} values of all oils increased significantly throughout the storage (p<0.05). While the K_{232} value of the control sample (sunflower oil) at the beginning was 2.50, it reached 18.61 at the end of the 12-day storage period. The start and end values were recorded as 3.05 and 8.06 for control sample of olive oil. The enrichment of sunflower oil by the essential oils had slight positive effects on preventing the increase in K_{232} values without regard to the concentration level (p<0.05). However, the similar effect was not observed in the case of olive oil. Laurel and French lavender essential oils were determined to influence K_{232} value positively on the 4th and 8th days of storage, like the peroxide value pattern. The same oxidation-preventive

effect was not observed on the 12th day. Aysel et al. (2013) previously reported preventive effects of mixture of origanum and rosemary on the oxidative stability of soybean oil.

The changes in K_{270} values of sunflower and olive oils during accelerated storage were given in Table 1 and 2. The results show that K_{270} values of all samples enriched with essential oils generally showed a decreasing trend during storage at 60°C. This decreasing tendency was more pronounced for olive oil. Similarly, Wang et al. (2018) stated that the addition of *Coriandrum sativum* L. essential oil to sunflower oil suppressed the increase in K_{232} and K_{270} values, and this was due to the inhibition of the formation of conjugated dienes and trienes. K_{270} values of the samples did not exceed the specific absorption E (270 nm) value (≤ 1.15) determined for olive oil in ultraviolet light according to the TGK Olive Oil and Pomace Oil Communiqué. Taoudiat et al. (2018) reported in their study that the addition of *Laurus nobilis* L. essential oil to olive oil did not significantly affect the K_{232} value but suppressed the increase in the K_{270} value.

The change in the fatty acid composition of sunflower oil samples enriched with essential oils during storage at 60°C is given in Table 3. The main fatty acid was linoleic acid, covering 62.19% of all fatty acids in the control sample. The lowest linoleic acid level (61.99%) was detected on the 8th day in the samples enriched with 500 ppm L. nobilis L. The highest level (62.65%) was detected on the 8th day in the samples enriched with 1000 ppm *L. stoechas* L.

The second abundant fatty acid was oleic acid, which ranged from 27.46-28.94%, and it was found to be 28.90% in the control sample at the 0th day. The highest (28.94%) and the lowest (27.46%) values were detected on the 8th day in the sample enriched with 1000 ppm *L. stoechas* L., and on the 0th day in the sample enriched with 500 ppm *L. stoechas* L. Statistically significant changes in oleic acid levels were observed during the storage period (p<0.05). Similar former works have reported significant changes in fatty acid profile of sunflower oils enriched with different concentrations of *Coriandrum sativum* L. (Wang et al., 2018).

Table 1. The quality parameters of sunflower oils enriched with essential oils during accelerated storage

Quality Parameters	Treatment	Storage time (Day)			
		0	4	8	12
FFA (%)	Control	$0.12\pm0.0^{A,a}$	$0.17\pm0.0^{B,b}$	$0.17\pm0.0^{B,c}$	$0.18\pm0.0^{AB,d}$
	L. nobilis L. (500 ppm)	$0.12\pm0.0^{A,a}$	$0.16\pm0.0^{A,b}$	$0.17\pm0.0^{A,c}$	$0.18\pm0.0^{A,d}$
	L. nobilis L. (1000 ppm)	$0.12\pm0.0^{A,a}$	$0.16\pm0.0^{A,b}$	$0.17\pm0.0^{A,c}$	$0.18\pm0.0^{A,d}$
	L. stoechas L. (500 ppm)	$0.13\pm0.0^{A,a}$	$0.17\pm0.0^{B,b}$	$0.17\pm0.0^{B,c}$	$0.18\pm0.0^{B,d}$
	L. stoechas L. (1000 ppm)	$0.12\pm0.0^{A,a}$	$0.17\pm0.0^{B,b}$	$0.17\pm0.0^{B,c}$	$0.18\pm0.0^{B,d}$
PV (mEq O_2/kg oil)	Control	$2.01\pm0.1^{A,a}$	$41.94\pm0.7^{D,b}$	$83.68\pm0.7^{D,c}$	$137.33\pm1.8^{D,d}$
	L. nobilis L. (500 ppm)	$1.87\pm0.1^{A,a}$	$39.03\pm0.2^{B,b}$	$78.51\pm0.7^{B,c}$	$128.23\pm0.8^{A,d}$
	L. nobilis L. (1000 ppm)	$1.88\pm0.1^{A,a}$	$40.37\pm1.0^{C,b}$	$81.07\pm1.0^{C,c}$	$131.14\pm0.8^{B,d}$
	L. stoechas L. (500 ppm)	$1.89\pm0.1^{A,a}$	$37.62\pm0.6^{A,b}$	$84.44\pm0.8^{D,c}$	$134.82\pm0.8^{C,d}$
	L. stoechas L. (1000 ppm)	$1.89\pm0.1^{A,a}$	$37.83\pm0.4^{A,b}$	$72.81\pm1.4^{A,c}$	$131.61\pm0.7^{B,d}$
K_{232}	Control	$2.50\pm0.0^{A,a}$	$7.26\pm0.0^{E,b}$	$12.59\pm0.1^{C,c}$	$18.61\pm0.0^{E,d}$
	L. nobilis L. (500 ppm)	$2.67\pm0.1^{B,a}$	$7.09\pm0.1^{D,b}$	$10.83\pm0.0^{A,c}$	$17.70\pm0.0^{A,d}$
	L. nobilis L. (1000 ppm)	$2.70\pm0.0^{B,a}$	$6.84\pm0.1^{C,b}$	$11.30\pm0.0^{B,c}$	$17.89\pm0.0^{B,d}$
	L. stoechas L. (500 ppm)	$2.76\pm0.0^{C,a}$	$6.50\pm0.1^{A,b}$	$12.69\pm0.1^{D,c}$	$18.24\pm0.1^{D,d}$
	L. stoechas L. (1000 ppm)	$2.80\pm0.0^{C,a}$	$6.71\pm0.0^{B,b}$	$10.83\pm0.0^{A,c}$	$18.06\pm0.1^{C,d}$
K_{270}	Control	$3.20\pm0.0^{AB,b}$	$3.25\pm0.0^{B,b}$	$2.70\pm0.1^{A,a}$	$3.19\pm0.0^{B,b}$
	L. nobilis L. (500 ppm)	$3.20\pm0.0^{AB,ab}$	$3.29\pm0.0^{C,c}$	$3.23\pm0.0^{C,b}$	$3.18\pm0.0^{AB,a}$
	L. nobilis L. (1000 ppm)	$3.18\pm0.0^{A,a}$	$3.19\pm0.0^{A,a}$	$3.18\pm0.0^{C,a}$	$3.18\pm0.0^{AB,a}$
	L. stoechas L. (500 ppm)	$3.21\pm0.0^{BC,b}$	$3.29\pm0.0^{C,c}$	$3.36\pm0.0^{D,d}$	$3.15\pm0.0^{A,a}$
	L. stoechas L. (1000 ppm)	$3.24\pm0.0^{C,c}$	$3.36\pm0.0^{D,d}$	$2.89\pm0.1^{B,a}$	$3.15\pm0.0^{A,b}$

Uppercase letters show significant differences in each treatment and lowercase letters show significant differences in storage time, at p < 0.05

Table 2. The quality parameters of olive oils oils enriched with essential oils during accelerated storage

Quality Parameter	Treatment	Storage time (Day)			
		0	4	8	12
FFA (%)	Control	0.26±0.0^{A,a}	0.29±0.0^{A,b}	0.31±0.0^{AB,c}	0.32±0.0^{AB,d}
	L. nobilis L. (500 ppm)	0.26±0.0^{A,a}	0.29±0.0^{A,b}	0.30±0.0^{A,c}	0.33±0.0^{B,d}
	L. nobilis L. (1000 ppm)	0.29±0.0^{B,a}	0.31±0.0^{C,b}	0.31±0.0^{B,b}	0.33±0.0^{B,c}
	L. stoechas L. (500 ppm)	0.26±0.0^{A,a}	0.30±0.0^{B,b}	0.31±0.0^{AB,b}	0.32±0.0^{AB,c}
	L. stoechas L. (1000 ppm)	0.29±0.0^{B,a}	0.30±0.0^{BC,b}	0.31±0.0^{B,c}	0.32±0.0^{A,c}
PV (mEq O_2/kg oil)	Control	4.71±0.1^{C,a}	13.16±0.5^{B,b}	61.00±2.3^{A,c}	77.50±0.9^{A,d}
	L. nobilis L. (500 ppm)	4.23±0.1^{B,a}	12.47±0.2^{A,b}	52.37±5.9^{C,c}	79.72±1.6^{A,d}
	L. nobilis L. (1000 ppm)	4.18±0.1^{B,a}	12.18±0.2^{A,b}	43.28±1.2^{A,c}	81.46±5.7A^{,d}
	L. stoechas L. (500 ppm)	3.93±0.1^{A,a}	12.22±0.5^{A,b}	48.65±1.6^{B,c}	96.69±1.5^{C,d}
	L. stoechas L. (1000 ppm)	4.18±0.1^{B,a}	12.36±0.4^{A,b}	41.77±0.5^{A,c}	91.79±4.3^{B,d}
K_{232}	Control	3.05±0.1^{B,a}	3.95±0.1^{C,b}	7.06±0.1^{C,c}	8.06±0.1^{A,d}
	L. nobilis L. (500 ppm)	3.16±0.0^{C,a}	3.92±0.1^{C,b}	7.00±0.1^{C,c}	8.09±0.1^{A,d}
	L. nobilis L. (1000 ppm)	3.11±0.0^{BC,a}	3.71±0.1^{A,b}	5.92±0.1^{B,c}	9.57±0.1^{B,d}
	L. stoechas L. (500 ppm)	2.95±0.1^{A,a}	3.75±0.1^{AB,b}	6.15±0.1^{B,c}	11.16±0.1^{D,d}
	L. stoechas L. (1000 ppm)	3.07±0.0^{B,a}	3.87±0.1^{BC,b}	5.49±0.1^{A,c}	10.02±0.2^{C,d}
K_{270}	Control	0.77±0.0^{B,a}	0.78±0.0^{C,a}	0.66±0.0^{B,b}	0.60±0.0^{A,a}
	L. nobilis L. (500 ppm)	0.70±0.0^{A,b}	0.74±0.0^{B,c}	0.60±0.0^{A,a}	0.59±0.0^{A,a}
	L. nobilis L. (1000 ppm)	0.80±0.0^{C,d}	0.63±0.0^{A,b}	0.75±0.0^{C,c}	0.56±0.0^{A,a}
	L. stoechas L. (500 ppm)	0.87±0.0^{D,c}	0.74±0.0^{B,b}	0.72±0.0^{C,b}	0.60±0.0^{A,a}
	L. stoechas L. (1000 ppm)	0.78±0.0^{B,c}	0.93±0.0^{E,d}	0.74±0.0^{C,b}	0.64±0.0^{B,a}

Uppercase letters show significant differences in each treatment and lowercase letters show significant differences in storage time, at $p < 0.05$

Palmitic acid was the major saturated fatty acid of sunflower oil samples. While it was found to be 5.29% in the control sample at the beginning of storage, it varied between 4.93-5.32% in the other samples. The lowest value was detected on the 12th day in the sample enriched with 1000 ppm *L. stoechas* L. The highest value was detected on 0th day in the sample enriched with 1000 ppm L. *nobilis* L. Palmitic acid ratios were rarely affected statistically by the addition of essential oils.

Stearic acid was another saturated fatty acid in sunflower oil samples. It was found to be 2.67% in the control sample at the beginning of storage, whereas it had values varying from 2.32-2.72% in samples stored for different periods of time. Additionally, palmitoleic, heptadecanoic, heptadecenoic and linolenic acids were detected in oil samples. Palmitoleic acid level varied in 0.29-0.54%; whereas heptadecanoic, heptadecenoic and linolenic acid levels varied in 0.01-0.03%; 0.01-0.02% and 0.60-2.06%, respectively.

The change in the fatty acid composition of olive oil samples enriched with laurel and French lavender essential oils during storage at 60°C is given in Table 4. The main fatty acid was oleic acid covering 67.31% of all fatty acids of the control sample at the beginning of storage. The lowest oleic acid ratio (67.31%) was detected in the control sample and the highest level (69.37%) was detected on the 8th day in the control samples. Oleic acid levels were observed to fluctuate during the storage period. No common attitude for the change in oleic acid levels was detected towards the accelerated storage and by the addition of different levels of essential oils.

The second abundant fatty acid of olive oil samples was linoleic acid, varying in 14.28-16.42%. The lowest value was determined after 8 days of storage in the control sample, and the highest value was determined in the sample enriched with 1000 ppm laurel essential oil.

The third dominant fatty acid in olive oil was palmitic acid. While the palmitic acid level was 11.63% in the sample that was not stored; it varied among 11.43-12.10% in the samples stored for different periods of time and with different

amounts of added essential oil. The lowest value was determined in olive oil samples to which 1000 ppm French lavender essential oil was added, before the storage process was carried out. The highest value was detected in the sample to which 1000 ppm laurel essential oil was added at the end of the 4th day. It was also determined that the essential oil level did not cause a statistically significant difference in all samples. In addition, the presence of palmitoleic, heptadecanoic, heptadecenoic, stearic and linolenic acids was detected in olive oil samples. Palmitoleic and stearic acid levels were very close to each other. While palmitoleic acid varied between 1.68% and 1.95%, stearic acid level was determined between 1.67% and 1.82%. The levels of heptadecanoic, heptadecenoic and linolenic acids varied from 0.03-0.04, 0.06-0.09% and 0.80-1.24%, respectively. In the study of Arcoleo et al. (2009), cold-pressed lemon essential oil was used to preserve the shelf life and sensory profile of extra virgin olive oil. The effects of lemon oil added between 0.4-0.8% were observed for 10 months. It was found that although olive oils with lemon oil had higher oxidative stabilities; the addition of lemon oil did not reveal a significant difference in fatty acid composition.

Table 3. The fatty acid composition of sunflower oils enriched with essential oils during accelerated storage (%)

Oil sample	Day	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2	C18:3
Control	0	5.29±0.0^{A,c}	0.29±0.1^{A,a}	0.01±0.0^{A,a}	0.01±0.0^{A,b}	2.67±0.1^{AB,a}	28.90±0.1^{B,a}	62.19±0.1^{A,a}	0.63±0.2^{A,a}
	4	5.11±0.0^{A,bc}	0.42±0.1^{A,b}	0.01±0.0^{A,a}	0.01±0.0^{A,ab}	2.61±0.0^{A,a}	28.72±0.1^{A,a}	62.13±0.1^{A,a}	1.00±0.1^{A,b}
	8	5.22±0.2^{A,ab}	0.38±0.1^{A,ab}	0.01±0.0^{A,a}	0.01±0.0^{A,ab}	2.65±0.2^{A,a}	28.66±0.4^{A,a}	62.07±0.3^{A,a}	0.99±0.3^{A,b}
	12	5.01±0.0^{A,a}	0.48±0.0^{A,b}	0.01±0.0^{A,a}	0.01±0.0^{A,a}	2.39±0.0^{A,b}	27.96±0.2^{B,b}	62.29±0.2^{A,a}	1.84±0.1^{A,c}
L. nobilis L. (500 ppm)	0	5.14±0.1^{B,b}	0.42±0.0^{B,a}	0.02±0.0^{AB,a}	0.01±0.0^{A,a}	2.58±0.1^{A,a}	28.55±0.1^{A,a}	62.29±0.3^{A,a}	0.99±0.1^{B,a}
	4	5.15±0.1^{A,b}	0.38±0.1^{A,a}	0.02±0.0^{AB,a}	0.01±0.0^{A,a}	2.65±0.1^{A,a}	28.54±0.3^{A,a}	62.18±0.1^{A,a}	1.07±0.4^{A,a}
	8	5.17±0.1^{A,b}	0.44±0.1^{AB,a}	0.02±0.0^{A,a}	0.01±0.0^{A,ab}	2.63±0.1^{A,a}	28.57±0.4^{A,a}	61.99±0.4^{A,a}	1.17±0.2^{A,a}
	12	4.94±0.1^{A,a}	0.49±0.1^{A,a}	0.01±0.0^{A,a}	0.01±0.0^{AB,b}	2.34±0.0^{A,b}	28.08±0.1^{b,A}	62.17±0.1^{A,a}	1.95±0.1^{A,b}
L. nobilis L. (1000 ppm)	0	5.32±0.1^{A,b}	0.29±0.0^{A,a}	0.03±0.0^{C,a}	0.02±0.0^{A,a}	2.72±0.0^{B,a}	28.81±0.2^{AB,a}	62.04±0.2^{A,a}	0.78±0.2^{AB,a}
	4	5.08±0.1^{A,a}	0.41±0.1^{A,ab}	0.02±0.0^{AB,b}	0.01±0.0^{A,a}	2.58±0.1^{A,b}	28.44±0.1^{A,ab}	62.28±0.1^{A,a}	1.18±0.1^{A,b}
	8	5.07±0.1^{A,a}	0.44±0.1^{AB,b}	0.02±0.0^{A,b}	0.01±0.0^{A,a}	2.53±0.1^{A,b}	28.54±0.3^{A,a}	62.22±0.2^{AB,a}	1.17±0.3^{A,b}
	12	4.99±0.1^{A,a}	0.46±0.1^{A,b}	0.01±0.0^{A,b}	0.01±0.0^{AB,a}	2.40±0.1^{A,c}	28.14±0.3^{AB,b}	62.31±0.2^{A,a}	1.67±0.2^{A,c}
L. stoechas L. (500 ppm)	0	5.28±0.0^{A,a}	0.33±0.0^{A,a}	0.02±0.0^{B,a}	0.01±0.0^{A,a}	2.62±0.1^{AB,ab}	28.94±0.2^{B,c}	62.19±0.1^{A,a}	0.60±0.2^{A,a}
	4	5.21±0.4^{A,a}	0.36±0.2^{A,a}	0.02±0.0^{AB,a}	0.01±0.0^{A,a}	2.69±0.3^{A,b}	28.65±0.4^{A,bc}	62.17±0.4^{A,a}	0.88±0.5^{A,ab}
	8	5.10±0.1^{A,a}	0.46±0.1^{AB,a}	0.02±0.0^{A,a}	0.01±0.0^{A,a}	2.55±0.1^{A,ab}	28.28±0.4^{A,ab}	62.29±0.4^{AB,a}	1.29±0.3^{A,b}
	12	5.01±0.1^{A,a}	0.48±0.1^{A,a}	0.01±0.0^{A,a}	0.01±0.0^{B,a}	2.41±0.1^{A,a}	27.88±0.3^{AB,a}	62.38±0.2^{A,a}	1.81±0.3^{A,c}
L. stoechas L. (1000 ppm)	0	5.27±0.1^{A,a}	0.32±0.1^{A,a}	0.02±0.0^{BC,c}	0.01±0.0^{A,a}	2.69±0.1^{AB,c}	28.87±0.1^{B,c}	62.07±0.1^{A,a}	0.75±0.2^{AB,a}
	4	5.09±0.0^{A,b}	0.49±0.0^{A,b}	0.02±0.0^{B,bc}	0.01±0.0^{A,a}	2.60±0.0^{A,bc}	28.41±0.1^{A,b}	62.12±0.1^{A,a}	1.27±0.1^{A,b}
	8	5.12±0.1^{A,b}	0.52±0.1^{A,b}	0.02±0.0^{A,ab}	0.01±0.0^{A,a}	2.51±0.1^{A,b}	27.46±0.4^{B,a}	62.65±0.3^{B,b}	1.71±0.2^{B,c}
	12	4.93±0.0^{A,a}	0.54±0.0^{A,b}	0.01±0.0^{A,a}	0.01±0.0^{AB,a}	2.32±0.0^{A,a}	27.73±0.2^{A,a}	62.40±0.3^{A,ab}	2.06±0.1^{A,d}

Uppercase letters show significant differences in each treatment and lowercase letters show significant differences in storage time, at $p < 0.05$

Table 4. The fatty acid composition of olive oils enriched with essential oils during accelerated storage (%)

	Day	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2	C18:3
Control	0	11.63±0.1^{A,a}	1.95±0.0^{B,a}	0.04±0.0^{A,ab}	0.07±0.0^{A,ab}	1.78±0.0^{A,a}	67.31±0.7^{A,a}	16.16±0.5^{AB,b}	1.07±0.3^{A,a}
	4	11.76±0.3^{A,a}	1.68±0.0^{A,b}	0.04±0.0^{A,ab}	0.08±0.0^{A,b}	1.83±0.0^{A,a}	69.04±0.3^{A,b}	14.67±0.2^{A,a}	0.89±0.1^{A,a}
	8	11.83±0.5^{A,a}	1.70±0.1^{A,b}	0.04±0.0^{B,b}	0.08±0.0^{A,ab}	1.83±0.1^{C,a}	69.37±0.7^{C,b}	14.28±0.6^{A,a}	0.87±0.1^{A,a}
	12	11.79±0.2^{A,a}	1.90±0.1^{A,a}	0.03±0.0^{A,a}	0.06±0.0^{A,a}	1.71±0.1^{A,b}	67.91±0.5^{A,a}	15.55±0.6^{A,b}	1.05±0.1^{A,a}
L. nobilis L. (500 ppm)	0	11.70±0.1^{A,a}	1.89±0.1^{AB,b}	0.04±0.0^{A,ab}	0.07±0.0^{A,ab}	1.78±0.0^{A,c}	67.67±0.4^{AB,a}	15.85±0.4^{AB,a}	1.00±0.0^{A,b}
	4	11.50±0.6^{A,a}	1.68±0.1^{A,a}	0.04±0.0^{A,b}	0.09±0.0^{A,b}	1.77±0.1^{A,bc}	68.95±0.8^{A,b}	15.07±0.6^{A,a}	0.90±0.1^{A,a}
	8	11.76±0.1^{A,a}	1.90±0.0^{C,b}	0.04±0.0^{B,ab}	0.08±0.0^{A,ab}	1.72±0.0^{AB,ab}	67.91±0.5^{AB,a}	15.56±0.5^{BC,a}	1.02±0.0^{BC,b}
	12	11.76±0.1^{A,a}	1.90±0.0^{A,b}	0.03±0.0^{A,a}	0.07±0.0^{A,a}	1.71±0.0^{A,a}	68.30±0.4^{AB,ab}	15.20±0.4^{A,a}	1.04±0.1^{A,b}
L. nobilis L. (1000 ppm)	0	11.66±0.3^{A,a}	1.86±0.1^{AB,a}	0.04±0.0^{A,a}	0.07±0.0^{A,a}	1.77±0.1^{A,ab}	67.47±0.9^{AB,a}	16.42±0.1^{B,c}	1.20±0.3^{A,b}
	4	12.10±0.3^{A,a}	1.71±0.1^{A,a}	0.04±0.0^{A,a}	0.08±0.0^{A,a}	1.82±0.1^{A,b}	68.86±0.3^{A,b}	14.53±0.3^{A,a}	0.86±0.0^{A,a}
	8	11.90±0.2^{A,a}	1.81±0.1^{BC,a}	0.04±0.0^{B,a}	0.07±0.0^{A,a}	1.73±0.0^{B,ab}	67.96±0.4^{B,ab}	15.47±0.5^{BC,b}	1.03±0.1^{BC,ab}
	12	11.96±0.3^{A,a}	1.86±0.1^{A,a}	0.03±0.0^{A,a}	0.07±0.0^{A,a}	1.71±0.1^{A,a}	68.56±0.8^{AB,b}	14.85±0.9^{A,ab}	0.96±0.1^{A,ab}
L. stoechas L. (500 ppm)	0	11.61±0.1^{A,a}	1.83±0.0^{AB,a}	0.03±0.0^{A,ab}	0.06±0.0^{A,a}	1.78±0.0^{A,b}	67.42±0.5^{AB,a}	16.03±0.4^{AB,b}	1.24±0.2^{A,b}
	4	11.94±0.8^{A,a}	1.68±0.1^{A,b}	0.04±0.0^{A,c}	0.08±0.0^{A,b}	1.82±0.1^{A,b}	68.99±0.5^{A,b}	14.57±0.8^{A,a}	0.88±0.1^{A,a}
	8	11.66±0.1^{A,a}	1.88±0.1^{BC,a}	0.04±0.0^{AB,bc}	0.08±0.0^{A,ab}	1.68±0.0^{A,a}	67.61±0.3^{A,a}	15.97±0.2^{C,b}	1.09±0.1^{C,ab}
	12	11.62±0.4^{A,a}	1.89±0.0^{A,a}	0.03±0.0^{A,a}	0.06±0.0^{A,a}	1.69±0.0^{A,a}	68.82±0.4^{B,b}	14.86±0.3^{A,a}	1.03±0.0^{A,ab}
L. stoechas L. (1000 ppm)	0	11.43±0.6^{A,a}	1.78±0.1^{A,a}	0.03±0.0^{A,a}	0.07±0.0^{A,a}	1.77±0.1^{A,bc}	68.37±0.5^{B,a}	15.57±0.9^{A,a}	0.80±0.5^{A,a}
	4	12.03±0.2^{A,b}	1.74±0.2^{A,a}	0.04±0.0^{A,a}	0.08±0.0^{A,b}	1.80±0.1^{A,c}	68.62±1.0^{A,a}	14.79±1.0^{A,a}	0.89±0.1^{A,a}
	8	11.93±0.1^{A,ab}	1.78±0.0^{AB,a}	0.03±0.0^{A,a}	0.08±0.0^{A,ab}	1.73±0.0^{AB,ab}	68.57±0.3^{AB,a}	14.99±0.4^{B,a}	0.90±0.1^{AB,a}
	12	11.88±0.1^{A,ab}	1.87±0.0^{A,a}	0.03±0.0^{A,a}	0.07±0.0^{A,a}	1.67±0.0^{A,a}	68.62±0.1^{AB,a}	14.82±0.1^{A,a}	1.05±0.0^{A,a}

Uppercase letters show significant differences in each treatment and lowercase letters show significant differences in storage time, at $p < 0.05$

Conclusions

Lipid oxidation is an important reaction since it has detrimental effects not only on food quality but also on human health. It is imperative to reduce lipid oxidation and enhance the oxidative stabilities of lipid products. The food industry has broadly used antioxidant strategies to preserve the food quality. Synthetic antioxidants are commonly used in the industry to prevent oxidation. However, concerns about their adverse effects on human health have pushed producers to search for alternative natural antioxidants. In this study, sunflower and olive oils were enriched with laurel and French lavender essential oils at 500 and 1000 ppm levels and stored at 60 °C for 12 days. The changes in quality parameters and fatty acid distribution of oils were monitored. The peroxide and K_{232} values were slightly and positively affected by the inclusion of essential oils. However, the same preventive effect was not observed for the hydrolysis reaction. It is recommended that future studies focus on possible other utilization ways of laurel and French lavender, independently of their concentration level. These essential oils can be experimented especially in long term lipid storage studies at room temperature.

Acknowledgement

This research was supported by Aydın Adnan Menderes University Research Fund. Project Number: MF-20015.

Conflict of interest:

The authors declare no conflict of interest.

Author contributions:

Aslı Yorulmaz designed the study and wrote the article. Özge Yüzereroğlu conducted the experimental studies. Both authors contributed to the evaluation of the results.

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