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Determination of Antioxidant Activity and Essential Oil Components of Lavandin (*Lavandula* x *intermedia* Emeric Ex Loisel.) Grown Under Different Ecological Conditions by Microwave Hydrodistillation

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ABSTRACT

The importance and usage areas of medicinal and aromatic plants are increasing day by day. Especially essential oils have recently been frequently used in our daily lives. Lavandin (*Lavandula* x *intermedia* Emeric ex Loisel.) is an economically valuable plant from which essential oil is obtained from flower parts and used in many fields, especially in perfumery industry. This study aimed to determine the antioxidant activity and essential oil components of Lavandin, grown under different ecological conditions and to reveal the effects of ecological differences on these variables. For this purpose, the essential oil ratios of lavandin samples grown in different locations obtained by microwave hydrodistillation method were found to vary between 0.5% and 4.4%. Although there are different studies on lavender essential oil in the literature, there are not enough studies in which microwave hydrodistillation method is applied to lavandin samples grown in different locations. The major essential oil components were linalool (13.66%-26.40%) and linalyl acetate (10.88%-29.89%). It was determined that TP (Total phenolic matter) of lavandin samples was between 2.13-4.74 mg GAE/g sample, TF (Total flavonoid matter) was between 0.43-0.66 mg QE/g sample, FRAP (Iron (III) reduction) was between 27.62-79.50 µmol $Fe_2SO_4.7H_2O$/g sample and DPPH (radical scavenging activity) was between 0.54-1.84 SC_{50} mg/mL. The results obtained support the idea that ecological conditions are effective in antioxidant activity and essential oil ratio for lavandin plant and that the plant materials used in the study are suitable for use in the perfumery industry.

Farklı Ekolojik Koşullarda Yetiştirilen Lavandin (*Lavandula* x *intermedia* Emeric Ex Loisel.) Bitkisinin Antioksidan Aktivitesi ve Uçucu Yağ Bileşenlerinin Mikrodalga Hidrodistilasyon ile Belirlenmesi

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ÖZ

Tıbbi ve aromatik bitkilerin her geçen gün önemi ve kullanım alanları giderek artmaktadır. Özellikle uçucu yağlar yakın zamanlarda sıkça günlük hayatımızda kullanılmaktadır. Lavandin (*Lavandula* x *intermedia* Emeric ex Loisel.) çiçek kısımlarında uçucu yağ elde edilen ve parfümeri sanayii başta olmak üzere birçok alanda kullanılan ekonomik değeri olan bir bitkidir. Bu çalışmanın amacı; farklı ekolojik koşullarda yetiştirilen Lavandin bitkisinin antioksidan aktivitesi ve uçucu yağ bileşenlerini belirleyerek ekolojik farklılıkların bu değişkenler üzerindeki etkilerini ortaya koymaktır. Bu amaçla farklı lokasyonlarda yetiştirilen lavandin örneklerinin mikrodalga

Lavanta

hidrodistilasyon yöntemi ile elde edilen uçucu yağ oranlarının %0,5-%4,4 değerleri arasında değiştiği görülmüştür. Literatürde lavanta uçucu yağı konusunda farklı çalışmalar bulunsa da farklı lokasyonlarda yetişen lavandin örneklerine mikrodalga hidrodistilasyon yönteminin uygulandığı yeterli çalışmaya rastlanmamıştır. Majör uçucu yağ bileşenlerinin linalool (%13,66-%26,40) ve linalilyl asetat (%10,88-%29,89) olduğu görülmüştür. Lavandin örneklerine ait TP (Toplam fenolik madde) 2,13-4,74 mg GAE/g numune değerleri arasında, TF (Toplam flavonoid madde) 0,43-0,66 mg QE/g numune değerleri arasında, FRAP (Demir (III) indirgeme) 27,62-79,50 µmol $Fe_2SO_4.7H_2O$/g numune değerleri arasında ve DPPH (radikal temizleme aktivitesi) ise 0,54-1,84 SC_{50} mg/mL değerleri arasında olduğu belirlenmiştir. Elde edilen sonuçlar, ekolojik koşulların lavandin bitkisi için antioksidan aktivitesi ve uçucu yağ oranında etkili olduğunu ve çalışmada kullanılan bitki materyallerinin parfümeri sanayiinde kullanıma uygun olduğu fikrini desteklemektedir.

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1. Introduction

Since ancient times, people have used plants to survive and eat healthier food. Plants with special healing effects are called medicinal and aromatic plants. In addition, plants are used in many different areas such as spices, food, beverages, paints and cosmetics (Aslan and Karakuş, 2019). Aromatic medicinal plants are frequently used in the food industry and their use in industrial production is increasing (Acıbuca and Bostan Budak, 2018).

To facilitate the research of approximately 20,000 medicinal and aromatic plants in the world (Toker et al., 2015) and to provide useful information; various classifications such as alphabetical, botanical, morphological, pharmacological, chemical, used parts and essential oils have been prepared (Gıdık et al., 2019; Gerçek et al., 2022).

Essential oil plants, which are used in the perfumery industry and food industry due to their pleasant odours, have been used in many fields in recent years (Gubišová, and Čičová, 2023). Lavandin plant is also known as one of them (Baydar, 2009).

The essential oil of the lavender plant contains two main components: linalyl acetate and linalool. The linalyl acetate component determines the quality of lavender oil and essential oils obtained from lavender varieties containing this component in abundance are used especially in perfumery (Sönmez et al., 2018). Lavender and lavandin varieties with high camphor content are used in insecticide production (Baydar, 2013). Some scientific studies using lavender plants have revealed that the properties of these plants such as essential oil ratios, essential oil components and antioxidant activities vary according to the conditions of the region where they grow (Kara and Baydar, 2014; Sönmez et al., 2018).

In a previous study; *L. angustifolia*, *L. latifolia* and *L. stoechas* L. grown under different conditions in Egypt, France and Australia, linalool (39.5%), lianlyl acetate (26.7%), eucalyptol (43.08%), tau-cadinol (28.63%), and tau-cadinol (19.08%) were determined (Eldeghedy et al., 2022).

This study aimed to determine the antioxidant activity and essential oil components of Lavandin (*Lavandula* x *intermedia* Emeric ex Loisel.) grown under different ecological conditions and to reveal the effects of ecological differences on these variables. When the previous studies in the literature are examined; studies on the essential oil ratio and components of lavender samples are generally noteworthy. There is not enough research in which lavandin samples were grown in different locations and microwave hydrodistillation method was used. It is thought that this study can be a source for more comprehensive researches.

2. Material and Methods

2.1. Plant Material

In this study, dried flowers of lavandin (*Lavandula* x intermedia Emeric ex Loisel.) obtained from Isparta Central District, Burdur Central District, Antalya Central District, Antalya Güzeloba District and Kırklareli Babaeski District were used as plant material. Lavandin samples were obtained from farmers in the locations mentioned in 2020.

2.2. Climate and Soil Characteristics of the Locations where Lavandin (Lavandula x intermedia Emeric ex Loisel.) Samples were Grown

Climate data for the years 1950-2020 and 2019-2020 for the locations where plant samples were obtained were obtained from the Turkish Ministry of Environment, Urbanisation and Climate Change, General Directorate of Meteorology. In addition, soil samples from these locations were taken from 0-30 cm depth and analysed at the Soil, Water and Plant Analysis Laboratory of the Black Sea Agricultural Research Institute Directorate of the Ministry of Agriculture and Forestry. The climatic data of the central district of Burdur province for many years (1950-2020) and 2019-2020 are shown in Table 1.

When the climate data of Burdur province by years are analysed, it is seen that the average monthly total precipitation between 1950-2020 is 428.5 mm, and when the average monthly temperature values are examined, it is seen that the average temperature is 13.3˚C. When the data of Burdur province for 2020 are examined, it is seen that the total amount of precipitation by month is 382.4 mm, the monthly average temperature is 14.25˚C and the monthly relative humidity is 47.34%.

The climatic data of the central district of Isparta province for many years (1950-2020) and 2019-2020 are shown in Table 2. When the climatic data of Isparta province are examined according to years, the average monthly total precipitation between 1950-2020 is 547.9 mm. When the monthly average temperature values are examined, it is seen that the average temperature is 12.3˚C. When the data of Isparta province for 2020 are examined, it is seen that the total amount of precipitation by month is 484 mm, the monthly average temperature is 14.26˚C and the monthly relative humidity is 58.3%.

Table 1. 1950-2020 and 2019-2020 climate data for the central district of Burdur province

Years	January	February	March	April	May	June	July	August	September	October	November	December	Total/ Average
	Monthly Total Precipitation (mm)												
1950-2020	55.4	40.2	45.8	43.6	45.0	30.1	13.7	9.6	15.7	33.7	37.0	58.7	428.5
2019	62.4	17.2	29.4	43.4	25.2	78.2	9.0	0.8	17.2	20.4	9.6	40.0	352.8
2020	37.6	60.8	38.2	18.8	95.0	36.2	3.8	8.4	5.8	33.0	5.2	39.6	382.4
	Monthly Average Temperature (^{0}C)												
1950-2020	2.6	3.9	7.1	11.7	16.4	21.0	24.6	24.6	20.3	14.5	8.7	4.3	13.3
2019	3.3	5.4	8.3	10.8	17.8	21.6	24.2	25.4	20.9	16.5	11.0	5.2	14.2
2020	1.9	4.2	8.4	12.4	16.7	20.3	26.9	25.4	23.6	17.0	8.1	6.1	14.25
	Monthly Average Relative Humidity (%)												
1959-2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	67.0	56.2	48.9	49.3	39.8	45.8	34.0	31.9	38.0	45.2	53.6	62.3	47.66
2020	57.5	60.5	50.3	45.3	44.0	41.8	30.7	32.5	36.0	42.9	53.7	72.9	47.34

Table 2. 1950-2020 and 2019-2020 climate data for the central district of Isparta province

Years	January	February	March	April	May	June	July	August	September	October	November	December	Total/ Average
	Monthly Total Precipitation (mm)												
1950-2020	79.7	60.9	56.8	51.2	55.9	33.1	16.1	13.4	17.0	37.9	45.1	80.8	547.9
2019	97.0	55.4	40.3	50.8	34.2	53.3	9.5	2.7	26.5	9.9	28.6	45.3	453.5
2020	74.1	71.4	41.3	24.2	92.1	42.6	1.9	24.8	1.0	48.7	26.5	35.4	484.0
	Monthly Average Temperature (^{0}C)												
1950-2020	1.9	3.0	6.2	10.7	15.3	19.8	23.4	23.2	18.9	13.3	7.7	3.6	12.30
2019	2.5	4.5	7.3	9.9	16.8	20.7	23.3	24.4	20.0	15.7	9.8	4.6	13.29
2020	1.4	3.8	7.7	11.6	16.1	20.3	27.0	25.6	24.1	17.4	9.3	6.9	14.26
	Monthly Average Relative Humidity (%)												
1959-2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	81.3	72.1	63.0	64.4	53.4	59.8	44.9	43.0	50.1	59.1	71.6	77.5	61.68
2020	70.6	75.2	64.8	58.6	57.1	52.3	36.5	39.2	42.9	58.2	63.1	81.1	58.30

The climatic data of the central district of Antalya province for many years (1950-2020) and 2019-2020 are shown in Table 3. According to these data, it is seen that the average monthly total precipitation between 1950-2020 was 871.6 mm and the average monthly temperature was 20.1˚C. In addition, looking at the data for 2020, it is seen that the total amount of precipitation by month is 641 mm, the monthly average temperature is 20.56˚C and the monthly relative humidity is 50.37%.

Table 3. 1950-2020 and 2019-2020 climate data for the central district of Antalya province

Years	January	February	March	April	May	June	July	August	September	October	November	December	Total/ Average
Monthly Total Precipitation (mm)													
1950-2020	211.4	97.5	104.0	44.3	43.7	15.1	0.3	7.9	30.5	73.7	72.7	170.5	871.6
2019	425.9	68.9	97.2	30.1	8.7	22.2	0.0	0.5	3.5	15.4	93.9	307.2	1073.5
2020	87.3	105.6	60.6	21.0	57.6	3.9	-	-	0.2	25.9	39.4	239.6	641.1
Monthly Average Temperature (^{0}C)													
1950-2020	11.4	12.4	14.8	17.5	21.5	25.7	29.0	29.5	26.4	22.2	17.2	13.1	20.1
2019	10.6	12.9	14.7	16.6	21.5	26.0	28.7	30.0	26.8	24.1	18.9	13.6	20.36
2020	11.7	12.3	14.9	17.4	22.0	23.9	29.2	29.7	28.7	24.0	18.5	14.5	20.56
Monthly Average Relative Humidity (%)													
1959-2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	72.6	62.0	60.7	60.8	60.4	62.0	51.5	50.4	53.2	51.2	56.5	62.5	58.65
2020	44.6	60.9	56.3	63.3	56.4	60.4	60.4	51.9	51.8	53.7	37.3	67.9	50.37

Long-term (1950-2020) and 2019-2020 climate data for Güzeloba district of Antalya province are shown in Table 4. When these data are analysed; it is seen that the average monthly total precipitation between 1950-2020 is 1057.6 mm and the average monthly temperature is 18.8˚C. Looking at the data for 2020 in Güzeloba, Antalya province, total monthly precipitation is 716.7 mm, monthly average temperature is 19.92˚C and monthly relative humidity is 61.92%.

Table 4. 1950-2020 and 2019-2020 climate data for Güzeloba district of Antalya province

Years	January	February	March	April	May	June	July	August	September	October	November	December	Total/ Average
Monthly Total Precipitation (mm)													
1950-2020	227.9	146.0	100.2	52.4	31.4	8.9	4.8	4.8	16.3	73.1	135.9	255.9	1057.6
2019	456.2	109.0	56.2	29.6	3.4	16.4	0.2	0.2	30.4	11.6	111.8	253.2	1078.0
2020	62.0	78.2	56.0	10.6	36.0	2.0	-	-	1.4	35.8	22.8	411.9	716.7
Monthly Average Temperature (^{0}C)													
1950-2020	10.0	10.7	12.9	16.3	20.5	25.3	28.4	28.4	25.2	20.6	15.3	11.5	18.8
2019	9.9	11.7	13.6	16.0	21.7	26.3	28.9	30.0	26.4	23.2	17.3	12.2	19.76
2020	10.4	11.4	13.9	16.7	21.9	24.0	29.5	29.8	28.4	23.2	16.8	13.1	19.92
Monthly Average Relative Humidity (%)													
1959-2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	75.0	68.9	66.3	65.1	61.4	61.4	53.2	52.8	58.4	58.9	65.6	70.2	57.98
2020	54.3	67.1	64.6	69.0	60.3	61.9	61.3	54.1	58.3	62.0	52.3	77.9	61.92

The climate data of Babaeski district of Kırklareli province for many years (1950-2020) and 2019-2020 are shown in Table 5. When these data are examined, it is seen that the average monthly total precipitation between 1950-2020 was 629.7 mm and the average monthly temperature was 13.6˚C.

Looking at the data of this location in 2020, it is seen that the total monthly precipitation amount is 453 mm, the monthly average temperature is 14.95˚C and the monthly relative humidity is 78.42%.

Table 5. 1950-2020 and 2019-2020 climate data for Babaeski district of Kırklareli province

Years	January	February	March	April	May	June	July	August	September	October	November	December	**Total/ Average**
	Monthly Total Precipitation (mm)												
1950-2020	63.6	49.7	50.9	55.3	69.7	44.4	27.7	16.9	27.9	68.5	81.1	74.0	629.7
2019	126.8	36.4	10.0	37.6	54.2	49.4	66.2	31.6	17.6	80.4	41.0	27.0	578.2
2020	39.4	53.0	18.8	42.1	62.8	112.7	0.0	5.6	18.0	64.4	3.0	33.2	453.0
	Monthly Average Temperature (^{0}C)												
1950-2020	3.4	4.9	7.6	12.5	17.4	22.1	23.9	23.3	19.6	14.2	9.1	5.5	13.6
2019	4.1	5.4	9.5	11.8	17.8	23.8	24.0	25.4	21.0	16.0	15.6	8.4	15.23
2020	3.7	7.2	9.4	11.3	17.1	21.6	25.1	25.5	22.7	17.4	9.7	8.7	14.95
	Monthly Average Relative Humidity (%)												
1959-2020	-	-	-	-	-	-	-	-	-	-	-	-	-
2019	100.0	100.0	100.0	86.8	75.0	67.7	65.2	62.6	65.5	75.3	82.7	88.0	80.73
2020	83.2	85.8	83.6	72.8	76.6	77.9	67.7	66.2	69.5	81.7	86.2	89.9	78.42

The results of soil analyses of the locations where lavender plant samples used as material in this study were collected are shown in Table 6. According to the analysis results of the soil sample obtained from the central district of Burdur province, it was found to be poor in organic matter and highly calcareous, and slightly alkaline according to Gedikoğlu (1990) and Ülgen, and Yurtsever (1995). According to the analysis results of the soil sample obtained from the central district of Isparta province, saturation rate was 77% and pH value was 7.58. The soil sample was found to be slightly alkaline according to some studies (Gedikoğlu, 1990; Ülgen, and Yurtsever 1995). According to the results of the analysis of the soil sample of the central district location of Antalya province, it was found that it was poor in organic matter and highly calcareous and slightly alkaline according to Gedikoğlu (1990) and Ülgen, and Yurtsever (1995).

Table 6. Soil sample analysis results of the locations

		Saturation	pH	Total Salt	Lime	Organic Matter %	Absorbable Phosphorus	Absorbable Potassium
Burdur	Value	59.4	7.58	0.01	40.88	1.86	8.54	109.5
	Degree	Clay-Loamy	Mildly Alkaline	Unsalted	Too much lime	Few	Medium according to Olsen (Kg/da)- Low according to Bray and Kurtz	High (Kg/da)
	Analysis Method/Reference	TS 8333 (+%10) (Air Dry)	Yurdakul 2018	TS 8334 (In mud)	TS EN ISO 10693 (Modified)	TS 8336	Olsen (Concentration)	TS8341 (Concentration)
Isparta	Value	77	7.58	0.04	21.67	3.32	6.33	199.5
	Degree	Clay	Mildly Alkaline	Unsalted	Much lime	Good	Medium according to Olsen (Kg/da)- Low according to Bray and Kurtz	High (Kg/da)
	Analysis Method/Reference	TS 8333 (+%10) (Air Dry)	Yurdakul 2018	TS 8334 (In mud)	TS EN ISO 10693 (Modified)	TS 8336	Olsen (Concentration)	TS8341 (Concentration)
Antalya province	Value	66	7.71	0.03	22.48	3.33	44.91	203.4
	Degree	Clay-Loamy	Mildly Alkaline	Unsalted	Much lime	Good	Very High (Kg/da) according to Olsen - Medium according to Bray and Kurtz	High (Kg/da)
	Analysis Method/Reference	TS 8333 (+%10) (Air Dry)	Yurdakul 2018	TS 8334 (In mud)	TS EN ISO 10693 (Modified)	TS 8336	Olsen (Concentration)	TS8341 (Concentration)
Antalya-Güzeloba	Value	72.6	7.94	0.04	33.11	1.1	3.05	61.2
	Degree	Clay	Mildly Alkaline	Unsalted	Too much lime	Few	Less according to Olsen (Kg/da)- Less according to Brau and Kurtz	High (Kg/da)
	Analysis Method/Reference	TS 8333 (+%10) (Air Dry)	Yurdakul 2018	TS 8334 (In mud)	TS EN ISO 10693 (Modified)	TS 8336	Olsen (Concentration)	TS8341 (Concentration)
Kırklareli-Babaeski	Value	70.4	7.59	0.03	10.06	1.05	1.83	187.8
	Degree	Clay	Mildly Alkaline	Unsalted	Medium Calcareous	Few	Medium according to Olsen (Kg/da)- Low according to Bray and Kurtz	High (Kg/da)
	Analysis Method/Reference	TS 8333 (+%10) (Air Dry)	Yurdakul 2018	TS 8334 (In mud)	TS EN ISO 10693 (Modified)	TS 8336	Olsen (Concentration)	TS8341 (Concentration)

According to the results of the analyses of the soil sample belonging to Güzeloba location of Antalya province, the soil was found to be poor in organic matter and highly calcareous and slightly alkaline according to Gedikoğlu (1990) and Ülgen, and Yurtsever (1995). According to the results of the analysis of the soil sample belonging to Babaeski district of Kırklareli province, the soil was found to be poor in organic matter and moderately calcareous and slightly alkaline according to Gedikoğlu (1990) and Ülgen, and Yurtsever (1995).

The plant samples used in this study were grown at a distance of 35 cm above the row and 140 cm between the rows. Irrigation was applied twice in July and once at the beginning of August. Harvesting took place in the last week of August and the first week of September. Plant samples dried in the shade were used.

2.3. Microwave hydrodistillation

Microwave hydrodistillation was carried out in a Milestone brand Ethos X model microwave extraction device. 150 g of dried flowers of lavandin was taken, soaked with 200 mL of water and placed in the extraction tank. The power of the microwave digestion was programmed to 1000 Watt. In the programme, the temperature increased to 100C° in 10 minutes and the process continued for 30 minutes. The moisture in the essential oil was removed with anhydrous sodium sulphate and then the dehydrated sample was placed in a sealed glass bottle and stored at 4°C until use.

2.4. Preparation of fatty acid methyl esters and GC-MS conditions

100 mg essential oil sample was taken in a 20 mL test tube and dissolved in 10 mL hexane. 100 µL of 2N potassium hydroxide was added and centrifuged after 30 s vortexing. At the end of centrifugation, 1 mL of supernatant (Regulation, 1991) was transferred to a vial and fatty acid analysis was performed in GC-MS. DB-23 60 m x 0.25 mm ID, 0.15 µm (J&W 122-2361) column and helium as carrier gas were used in the analyses. The oven temperature was set at 50°C for 1 min, 25°C increments until 175°C, 230°C for 5 min with 4°C increments, injection temperature 230°C. 1 µL was injected and the split ratio was set as 1/50 (IUPAC Standard Methods, 1992). The ionisation energy was applied at 70 eV with a scan time of 0.3 s and a mass range of 45-500 AMU. Management of the GC-MS system, parameter settings for GC and mass spectrometry, and data acquisition and processing were performed using Agilent GC-MS solution software and compounds were identified using NIST and WILEY libraries.

2.5. Plant material extraction for phenolic components and antioxidant capacity

Lavandin dried flower samples were stored in dry conditions until use. Ultrasonically assisted extraction was performed by applying the methods of Annegowda et al. (2012) and Wang et al. (2018). Dried lavandin flower samples were ground in a grinder. Four grams of sample was transferred to sterile Falcon tubes (15 mL) and 10 mL ethanol was added as solvent. This mixture was kept in an ultrasonic water bath (Kudos) for 30 min at 60°C at a frequency of 35 kHz. Then this reaction mixture was centrifuged at 10,000 rpm for 10 min and the supernatants were carefully transferred to sterile Falcon tubes. The volume was made up to 10 mL with ethanol (95%). Before analysis, a portion of the supernatant was filtered through a 0.45 µm filter.

2.6. Determination of total phenolic matter

It is known that phenolic compounds are oxidised by reducing Folin-Ciocalteu reagent in basic environments and oxidising themselves. It is known that the redox reaction between the Folin-Ciocalteu reagent, which acts as an oxidising agent, and phenolics forms the basis of this method. (Singleton and Rossi, 1965; Slinkard and Singleton, 1977). The total amount of phenolics in the sample is determined by measuring the absorbance of the coloured product formed as a result of this redox reaction spectrophotometrically at 760 nm wavelength. It is known that the measured absorbance value is directly proportional to the amount of phenolic matter. Generally, while performing spectrophotometric measurements, the amount is calculated by using the standard calibration graph. In this study, gallic acid was used as a standard for the determination of phenolic substances in Lavandin samples. Starting from the solution of gallic acid standard at a concentration of 1 mg/mL, working solutions of 0.500, 0.250, 0.125, 0.062, 0.031 and 0.015 mg/mL were prepared respectively. Absorbance graphs corresponding to the concentration values of these solutions were plotted. Using the standard calibration graph, the amount of phenolic substances in lavandin samples was calculated separately for each sample and the result was determined as mg gallic acid equivalent per gram sample (mg GAE/g).

2.7. Determination of total flavonoid matter

Flavonoids, which constitute an important part of phenolic compounds, are among the natural antioxidants found in plants. The method described by Fukumoto and Mazza was used to determine the total amount of flavonoids in lavandin samples (Fukumoto, & Mazza, 2000). The absorbance of the coloured product resulting from the redox reaction between flavonoids and aluminium (III) was measured at 415 nm wavelength to determine the total flavonoid content. Thus, 1 mg/mL quercetin stock solution was prepared to create a standard calibration graph of quercetin for the determination of the result. From this stock solution, 0.500, 0.250, 0.125, 0.125, 0.062, 0.031 and 0.015 mg/mL solutions were prepared by serial dilution method and absorbance value was determined. A standard calibration graph was obtained by plotting absorbance against quercetin concentration. The total amount of flavonoids in lavandin samples was calculated using the standard calibration graph and the results obtained were determined as mg Quercetin equivalent per gram sample (mg QE/g).

2.8. Determination of DPPH radical scavenging activity

DPPH (2,2-diphenyl-1-picrylhydrazyl) is a synthetically produced radical and produces maximum absorbance at 517 nm wavelength. In order to determine the radical scavenging activity of various components in lavandin samples, methanolic solution of DPPH at 100 µM concentration was used. For the determination of DPPH radical scavenging activity, solutions of lavandin samples produced by serial dilution method were added to the DPPH radical concentration and the solvents of these lavandin samples were used as reagent blind. The solutions of lavandin samples and the radical were mixed in a 1:1 ratio and the absorbance values at 517 nm wavelength were measured spectrophotometrically and the radical scavenging power of the antioxidant substances in lavandin samples was calculated by drawing a graph from the values obtained. The data obtained as a result of these studies were evaluated as SC_{50} value (Cuendet et al.,1997). SC_{50} value is known as the amount of antioxidant substance needed to halve the radical concentration in the environment. To determine the SC_{50} values of lavandin samples, working solutions of different concentrations were obtained by serial dilution. As a result of the interaction of each sample with the radical, absorbance values were measured at 517 nm wavelength and the SC_{50} value of lavandin samples was determined as mg/mL with the help of the exponential equation obtained by drawing the absorbance graph against the concentrations of lavandin samples.

2.9. Determination of iron (III) reducing antioxidant power-FRAP

Fe (III)-TPTZ-2,4,6-tris(2-pyridly)-S-triazine complex is reduced in the presence of antioxidants. The resulting Fe (II)-TPTZ complex shows maximum absorbance at 593 nm wavelength (Benzie and Strain, 1999). It is known that the standardisation and application of this FRAP method are easier than some other methods. FRAP reagent was obtained freshly by mixing 300 mM pH:3.6 acetate buffer, 10 mM TPTZ and 20 mM $FeCl_3$ solutions in a 10:1:1 ratio. $FeSO_4.7H_2O$ was used to obtain a standard calibration graph. The solutions required for the realisation of the study were obtained by serial dilution from 1000 μM stock solution. After the experimental procedures, the antioxidant power in lavandin samples was determined as the equivalent of $FeSO_4.7H_2O$ by plotting the absorbance graph against the solution concentration.

2.10. Statistical Analysis

SPSS 25.0 version statistical analysis program was used for statistical evaluation of the data obtained in this study. Pearson correlation analysis was performed to determine the effect of climate and environmental factors on oil ratio and fatty acid composition. In addition, Hierarchical Cluster Analysis (HCA) was performed to determine the proximity of lavandin samples obtained from different locations in terms of oil ratio, phenolic components and antioxidant capacity.

3. Results and Discussion

3.1. Essential Oil Ratios and Components of Lavandin (Lavandula x intermedia Emeric ex Loisel.) Samples

Essential oils are found in many medicinal and aromatic plants. In addition to giving plants a pleasant odour, these oils are also used in various industrial fields with the different components they contain (Bozari et al., 2013; Yuca et al., 2024). The flowers of lavandin plant are grown especially for the use of essential oil. In this study, the essential oil ratio (Table.7) and essential oil components (Table 8.) of the flower parts of *Lavandula* x *intermedia* Emeric ex Loisel. plants obtained from Isparta Central District, Burdur Central District, Antalya Central District, Antalya Güzeloba District and Kırklareli Babaeski District were determined.

Table 7. Essential Oil Ratios of *Lavandula* x *intermedia* Emeric ex Loisel

Location	Essential oil content (%)
Burdur	2.2 ±0.04
Kırklareli/Babaeski	1.4±0.01
Isparta	1.1±0.02
Antalya	0.5±0.01
Antalya/Güzeloba	4.4±0.06

When the essential oil ratios were analysed according to the locations, it was seen that the highest ratio was obtained from Antalya/Güzeloba location. Although it was closer location to Antalya centre location than the others, it was observed that there were differences between the results. It is thought that this situation may be due to the differences in the amount of organic matter, the amount of available phosphorus and the amount of available potassium among the soil properties or the differences in the total/average rainfall and moisture amounts of the locations. In some studies in the literature, it was revealed that factors such as environmental characteristics, altitude, irrigation and rainfall were effective on essential oil ratios (Lane et al., 2008; Telci et al., 2010; Najar et al., 2019; Fernández-Sestelo et al., 2020; Salata et al., 2020).

In a previous study (Aćimović et al., 2022), the essential oil ratios of different *Lavandula* x *intermedia* samples were determined and reported to be between 1.03%-1.26%, which is different from this study. However, in a recent similar study, essential oil ratios of *Lavandula* spp. were reported to be between 0.5%-2.0% (Pokajewicz et al., 2022). Although the values obtained for essential oil ratios in this study (0.5%-4.4%) are similar to some previous studies, there are also differences. Although the methods and plant materials used in the studies are similar, it is thought that the reason for the differences is the variability of environmental conditions. This situation suggests that natural variables such as temperature and precipitation related to growing conditions are effective on essential oil ratios.

The essential oil components of *Lavandula* x *intermedia* Emeric ex Loisel. samples were analysed using Agilent GC-MS solution software and the compounds were identified using NIST and WILEY libraries. A total of 97 different essential oil components of lavandin samples obtained from five different locations used in the study were determined (Table 8). Accordingly, it was observed that linalyl acetate (24.11%) was the major component in the samples grown at Burdur location, followed by linalool (24.00%) and borneol (4.62%). In the samples grown in Kırklareli/Babaeski location, linalool (13.66%) was the major component, followed by linalyl acetate (10.88%) and estergole (7.38%). In the samples grown in Isparta location, linalyl acetate (29.89%) was the major component, followed by linalool (14.58%) and borneol (6.68%). It was observed that linalool (21.23%) was the major component in the samples grown in Antalya location, followed by linalyl acetate (18.14%) and camphor (12.93%). In the samples grown in Antalya/Güzeloba location, linalool (26.40%) was the major component, followed by ocimene (18.54%) and camphor (7.72%).

In *Lavandula* x *intermedia* Emeric ex Loisel. samples grown in all locations, the highest linalyl acetate was observed in the sample grown in Isparta location with a value of 29.89%. The fact that linalyl acetate and linalool components, which are expected to be in plants used especially in perfumery production, are among the major components in *Lavandula* x *intermedia* Emeric ex Loisel. samples obtained from all locations draw attention to the economic value of this plant.

Table 8. Essential Oil Components of *Lavandula* x i*ntermedia* Emeric ex Loisel

	Burdur		Kırklareli / Babaeski		Isparta		Antalya		Antalya / Güzeloba	
Components	**RT (min)**	**%**	**RT (min)**	**%**	**RT (min)**	**%**	**RT (min)**	**%**	**RT (min)**	**%**
Beta pinene	8.95	0.06	8.96	0.21	35.09	0.05	8.95	0.11	-	-
Alpha pinene	-	-	7.59	0.73	7.58	0.20	7.58	0.29	7.58	0.30
Beta Myrcene	9.46	0.46	9.47	0.47	9.46	0.38	9.47	0.26	9.47	0.51
1,8-Cineole	10.89	4.33	10.99	10.00	10.89	4.88	10.93	6.66	10.88	3.97
Limonene	-	-	-	-	-	-	-	-	-	-
3-octanone	9.32	0.72	9.33	0.64	9.32	0.62	9.33	0.90	9.33	0.80
Ocimene	11.45	0.39	11.16	1.51	11.45	0.38	11.45	0.36	19.07	18.54
Linalool oxide	12.95	3.60	12.71	3.27	12.59	1.03	12.37	2.33	12.73	5.74
1-Octen-3-ol, acetate	13.88	0.43	11.49	0.32	13.89	0.33	13.87	0.46	13.91	0.43
Sabinene hydrate	22.02	0.33	22.01	0.13	-	-	-	-	-	-
Camphor	15.09	9.42	14.99	2.40	15.06	6.07	15.15	12.93	15.09	7.72
Linalool	13.72	24.00	13.66	13.66	19.65	14.58	13.73	21.23	13.76	26.40
Linalyl asetat	19.11	24.11	19.03	10.88	19.17	29.89	19.08	18.14	-	-
Bornyl asetat	19.85	0.31	19.86	0.55	19.88	0.17	18.84	0.18	-	-
Lavandulyl asetat	20.03	1.38	23.03	0.74	20.06	1.95	20.03	1.58	20.04	1.91
Terpinen -4-ol	-	-	16.15	2.12	-	-	-	-	-	-
Beta-farnesene	25.30	0.71	25.29	0.29	25.30	0.81	25.28	0.52	25.28	0.31
Caryophyllene	24.19	1.02	24.17	0.42	24.20	1.28	24.17	0.76	24.16	0.33
Crypton	16.41	0.35	-	-	16.42	0.28	16.43	0.46	16.44	0.15
lavandulol	-	-	20.13	5.06	-	-	-	-	-	-
Borneol	15.77	4.62	15.89	6.38	15.84	6.68	15.81	4.88	15.82	5.35
Germacrene D	-	-	-	-	26.07	0.27	-	-	-	-
Geranyl asetat	22.39	0.34	22.40	0.42	-	-	23.01	0.71	23.02	0.96
Alpha amorphene	27.05	0.14	27.07	0.33	27.05	0.18	27.05	0.38	-	-
Nerol	23.02	0.67	17.96	0.13	20.53	0.49	17.96	0.13	17.97	0.24
Cuminol	-	-	-	-	-	-	-	-	-	-
Caryophyllene oxide	29.11	0.44	28.71	1.79	29.11	0.57	29.13	1.07	29.12	0.93
Alpha bisabolol	32.12	1.59	-	-	32.12	1.27	32.09	0.68	32.08	0.39
Alpha cadinol	-	-	30.85	0.71	-	-	30.80	0.18	30.79	0.05
2H-Pyran, 3,6-dihydro-4-methyl-2-(2-methyl-1-propenyl)	9.56	0.02	9.56	0.20	15.29	0.14	15.30	0.24	15.31	0.36
Hexyl methyl ether	4.69	0.05	4.69	0.07	4.69	0.04	4.69	0.09	4.69	0.10
1-Hexanol	5.70	0.14	5.70	0.13	5.70	0.06	5.70	0.09	5.70	0.10
Oxepine	7.61	0.30	-	-	-	-	-	-	-	-
Camphene	8.04	0.36	8.06	0.97	8.04	0.30	8.04	0.57	8.04	0.41
Cyclotetrasiloxane, octamethl-	9.78	0.04	-	-	-	-	-	-	-	-
Herboxide Second Isomer	10.02	0.12	10.03	0.14	10.02	0.07	14.52	0.15	10.02	0.43
Acetic acid, hexyl ester	10.26	0.96	10.31	1.09	10.25	0.80	10.27	1.15	10.26	0.94
Benzene, 1-methyl-2-(1-methylethyl)	10.61	0.08	10.70	1.30	10.61	0.05	10.62	0.15	10.61	0.15
2,3-Dimethylpenta-3,4-dienoic acid	11.18	0.58	-	-	-	-	-	-	11.17	0.44
2,6-Dimethyl-1,3,5,7-octatetraene,E,E	14.12	0.07	14.36	0.26	14.52	0.14	14.39	0.25	14.42	0.16
Butanoic acid, hexyl ester	16.65	2.71	-	-	16.64	2.03	16.64	2.09	16.69	3.18
Estragole	16.81	0.25	16.97	7.38	16.83	0.74	16.86	1.63	16.89	2.53
Butanoic acid, 2-methyl-, hexyl ester	18.14	0.33	-	-	18.14	0.18	18.14	0.22	18.14	0.22
Carvacrol	20.34	0.14	20.28	0.21	-	-	20.34	0.10	-	-
Hexyl tiglate	21.29	0.44	21.29	0.09	21.29	0.33	21.28	0.35	21.29	0.39
Hexanoic acid, hexyl ester	23.09	0.26	-	-	-	-	23.08	0.24	-	-
p-Cymene	24.00	0.12	24.00	0.06	-	-	-	-	-	-
Coumarin	24.64	0.09	28.70	0.09	24.64	0.08	24.64	0.56	24.63	0.03
beta,-Selinene	26.60	0.08	-	-	-	-	-	-	-	-
2-Pentadecanone, 6,10,14-trimethyl	34.01	0.17	34.01	0.07	34.01	0.08	34.01	0.03	-	-
Acetic acid, octyl ester	17.27	0.13	-	-	17.27	0.07	17.27	0.07	17.27	0.08
(1R,6S,7S)-3,7-Dimethyl-7-(4-methyl-3-penten-1-yl)bicyclo[4,1,0]hept-2-ene	26.00	0.06	-	-	-	-	-	-	-	-
1H-Cycloprop[e]azulene, decahydro-1,1,4,7-tetramethyl-	28.22	0.07	-	-	-	-	-	-	-	-
Exo methylene isomer of Caryophyllenoll	30.64	0.14	30.68	0.28	-	-	-	-	-	-
Naphthalene, 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)	30.81	0.18	-	-	-	-	26.05	0.25	-	-
geranyl-p-cymene	34.77	0.03	-	-	-	-	-	-	-	-
Sabinene	35.10	0.06	8.86	0.06	8.86	0.04	8.86	0.04	8.86	0.05
2-Cyclohepta-2,4,6-trienyl-ethanol	35.43	0.16	-	-	-	-	-	-	-	-
gamma,-Terpinene	35.93	0.04	11.82	0.15	11.80	0.04	11.80	0.06	11.80	0.06
(4S,7R)-Bisabolol-1(6),2,10-triene	23.72	0.08	-	-	23.72	0.06	-	-	-	-
3-Buten-2-ol, 2-methyl	-	-	2.02	0.05	-	-	-	-	2.02	0.04
Hexanal	-	-	4.12	0.03	-	-	-	-	-	-
4-Methylene-5-Hexenal	-	-	6.39	0.05	-	-	-	-	-	-
Tricyclene	-	-	7.21	0.09	-	-	7.21	0.04	-	-
alpha,-Thujene	-	-	7.38	0.05	-	-	-	-	-	-
1,3,5-Cycloheptatriene, 3,7,7-trimethyl	-	-	8.76	0.09	-	-	-	-	-	-
Butanoic acid, butyl ester	-	-	9.64	0.18	-	-	-	-	-	-
Delta,3-Carene	-	-	10.09	0.09	-	-	-	-	-	-
beta,-Ocimene	-	-	11.51	1.28	-	-	11.10	0.50	11.46	0.56
Bicyclo[2,2,1]heptan-2-one, 3,3-dimethyl	-	-	12.71	0.12	-	-	-	-	-	-
verbenene	-	-	8.22	0.06	-	-	-	-	-	-
Bicyclo[3,1,1]heptan-2-one, 6,6-dimethyl-, (1R)	-	-	14.70	0.10	-	-	-	-	-	-
trans-Verbenol	-	-	14.77	0.18	-	-	-	-	-	-
Pinocarvone		-	15.56	0.18	-	-	15.58	0.07	-	-

Propanol	-	-	16.51	0.89	-	-	-	-	-	-
Phenol, 5-methyl-2-(1-methylethyl)	-	-	16.64	0.32	-	-	-	-	-	-
[3,3,3]Propellane	-	-	17.29	0.38	-	-	-	-	-	-
trans-Carveol	-	-	17.63	0.09	-	-	17.63	0.11	17.63	0.12
Propanal, 2-methyl-3-phenyl-	-	-	18.27	0.12	18.30	0.22	18.26	0.17	-	-
D-Carvone	-	-	18.42	0.15	-	-	-	-	-	-
1,7-exo-Trimethylenebicyclo[3,2,1]octane	-	-	18.70	0.13	-	-	-	-	-	-
1-Cyclohexene-1-carboxaldehyde, 4- (1-methylethenyl)-	-	-	19.60	0.14	-	-	-	-	-	-
Eucarvone	-	-	20.74	0.07	-	-	-	-	-	-
Eugenol	-	-	22.15	0.09	-	-	-	-	-	-
2,7-Diazaspiro[4,4]nonane, 2-ethyl Octane, 3-ethyl-2,7-dimethyl-	-	-	23.58	0.05	-	-	-	-	-	-
Benzene, 1,2-dimethoxy-4-(2-propenyl)	-	-	23.68	0.14	-	-	-	-	-	-
alpha,-Terpinene	-	-	24.80	0.11	-	-	-	-	-	-
2-(Trimethylsilylethynyl)pyridine	-	-	28.91	0.07	-	-	-	-	-	-
Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-dimethyl-4-(1-methylethyl)-	-	-	30.02	0.12	-	-	-	-	-	-
Caryophyllenol-II	-	-	31.82	0.26	-	-	-	-	-	-
14-Norcadin-5-en-4-one isomer B	-	-	32.20	0.13	-	-	-	-	-	-
Cadina-4,10(15)-dien-3-one	-	-	33.08	0.08	-	-	-	-	-	-
4-(1,1-Dimethyl-4-formylbutyl)-3-cyclohexen-1-one	-	-	33.79	0.11	-	-	-	-	-	-
(+-)-Oxo-T-cadinol	-	-	34.42	0.05	-	-	-	-	-	-
Hexadecanoic acid, methyl ester	-	-	34.56	0.04	-	-	-	-	-	-
2-,Beta,-Pinene	-	-	35.09	0.05	8.95	0.10	26.89	0.32	8.95	0.07
1,6,10,14-Hexadecatetraen-3-ol, 3,7,11,15-tetramethyl-, (E,E)-	-	-	35.27	0.08	-	-	-	-	-	-
5-Methyl-5-[(E)-2-(2-furyl)ethenyl]-1,1-dichloro-4,6 dioxaspiro[2,4] heptane	-	-	35.61	0.03	-	-	-	-	-	-
cis-Ocimene	-	-	-	-	11.09	0.40	-	-	11.10	0.52
1,7,7-Trimethylbicyclo[2,2,1]heptan-2-ol	-	-	-	-	16.02	0.26	-	-	-	-
3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)	-	-	-	-	16.10	0.22	16.10	0.19	-	-
Endobornyl acetate	-	-	-	-	17.82	0.25	-	-	17.83	0.32
4-Pentylamino-3-chloroacetamido 2-naphthoquinone	-	-	-	-	21.19	0.02	-	-	-	-
Neryl acetate	-	-	-	-	22.39	0.37	22.39	0.25	22.39	0.41
Zingiberene	-	-	-	-	23.22	0.07	-	-	-	-
delta,-Cadinene	-	-	-	-	27.93	0.15	-	-	-	-
Butanoic acid, 3-methyl-, 1-ethenyl-1,5- dimethyl-4-hexenyl ester	-	-	-	-	26.90	0.54	-	-	-	-
1-Oxaspiro[2,5]octane, 5,5-dimethyl-4-(3-methyl-1,3-butadienyl)-	-	-	-	-	28.21	0.10	28.20	0.27	28.19	0.12
1-Methyl-6,beta,-(4,4-dimethyl-3-oxocyclopentene-1-yl)-1-,beta,-bicyclo[3,1,0]he	-	-	-	-	28.39	0.06	-	-	-	-
cis-Z-,alpha,-Bisabolene epoxide	-	-	-	-	31.27	0.31	-	-	-	-
Tricyclo[3,2,2,0]nonane-2-carboxylic acid	-	-	-	-	31.78	0.08	-	-	-	-
Ethyl 2-(5-ethyl-5-vinyltetrahydr ofuran-2-yl) propan-2-yl carbonate	-	-	-	-	-	-	12.90	1.64	-	-
Hotrienol	-	-	-	-	-	-	13.79	0.45	-	-
Epoxylinalol	-	-	-	-	-	-	16.04	0.38	15.98	0.79
Bicyclo[3,1,1]hept-3-en-2-one, 4,6,6-trimethyl-, (1S)-	-	-	-	-	-	-	17.21	0.08	17.23	0.13
Phosphorothioic acid, O,O,S-triethyl ester	-	-	-	-	-	-	23.39	0.20	-	-
Acetic acid, (4-iodophenoxy)-	-	-	-	-	-	-	24.49	0.40	-	-
1,2,5,6-Tetrahydropyridine, 1-methyl-6-[2-pyridyl]-	-	-	-	-	-	-	25.58	0.12	-	-
1-Acetyloxyindole	-	-	-	-	-	-	25.81	0.24	-	-
dimethyl(7,7-(2-silaprop-2-ylidene)-bis(tricyclo-[4,1,0,0(2,7)]hept-1-yl)germani	-	-	-	-	-	-	25.89	0.14	-	-
Methylmercuric iodide	-	-	-	-	-	-	27.13	0.23	-	-
Bisabolol oxide	-	-	-	-	-	-	31.27	0.22	31.26	0.10
(9R,9aS)-9-(p-Toluenesulfonyl)-2,3,5,8,9,9a-hydro-1H-pyrrolo[1,2-a]a zepin-3-one	-	-	-	-	-	-	31.78	0.11	-	-
3-bromo-2,5 bis (dicyanomethylene)-2,5-dihydroselenophene	-	-	-	-	-	-	33.69	0.05	-	-
p-Mentha-1(7),8-diene	-	-	-	-	-	-	35.09	0.04	-	-
1,10-epoxy-2-hydroxykaunio	-	-	-	-	-	-	35.25	0.06	-	-
Dimethyl triselenide	-	-	-	-	-	-	35.30	0.07	-	-
N-(4-Bromo-3-Methyl-phenyl)-N'-(2-Hydroxy-propyl)-oxalamide	-	-	-	-	-	-	36.21	0.12	-	-
Methyl eicos-11-en-14-ynoate 1,3-Pentadiene, 3-methyl-, (E)-	-	-	-	-	-	-	-	-	2.20	0.03
2-Butenal, 3-methyl-	-	-	-	-	-	-	-	-	3.84	0.10
Furan, 2,5-dimethyl	-	-	-	-	-	-	-	-	6.28	0.05
2-n-heptadecanyl-4,4-dimethyloxazoline	-	-	-	-	-	-	-	-	7.74	0.17
Lilac aldehyde C	-	-	-	-	-	-	-	-	15.19	0.19
m-Toluamide	-	-	-	-	-	-	-	-	16.34	0.09
Butanoic acid, 3-methyl-, hexyl ester	-	-	-	-	-	-	-	-	18.30	0.32
3-(4'-Methoxyphenyl)-5-phenylisoxazoline	-	-	-	-	-	-	-	-	19.22	0.07
Acetic acid, 1,7,7-trimethyl-bicyclo[2,2,1]hept-2-yl ester	-	-	-	-	-	-	-	-	19.84	0.16
2,6-Octadıen-1-Ol, 3,7-Dımethyl-, Acetate	-	-	-	-	-	-	-	-	26.89	0.19
Papaverine	-	-	-	-	-	-	-	-	30.69	0.02
4,4'-dimethyl-2,2'-biquinolinyl	-	-	-	-	-	-	-	-	35.43	0.03
7-bromopentacyclo[5,4,0,0(2,6),0(3,10),0(5,9)]undecane-8,11-dione	-	-	-	-	-	-	-	-	36.68	0.06

Among the essential oil components of Lavandin samples grown in different locations and used as plant material in this study, linalool and linalyl acetate were found to be the major components, while camphor and estergole components were found more than other components. According to the results obtained in this study, linalool component was found to be between 13.66%-26.40%. Kara and Baydar (2013) and Katar et al. (2020) reported that the linalool component was between 37.1%-55.4% and 41.34%-53.10%, respectively in their similar studies and showed different results from our study. In addition to these; Kara and Baydar (2014) reported that the linalool content of lavandin and lavender samples, to which they applied drying method under different conditions, varied between 14.10-53.12% and showed values supporting the results obtained in our study. It is seen that there are similarities as well as differences between the previous similar studies in the literature and our study. Since the essential oil components may vary according to the storage conditions of the plants, growing conditions and the method of obtaining the essential oil, different results are expected.

Linalyl acetate, which is among the important essential oil components of medicinal aromatic plants, was determined among the major components in the plant samples in this study. In this study, linalyl acetate value was determined between 10.88% and 29.89%. In a similar study, Kara and Baydar (2011) determined the constituents in lavender essential oil and found similar linalyl acetate ratios (24.0%-29.0%) with our study. In addition, there are also results in the literature that support our study by reporting that lavandin samples contain 10%-30% linalyl acetate in some studies (Wichtl et al., 2004; Baydar, and Kineci, 2009; Edwards et al., 2015). Katar et al. (2020) reported in a similar study that the linalyl acetate ratios of lavandin samples varied between 1.83%-23.54% and showed lower values than our study. It has been reported in previous studies that variables such as cultivation techniques, plant parts and harvest time affect the results in obtaining different results although similar or the same species are included in the studies using essential oil plants (Orhan, 2007; Pinto et al., 2007; Atalay, 2008).

Camphor is known as a very abundant essential oil component in lavender and lavandin plants. In this study, camphor content was determined between 2.40% and 12.93%. Alatrache et al. (2007) reported that the camphor component was 12.4% in their study, Lafhal et al. (2016) reported that the camphor component was 4.7%-9.2%, Karık et al. (2017) reported that the camphor content in lavandin samples was 3.18%-11.54% in their study and showed results supporting the camphor values of the samples used in our study. In addition, in some previous studies, camphor values were found between 0.18%-6.00% and lower values were also found (Kara and Baydar, 2011; Kara and Baydar, 2014). Camphor is generally considered to be a very undesirable compound in essential oil plants. In addition, since it is known that camphor content varies depending on environmental conditions, it is thought that it is possible to grow lavandin with lower camphor values. Considering all this information, it is important to determine the appropriate production conditions for lavandin plants with low camphor content by conducting more comprehensive studies using breeding studies and cultivation techniques to reduce camphor content.

3.2.TP, TF and Antioxidant Activities of Lavandin (Lavandula x intermedia Emeric ex Loisel.) Samples

In this study, dried flowers of lavandin (*Lavandula* x *intermedia* Emeric ex Loisel.) grown in Burdur central district, Kırklareli Babaeski district, Isparta central district, Antalya central district, Antalya Güzeloba locality were used as plant material. Plant samples were obtained from plants grown in 2020. TP, TF, FRAP, DPPH values were determined to the total phenolic matter, total flavonoid matter contents and antioxidant activities of the plant samples (Table 9).

Table 9. TP, TF Values and Antioxidant Activity of *Lavandula* x *intermedia* Emeric ex Loisel.

Locations	**TP (mg GAE/ g sample)**	**TF (mg QE/g sample)**	**FRAP (µmol $Fe_2SO_4.7H_2O$/g sample)**	**DPPH SC_{50} mg/mL**
Burdur	4.51±0.63	0.43±0.007	73.50±0.799	0.63±0.018
Kırklareli/Babaeski	2.74±0.07	0.65±0.008	29.09±0.501	1.56±0.032
Isparta	4.12±0.14	0.53±0.010	54.96±0.921	0.93±0.027
Antalya	4.74±0.15	0.66±0.006	60.79±0.843	0.54±0.008
Antalya/Güzeloba	2.13±0.11	0.43±0.090	27.62±0.499	1.84±0.001
Troloks				0.004±0.00

In this study, the highest TP (4.74±0.15 mg GAE/g sample) and TF (0.66±0.006 mg QE/g sample) values were observed in the samples grown in Antalya location, the lowest TP value (2.13±0.11 mg GAE/g sample) was observed in the samples grown in Antalya Güzeloba location and the lowest TF value (0.43±0.007 mg QE/g sample) was observed in the samples grown in Burdur location. Although Antalya and Antalya/Güzeloba locations are very close in terms of location, they show differences in terms of TP value. It is thought that these differences may be due to the methods applied in the cultivation of the plants or the differences in the methods applied in plant nutrition. The highest value for FRAP (73.50±0.799 µmol $Fe_2SO_4.7H_2O$/g sample) was observed in samples grown at Burdur location and the lowest value (27.62±0.499 µmol $Fe_2SO_4.7H_2O$/g sample) was observed in samples grown at Antalya/Güzeloba location. For DPPH, the lowest value (0.54±0.008 SC_{50} mg/mL) was observed in the samples grown at Antalya location and the highest value (1.84±0.001 SC_{50} mg/mL) was observed in the samples grown at Antalya/Güzeloba location.

Phenolic substance content and antioxidant activity are among the important properties of medicinal aromatic plants. Lavandin samples grown in different locations used in this study had TP values between 2.13-4.74 mg GAE/g sample, TF values between 0.43-0.66 mg QE/g sample, FRAP values between 27.62- 79.50 µmol $Fe_2SO_4.7H_2O$/g sample and DPPH values between 0.54-1.84 SC_{50} mg/mL. Bajalan et al. (2016) reported TP values between 0.48-0.54 mg GAE/mL and Çelik (2019) reported TP values between 0.43-0.89 mg GAE/mL in their studies using Lavandula x intermedia samples. Kıvrak (2018), in a similar study using lavender and lavandin samples, reported that the DPPH value for lavandin samples was between 0.89-0.93 SC_{50} mg/mL, and Çelik (2019) reported the DPPH value for lavandin samples used in his study as 0.035 ± 0.003 IC_{50} mg/mL.

Previous studies in the literature using similar plants and methods have shown different values as well as results supporting our study. It is thought that the ecological conditions in which the plants are grown, environmental factors such as rainfall and temperature, harvest maturity of the plant, post-harvest storage conditions, extraction methods used in the methods and solvents applied are effective in the emergence of these differences as well as similarities.

The statistical method to determine the relationship between more than one variable and the level of importance of this relationship is called correlation. This method is currently used in the statistical evaluation of the results of scientific studies. Pearson correlation coefficient and Spearman correlation coefficients are known as the most commonly used correlation types today. When determining whether there is a correlation between two variables, one of the variables is called dependent and the other is called independent variable. The correlation coefficient is known as a numerical value that reveals the level and direction of the relationship between the dependent variable and independent variables. The correlation coefficient is expressed by r and its value varies between -1.0 and +1.0. In this study, the relationship between the essential oil ratios and antioxidant activities of *Lavandula* x *intermedia* Emeric ex Loisel. samples and the soil and climate data of the locations where they were grown were calculated using Pearson's correlation coefficient (r_P) using SPSS version 25.0 (Steel, & Torrie, 1980) software programme (Table 10).

Table 10. Correlation between TP, TF, Antioxidant Activity and Essential Oil Ratios of *Lavandula* x *intermedia* Emeric ex Loisel.

		S	pH	TS	L	OM	AF	AP	AMRH	AMWS	MTR	MAT
Essential Oil Ratio	r_p	0.079	0.746	0.148	0.540	-0.690	-0.547	**-0.952****	-0.006	0.699	0.140	0.245
	p	0.900	0.148	0.812	0.347	0.197	0.340	**0.013**	0.992	0.189	0.822	0.692
TP	r_p	-0.470	-0.579	-0.491	0.196	0.801	0.639	0.503	-0.689	**-0.983****	-0.053	-0.160
	p	0.425	0.306	0.400	0.752	0.103	0.246	0.388	0.198	**0.003**	0.932	0.797
TF	r_p	0.130	-0.317	0.188	-0.862	0.289	0.512	0.838	0.532	-0.108	0.191	0.151
	p	0.835	0.603	0.762	0.060	0.637	0.378	0.076	0.356	0.862	0.758	0.808
FRAP	r_p	-0.606	-0.515	-0.652	0.486	0.635	0.454	0.209	-0.845	**-0.929***	-0.167	-0.246
	p	0.279	0.374	0.233	0.406	0.250	0.442	0.735	0.072	**0.023**	0.789	0.690
DPPH	r_p	0.527	0.551	0.534	-0.236	-0.769	-0.655	-0.460	0.711	**0.970****	0.032	0.130
	p	0.362	0.335	0.354	0.702	0.128	0.231	0.436	0.179	**0.006**	0.960	0.834

S: Saturation, pH: Acidity, TS: Total Salt Content, L: Lime Content, OM: Organic Matter Amount, AF: Absorbable Phosphorus, AP: Absorbable Potassium, AMRH: Average Monthly Relative Humidity, AMWS: Average Monthly Wind Speed, MTR: Monthly Total Rainfall, MAT: Monthly Average Temperature
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

When Pearson correlation coefficients between antioxidant activity and essential oil ratios of *Lavandula* x *intermedia* Emeric ex Loisel. samples grown in different locations and soil properties and climatic data used in this study were analysed; it was determined that there was a negative correlation between the variable of essential oil ratio and the variable of available potassium. The correlation coefficient obtained was calculated as rp=-0.952 (p=0.013), (p<0.05 significance level). In addition, the correlation coefficient between TP, FRAP and DPPH and monthly average wind speed variable was calculated as rp=-0.983 (p=0.003), (p<0.01 significance level), rp=-0.929 (p=0.023), (p<0.05 significance level), rp=-0.970 (p=0.006), (p<0.01 significance level), respectively.

Hierarchical clustering analysis (HCA) is a method known to classify the results obtained in studies according to their similarities. In this study, HCA was performed according to the essential oil ratios, TP, TF and antioxidant activities (FRAP, DPPH) data of *Lavandula* x *intermedia* Emeric ex Loisel. The obtained dendrogram is shown in Figure 1.

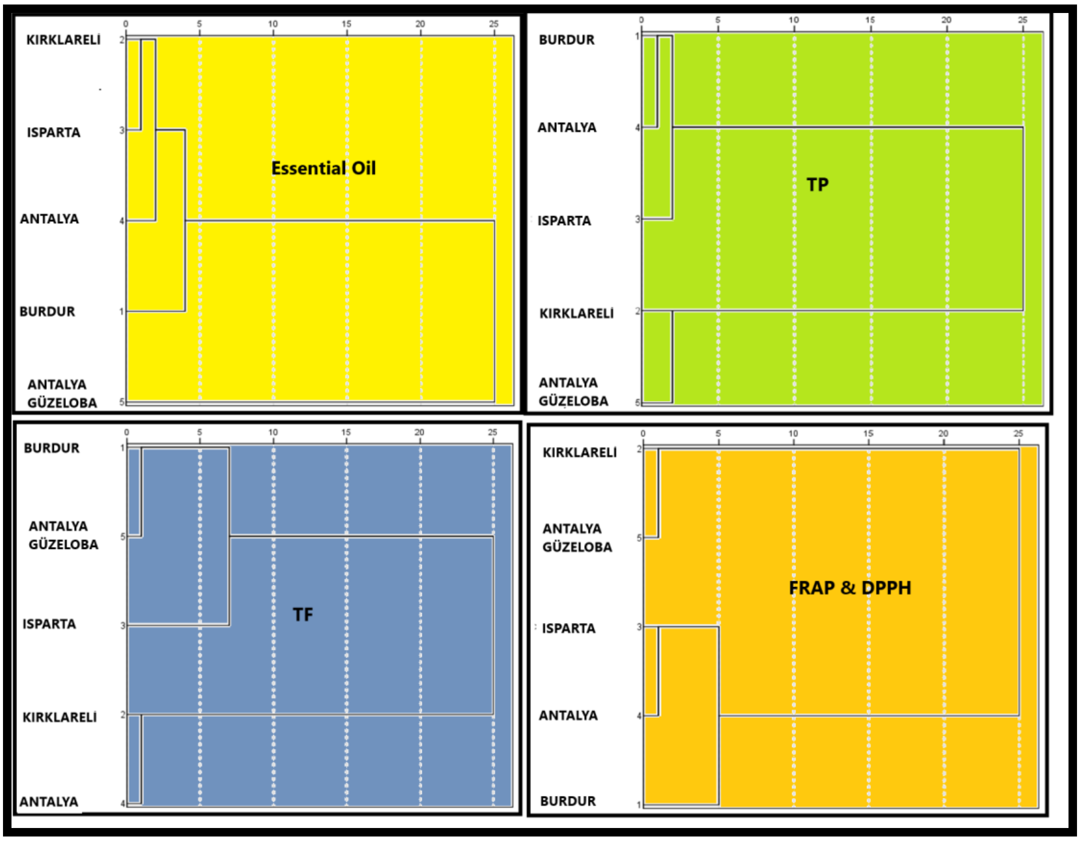

Figure 1. Dendrograms obtained according to essential oil ratio, TP, TF, FRAP and DPPH values of *Lavandula* x *intermedia* Emeric ex Loisel. samples grown in different locations

According to the essential oil ratios of the lavandin samples used in this study, two main groups were observed in the equilibrium obtained. While one of these main groups was formed by the samples obtained from Antalya/Güzeloba location, the other main group was divided into two subgroups and one of these subgroups was divided into two subgroups. When the similarities and differences of the samples used in this study with each other in terms of essential oil ratios were analysed; it was seen that the samples obtained from Kırklareli and Isparta locations were the closest to each other and the samples obtained from Antalya/Güzeloba location were the most distant to these samples. According to the TP values of the lavandin samples used in this study, it was observed that there were two main groups in the equilibrium obtained. These main groups were divided into two sub-groups, and one sub-group was also divided into two sub-groups. When the similarities and differences of the samples used in this study were analysed in terms of TP values, it was seen that the samples obtained from

Antalya and Burdur locations were the closest to each other. In addition, it was observed that there were two main groups in the equilibrium obtained according to the TF values of the samples. These main groups were divided into two sub-groups, and one sub-group was also divided into two sub-groups. When the similarities and differences of the samples used in this study with each other in terms of TF values were analysed; it was seen that the samples obtained from Antalya and Kırklareli locations, Burdur and Antalya/Güzeloba locations were the closest to each other. In addition, it was observed that there were two main groups in the equilibrium obtained according to the antioxidant activity (FRAP and DPPH) values of the samples. These main groups were first divided into two subgroups, and one subgroup was also divided into two subgroups. When the similarities and differences of the samples used in this study in terms of antioxidant activity (FRAP and DPPH) values were analysed, it was seen that the samples obtained from Antalya/Güzeloba and Kırklareli locations were the closest to each other.

4. Conclusion

In this study, *Lavandula* x *intermedia* Emeric ex Loisel. samples grown in Burdur Central district, Kırklareli Babaeski district, Isparta Central district, Antalya Central district and Antalya Güzeloba locality were used as plant material. The similarities and differences of these samples were determined according to their essential oil ratios and essential oil components as well as TP, TF and antioxidant activities (FRAP and DPPH) values. The different climatic and soil characteristics of the localities revealed differences in the parameters evaluated. In addition, some samples were found to be similar to the determined parameters.

According to the HCA analysis between the lavandin samples; it was observed that the samples produced in Kırklareli and Isparta locations were the most similar to each other in terms of essential oil ratios, the samples produced in Antalya and Burdur locations according to TP values, the samples produced in Antalya/Güzeloba and Burdur locations according to TF values, and the samples were grown in Antalya/Güzeloba and Kırklareli locations according to DPPH and FRAP values. Although there were differences between the locations in terms of climate and soil characteristics, many similarities were observed.

When the data obtained in this study are evaluated; according to the essential oil ratio, linalool content, TP, FRAP and DPPH values, the idea that Burdur location is suitable for the cultivation of lavandin plant emerges.

Although the lavandin samples contained different amounts of essential oil components, the main components were observed to be linalyl acetate and linalool. These main components indicate that *Lavandula* x *intermedia* Emeric ex Loisel. samples used in the study may be suitable for use in the perfumery industry, especially if they have lower camphor content. Especially the lowest camphor content was observed in the samples grown in Kırklareli location. This shows that the samples grown in Kırklareli location can be evaluated for lavandin production studies with low camphor content and high linalool content.

Lavandula x *intermedia* Emeric ex Loisel. is known as a plant with high camphor content compared to lavender. Considering that camphor content varies depending on conditions such as environmental conditions, cultivation techniques and harvest time, it is thought that it is possible to obtain higher quality essential oil with lower camphor content from *Lavandula* x *intermedia* Emeric ex Loisel. plants by providing suitable conditions. It has been observed that there are some deficiencies in the literature on *Lavandula* x *intermedia* Emeric ex Loisel. It is important to carry out similar and more comprehensive studies to fill this gap in the literature. It is thought that the studies such as total phenolic matter, antioxidant activity, essential oil ratios and constituents by using *Lavandula* x *intermedia* Emeric ex Loisel. plant material grown in wider locations can fill the deficiencies in this subject to a great extent.

In future studies to be carried out with lavandin plant; more comprehensive researches can be carried out on the reduction of camphor content by considering the effect of environmental factors. In addition, it is thought that researches including more comprehensive quality and content analyses will provide support to the literature in order to expand the usage areas of this plant.

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Conflict of interest

The authors declare that have no competing interests.

Consent for publication

The authors declare that B.G. wrote the manuscript, N.Ö.S. provided the plants, B.G. and N.Ö.S. performed the chemical analyses together, and B.G. performed the statistical analyses.

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