

Antimicrobial potential of essential oils and their chemical components

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(Received in revised form: December 1, 2023)

ABSTRACT

Essential oils (EO) extracted by hydrodistillation from four aromatic plants endemic to the Djebabra region in Algeria (*Eucalyptus globulus*, *Lavandula aspic*, *Pistacia lentiscus* and *Myrtus communis*) were analysed by gas chromatography coupled with mass spectrometry (GC/SM). The obtained results showed that *M. communis* essential oil is the richest in terpinen-4-ol, *L. aspic* in terpenyl, *E. globulus* essential oils in 3-carene, and *P. lentiscus* essential oil in germacrene. In addition, the main bioactive compounds present in the essential oil of myrtle rich in alpha-pinene (57.58 %), limonene (7.38 %) and 1,8 cineole (17.61 %). The essential oil of *Pistacia lentiscus* is rich in α -pinene (18.72 %), limonene (5.90 %) and β -myrcene (36.92 %); eucalyptus essential oil has significant concentrations of p-cymene (19 %), β -phellandrene (11 %) and 1,8 cineole (8.0 %), while the essential oil of lavender is rich in eucalyptol (57.0 %), terpinyl formate (4.0 %), and terpinyl acetate (1.0 %) bioactive compounds, respectively. The obtained results from the in vitro study revealed that most of the essential oils exhibited antimicrobial properties. Among the tested essential oils, *P. lentiscus* and Eucalyptus were discovered to demonstrate the strongest antifungal activity. The recorded MIC of *S. Typhi* NCTC 6017 was 86.3 μ g/mL and 56.1 μ g/mL of *E. coli*, compared to *E. globulus*. Similarly, only *S. aureus* showed antibacterial activity towards *M. communis* (68.4 μ g/mL), *L. aspic* and *E. globulus* (86.3 μ g/mL). Based on the obtained results, it is possible to conclude that four plants endemic essential oil might be used as an ecological antimicrobial in treating infectious diseases caused by the tested pathogens.

Keywords: Antibacterial activity, Chemical composition, Essential oils, *Eucalyptus globulus*, *Lavandula aspic*, MIC, *Myrtus communis*, *Pistacia lentiscus*.

INTRODUCTION

The spread of drug resistant microbial pathogens is one of the most serious threats to successful treatment of infectious diseases (29). Indeed, antibiotic resistance leads to treatment difficulties for previously minor infections and can sometimes lead to situations of therapeutic impasse (absence of active antibiotics). Now, new natural antimicrobial plant sources are being sought. Natural substances from plants have multiple benefits used in food pharmacy, cosmetology and industry. Among these bioactive compounds we find essential oils. Many aromatic and medicinal plants, herbs, and spices have been proposed as a significant source of natural antimicrobials as an alternative to synthetic drugs to treat bacterial infections (31). Myrtle (*Myrtus communis*), eucalyptus (*Eucalyptus globulus*), lavender (*Lavandula aspic* or *latifolia*), and pistachio (*Pistacia lentiscus*) are aromatic and medicinal plants that belong to three different botanical families. With industrial development, especially in the past twenty years, large efforts have been made to identify and quantify these plants' phenolic components (21,23). The essential oils of these plants are rich in α -pinene, 1,8-cineole, α -myrcene, limonene and α -caryophyllene, p-cymene, and -terpinene (4,6,13,24,40). Essential oils (EOs) are volatile, complex compounds

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characterized by a strong odor and are formed by aromatic plants as secondary metabolites. They have been widely used for bactericidal, virucidal, fungicidal, anti-parasitical, anti-septics, anticancer, antioxidant, antidiabetic, cardiovascular, and cosmetic and food applications (3,13,14). Among the various plants with putative pharmacological properties, *Myrtus communis*, *Pistacia lentiscus*, *Eucalyptus globulus* and *Lavandula latifolia* are common in Algeria. Research on extracts of both *Myrtaceae* and *Lamiaceae* family plant chemicals has investigated their composition and their other beneficial properties in in vitro and in vivo experiments (34,39). As they are secondary plant metabolites, the concentration is influenced by genetic and paragenetic factors, so the constant investigation and determination of their concentrations in plants are of high importance (22). In recent decades, *E. coli* and *S. aureus* have been accounted for the most significant number of outbreaks, cases, and deaths worldwide (29). The use of natural antibacterial alternatives appears to be an appealing strategy to regulate the incidence of pathogenic bacteria, hence reducing health hazards and economic losses caused by the emergence of these pathogens (32). This study examined the chemical composition of essential oils of pistachio trees, myrtle, eucalyptus, and lavender as well as their antibacterial properties against pathogenic bacteria including *E. Coli*, *S. aureus*, *S. Typhi*, *B. subtilis* and *C. albicans* in-vitro conditions.

MATERIALS AND METHODS

Plant material

P. lentiscus, *M. communis*, *E. globulus*, and *L. aspic* were collected during February 2023 in Djbabra, 30 km Southeast from Algiers (Latitude: 36.5842. Longitude: 3.27054 36° 35'3"North, 3°16'14" East. The plant parts are deposited in the herbarium of the national higher agronomic school El-Harrach (Algeria).

Essential oils (EOs)

Fractions of each dried plant material (200 g) were submitted to hydrodistillation using an alembic/Clevenger-type apparatus for 3 h as previously described (5). Anhydrous sodium sulfate was used to remove water after extraction. EOs was stored in airtight containers in a refrigerator at 4 °C until GC and GC/MS analyses and biological tests. EOs were diluted in hexane (1/30, v/ v) for GC/FID analysis.

Gas chromatography-flame ionization detector (GC/FID) analysis

Gas chromatography was performed on an Agilent gas chromatograph Model Chrompack CP 9002, equipped with a DB5 MS column (30 m, 0.25 mm, 0.25 µm film thickness). Hydrogen was used as carrier gas (flow 1.0 ml/min). Oven temperature program was from 50 °C (3 min) to 280 °C at 2 °C/min, 1 min post run at 280 °C. Sample (1 mL) was injected in split mode (1:50); injector and detector temperatures were 250 and 280 °C, respectively.

Gas chromatography-mass spectrometry (GC/MS) analysis

EOs were analysed on an Agilent gas chromatograph Model Trace GC Ultra DSQII equipped with a HP5-MS column (30 m 0.25 mm ID 0.25 mm film thickness), programming from 50 °C (5 min) to 280 °C at 3 °C/min, 1min hold. Helium was used as carrier gas (average flow 1.0 ml/min). Oven temperature program was from 50 °C (1.0 min) to 280 °C at 3 °C/ min, 1 min post run at 280 °C. Sample (1 mL) was injected in split mode (1:150); injector and detector temperature were at 250 °C and 280 °C respectively. The MS working in electron impact mode at 70 eV; electron multiplier, 1500 V; ion source temperature,

200 °C; mass spectra data were acquired in the scan mode in m/z range 35-450. Identification is made by comparison of mass spectra with NIST and WILEY databases.

Identification of components

Oil constituents were identified by comparison of their retention indices with those of the literature, determined in relation to a homologous series of n-alkanes (C8-C32) under the same operating conditions. Further identification was made by comparison of their mass spectra with those stored in NIST library (37) or with mass spectra from literature (1). Component relative percentages were calculated based on GC peak areas. The major identified compounds are given in Table 1.

Antimicrobial activity

The antimicrobial activities of the essential oil were evaluated out in vitro against Gram-positive bacteria: *Staphylococcus aureus* ATCC 8739, *Bacillus subtilis* ATCC 6633, Gram-negative bacteria: *Escherichia coli* ATCC 8739, *Salmonella typhi* NCTC 6017 and two yeasts: *Candida Albicans* ATCC 16404, *C. krusei*, microbial inoculums were prepared from overnight broth culture in physiological saline (0.8 % of NaCl) to obtain an optical density ranging from 0.08 to 0.1 at 625 nm. Muller Hinton agar (MHA) was placed in Petri dishes, solidified, and inoculated with the test bacteria. Sterile discs (6 mm) filled with 10 µl of undiluted and diluted essential oil (1/1, 1/2, 1/3 v/v of DMSO) were placed on inoculated agar. DMSO was used as a negative control, and the antibiotic Colistine (30 µg), was used as the positive control. The bacterial growth inhibition was determined as the diameter of the inhibition zones around the discs. All the tests were performed in triplicate. The Petri dishes were incubated at 37 °C for 18 to 24 h aerobically. After incubation, inhibition zone diameters were measured (12). The sensitivity to the essential oil was classified according to the diameter of the inhibition halos as follows: not sensitive (-) for diameters less than 8 mm; sensitive (+) for diameters ranging from 9 to 14 mm; very sensitive (++) for diameters ranging from 15-19 mm and extremely sensitive (+++) for diameters larger than 20 mm (30). The MIC value is the lowest concentration of the natural product that visually inhibits microbial growth. From the tubes without visible growth, 10 µL of solution are removed and spread on Mueller-Hinton agar and incubated for a further 24 h/37 °C to determine the minimum bactericidal concentration (CMB). The absence of colony-forming units (or a growth of less than 0.1 % of the initial inoculum) indicates that the essential oils are bactericidal.

Statistical analysis

The study of variance was used to determine the significant differences between the different treatments (36). Differences between means were tested at through LSD. p-values less than 0.05 are considered significantly different.

RESULTS AND DISCUSSION

Composition analysis of the various essential oils by hydrodistillation, followed by GC/MS and GC/FID analyzes allowed determining the composition of EOs of the four plants. Chromatograms with the identified peaks are shown in Table1. Percentage composition of the oil components (Table 1) revealed a determined number of constituents for the four EOs representing, 93.12, 92.56, 92.0 and 90.0 respectively for *Pistacia lentiscus*, *Myrtus communis*, *Eucalyptus globulus* and *Lavandula aspic*.

Table 1. Chemical composition (in %) of essential oils of the four aromatic plants tested

S N.	Compounds	RT (mn)	Area (%)			
			<i>L. pistacia</i>	<i>M. communis</i>	<i>E. globulus</i>	<i>L. aspic</i>
1	3-Carene	5.721	–	–	5	3
2	Cyclohexene, 4-methylene-1-(1-methylethyl)-	6.373	–	–	1	2
3	Bicyclo[3.1.0]hex-2-ene,4-methyl(1-methylethyl)	6.447	–	–	1	5
4	Cyclohexane, 1-methylene-4-(1-methylethenyl)	6.455	–	–	5	–
5	1,3-Cyclohexadiene, 1-methyl-4-(1-methylethyl)-	7.108	–	–	1	–
6	p-Cymene	7.326	0.35	1.55	19	–
7	Benzene, 1,2,4,5-tetramethyl-	7.354	–	–	–	1
8	[2,5-13C2]-1,3-Cyclopentadiene	7.395	–	–	1	–
9	α -Phellandrene	7.417	1.75	–	14	–
10	5-Methylenespiro [3.5] nonane	7.471	–	–	6	6
11	Eucalyptol	7.506	–	–	8	57
12	gamma-Terpinene	7.823	2.35	0.54	2	1
13	Benzene, 4-ethenyl-1,2-dimethyl-	8.334	–	–	1	1
14	(6,6-Dimethylbicyclo[3.1.1]hept-2-en-2-yl)methyl ethyl carbonate	9.219	–	–	–	1
15	Camphor	9.323	–	–	–	4
16	Isobornyl formate	9.656	–	–	–	4
17	4-Terpinenyl acetate	9.831	–	–	–	1
18	Isobornyl thiocynoacetate	9.860	–	–	5	–
19	2-Cyclohexen-1-one, 4-(1-methylethyl)	10.03	–	–	5	–
20	Terpinyl formate	10.04	–	–	–	2
21	alpha-Thujenal	10.16	0.51	0.28	–	1
22	2-Cyclohexen-1-one, 3-methyl-6-(1-methylethyl)-	11.07	–	–	3	–
23	4-Isopropylcyclohexa-1,3-dienecarbaldehyde	11.55	–	–	3	–
24	alpha-pinene	12.43	18.72	57.58	–	–
25	Camphene	13.06	2.22	0.20	–	–
26	Azulene, 1,2,3,3a-octahydro-1,4-dimethyl-7 [(1.alpha.,3a.beta.,4.alpha.,7.beta.)]	13.91	–	–	1	–
27	Antibiotic NFAT 133	14.59	–	–	2	–
28	Sabinene	14.71	3.50	–	–	–
29	beta-pinene	14.85	6.17	0.65	–	–
30	(1R,5S)-1,8-Dimethyl-4-(propan-2-ylidene)	14.90	–	–	–	1
31	Aromadendrene, dehydro-	15.90	–	–	7	–
32	beta-Myrcene	16.09	36.92	0.23	–	1
33	(3bR,4S,7aS)-7,7,8,8-Tetramethyloctahydro-2,3-bmthanocyclopenta[1.]cyclopropa[1,2]benzen-4-ol	16.22	–	–	1	–
34	Limonene	18.13	5.90	7.38	–	–
35	1.8 Cineole	18.47	–	17.67	–	–
36	beta-Phellandrene	19.58	0.18	–	–	–
37	Terpinolene	22.14	0.83	0.42	–	–
38	Linalol	23.43	0.16	0.86	–	–
39	Terpinène-4.ol	28.74	1.86	0.38	–	–

40	alpha-Terpeneol	29.55	0.35	1.07	–	–
41	Acétate de Borenyl	33.38	0.52	–	–	–
42	Mertenol	36.37	0.66	0.28	–	–
43	Citral	36.94	0.38	–	–	–
44	Eugenol	42.40	0.18	–	–	–
45	Acetate de Myrtenyle	42.91	–	1.67	–	–
46	Acetate de Geranyle	44.21	–	1.30	–	–
47	Béta Caryophyllenne	45.35	3.47	–	–	–
48	Germacrene	49.18	5.64	–	–	–
	Total of identified compound (%)	93.12	92.56	92,0	90,0	93.12

A total of 22 compounds were identified in the EO of *P.lenticus*. The major compounds were identified: β -myrcene (36.92 %), α -pinene (18.72 %), β -pinene (6.417 %), limonene (5.90 %), Germacrene-D (5.64 %). The minor compounds were Limonene (3.69 %), Sabinene (3.50 %), β -Caryophyllene (3.47 %), and γ -Terpinene (2.35 %). These results were comparable to those reported by P Magiatis *et al.* (27)

In the EO of *M. communis*, 20 compounds were identified, among which α -pinene (57.58 %), 1.8-cinéole (17.61 %) and limonene (7.38 %) were the most dominant. The minor components were Myrtenyl acétat (1.67 %), p-Cymene (1.55 %), Geranyl acetat (1.30 %), α -Terpeneol (1.07 %), and β - Caryophyllene (1.03 %). A similar composition has been reported by Y Mohamadi *et al.* (28) but differs from the chemotype isolated by Bettaieb *et al.* (6).

EO of *E. globulus* pointed out 21 compounds, major compounds appear such a sp-cymene(19 %), α -Phellandrene (14 %), Eucalyptol (8 %), Other notable compounds identified in the essential oil were 3-Carene (6 %), Cyclohexane,1-methylene-4-(1-methylethenyl) (5.0 %), γ -terpinène (2,0 %), benzen-4-ol (1.0 %) and Azulene (1.0 %). Although it is different from the chemotype obtained by Harkat-Madouri *et al.* (19) and Boukhatem *et al.* (9), a similar composition has been described by Benabdesslem *et al.*, (7).

Sixteen compounds were identified in the EO of *Lavandula aspic*. Eucalyptol (57.0 %) was the most dominant followed by 5-Methylenespiro (27.28) nonane (6.0 %), Camphor (4.0 %) and bicyclo [3.1.0] hex-2-ene, 4-methyl-1(1methylethyl) and β -Myrcene (1.0 %) were the minor components of this EO. These results were comparable to those reported by (10) described eucalyptol as the main constituents.

Antibacterial activity of the essential oils

This antibiotic resistance has led to a search for new antimicrobial substances of natural origin. Essential oils are known to be rich in bioactive compounds with numerous curative properties (15). All investigated essential oils in our research with their main components exhibit a broad spectrum of antimicrobial activity, which can be principally attributed to α -pinene and 1.8-cineole (myrtus), β -myrcene (pistachio), p-cymene and β -phellandrene (eucalyptus) and eucalyptol (lavender), as active substances. For that purpose we evaluated the antimicrobial activity of EOs we isolated. Among the four plants, compared to pathogenic bacteria (Table 2). The assessment of the antimicrobial activity in essential oils used in our study was determined by the disc diffusion method compared to *E. coli*, *S. aureus*, *S. Typhi*, *B. subtilis*, *C. albicans* and *C. krusei*.

Table 2. Zone of inhibition of essential oils used in the study (mm).

Bacteria	Colistine	Eucalyptus	Lavender	Myrtle	Pistachio
<i>E. coli</i> ATCC 8739	15±0.1	15±0.1	20±0.1	<10	7±0.2
<i>S. Typhi</i> NCTC 6017	11±0.1	14±0.1	20±0.1	10±0.2	NO
<i>S. aureus</i> ATCC 8739	8±0.0	13±0.1	20±0.1	35±0.1	12±0.01
<i>B.subtilis</i> ATCC 6633	10±0.1	12±0.2	25±0.1	14±0.2	12±0.01
<i>C. albicans</i> ATCC 16404	0	25±0.1	18±0.1	14±0.1	35±0.1
<i>C. krusei</i>	0	22±0.1	15±0.1	12±0.0	30±0.1

The essential oil from *P. lenticus* had the weakest antibacterial activity against all bacteria tested with an inhibitory diameter ranging from 7 to 12 mm. The essential oil from the *M. communis* and *L. aspic* was very effective against *S. aureus*, *B. subtilis*, with an inhibitory diameter respectively of 35 mm, and 25 mm. strain has low sensitivity to the essential oils of *P. lenticus*, it was ineffective against *S. typhi* and *E. coli*. The best activities of essential oils against *E. coli* and *S. typhi* are those of *E. globulus* and *Lavender* essential oils. The highest antifungal activity was observed with the *P. lenticus* and *E. globulus* essential oils with an inhibitory diameter ranging from 25 to 35 mm.

The minimum MIC inhibitory concentrations vary from 0.0563 to 0.0964 mg/ml and the minimum bactericidal and fungicidal (CMB and CMF) concentrations vary from 0.0563 to 0.0964 mg/ml. So in general, the essential oils of *M communis*, *E. globulus* and *L. aspic* exhibits remarkable activities with respect to all the strains studied. According to the CMB / MIC and MCF/MCI ratio, the essential oil Lavender, Myrtus and Eucalyptus have bactericidal effects against all the strains tested. *P. lenticus* oil showed moderate to high antifungal activity against the yeasts *Candida albicans* and *Candida. krusei*, but weak to none activity against the Gram-negative bacteria *S. typhi* and *E. coli* (Table 3). Bosnić et al. (8) investigated the antimicrobial activity of sage, rosemary, eucalyptus, melissa, lavender, and thyme essential oils against Gram-positive and Gram-negative bacteria. Based on their findings, it was concluded that the most active essential oils were eucalyptus and rosemary, with the MICs ranging from 0.0561 to 0.0965 mg/ml. The results of Hanamanthagouda, MS. et al., (18) confirmed that lavender essential oil was inhibitory against various bacterial and fungal strains, respectively. In general, it has also been established in numerous studies that the activity of an essential oil is related to the majority compounds and the possible synergistic effects between the constituents.

Table 3. Minimum inhibitory concentrations (MIC) of essential oils (µg/ml)

Bacteria	Eucalyptus		Lavender		Myrtle		Pistachio	
	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
<i>E.coli</i> ATCC 8739	56.1	68.4	56.1	86.3	86.3	96.5	–	–
<i>S.typhi</i> NCTC 6017	86.3	96.5	86.3	96.5	86.3	96.5	–	–
<i>S.aureus</i> ATCC 8739	86.3	96.5	86.3	96.5	86.3	96.5	86.3	96.5
<i>B.subtilis</i> ATCC 6633	68.4	86.3	86.3	96.5	68.4	86.3	86.3	96.5
<i>C.albicans</i> ATCC 16404	56.1	68.4	56.1	68.4	86.3	96.5	86.3	96.5
<i>C. krusei</i>	86.3	96.5	86.3	96.5	–	–	86.3	96.5

Antibacterial tests showed that *Staphylococcus aureus* was the most sensitive bacterium to essential oils of *M. communis*. This activity could be attributed to the presence of high concentrations of α -pinene, limonene and 1.8-cineole, three monoterpenes considered as potential antibacterial and antifungal agents. Many authors have noted an

antibacterial activity of the *M. communis* oils against *S. aureus* (2,16,17, 20,35,41,42). Lis-Balchhin showed that EOs containing large quantities of 1.8-cineole are the best antibacterial agents. The strong antimicrobial activity of eucalyptus and lavender EOs could also be associated with its high content of eucalyptol, p-cymene. Our results show that *C. albicans* is highly sensitive to essential oils of *P. lentiscus*; this strong antifungal activity EO of pistachio could also be associated with its high content of β -myrcene. Eos is considered complex mixtures of numerous chemical molecules. The phenolic components present in EOs have been recognized by several authors for their antimicrobial activity (38). According to studies concerning the mechanisms of antimicrobial action of these molecules, it seems that following a disintegration of the bacterial cell membrane caused by these substances, the escape of intracellular metabolites causes the death of the cell (11, 33). Longaray-Delamare *et al.* (25) attributed the strong antibacterial activity of EOs to the presence of β -caryophyllene, a pistachio compound used in this study. However, additional research will be needed to evaluate the effectiveness of a combination of these Eos.

CONCLUSIONS

Based on the obtained results, it can be concluded that myrtle essential oil is richest in α -pinene, lavender essential oil in 1.8-cineole, eucalyptus essential oil in p-cymene and pistachio essential oil in β -myrcene. Our study showed myrtle essential oil's antibacterial activity towards *S. aureus*, while essential oil pistachio exhibited their antifungal activity towards *C. albicans* and *C. krusei*. The other essential oils exhibited their antimicrobial activity towards *E. coli*, *S. Typhi*, and *B. subtilis*, with the MICs ranging from 0.0561 to 0.0863 mg/ml. Although results showed some potential in the *in vitro* activity of investigated essential oils for pathogenic bacteria, further research *in vivo* conditions is necessary to evaluate the antimicrobial activity of investigated essential oils.

DECLARATION

We declare that all authors of this manuscript made a significant contribution and we have not excluded any author that substantially contributed. We have followed the ethical norms established by our respective institutions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

The authors declare that the study was carried out following scientific ethics and conduct. However, this study did not involve any use of animals, hence no ethical approval has been obtained from the concerned committee.

REFERENCES

1. Adams, D.R.P. (2007). *Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry*. 4th Ed. Allured Publishing Corporation 362 S. Schmale Road Carol Stream. IL. 60188-2787,811.
2. Akin, M., Aktumse, A. and Nostro, A. (2010). Antibacterial activity and composition of the essential oils of *Eucalyptus camaldulensis* Dehn. and *Myrtus communis* L. growing in Northern Cyprus. *African Journal of Biotechnology* **9** (4): 531-535.

3. Bakkali, F., Averbeck, S., Averbeck, D. and Idaomar, M. (2008). Biological effects of essential oils-a review. *Food and Chemical Toxicology* **46**: 446-475.
4. Barra, A., Coroneo, V., Dessi, S., Cabras, P. and Angioni, A. (2007). Characterization of the volatile constituents in the essential oil of *Pistacia lentiscus* L. from different origins and its antifungal and antioxidant activity. *Journal of Agricultural and Food Chemistry* **55**(17): 7093-7098.
5. Bassole, I.H.N., Lamien-Meda, A., Bayala, B., Obame, L.C. and Ilboudo, A.J. (2011). Chemical composition and antimicrobial activity of *Cymbopogon citratus* and *Cymbopogon giganteus* essential oils alone and in combination. *Phytomedicine* **18**(12): 1070-1074.
6. Bettaieb, A., Darej, C. and Moujahed, N. (2016). Myrtle (*Myrtus communis*) essential oil effect on *in-vitro* ruminal fermentation of a diet based on ray-grass and concentrate. *Options Méditerranéenne's A* **115**: 543-548.
7. Benabdesslem, Y., Hachem, K. and Mébarket, M. (2020). Chemical composition of the essential oil from the leaves of *Eucalyptus globulus* Labill. growing in Southwest Algeria, *Journal of Essential Oil Bearing Plants* **23** (5): 1154 - 1160.
8. Bosnić, T., Softić, D. and Grujić-Vasić, J. (2006). Antimicrobial activity of some essential oils and major constituents of essential oils. *Acta Medica Academica* **35**: 9-14.
9. Boukhatem, M.N., Amine, F.M., Kameli, A., Saidi, F., Walid, K.S. and Bouziane, M. (2014). Quality assessment of the essential oil from *Eucalyptus globulus* Labill. of Blida (Algeria) origin. *International Letters of Chemistry, Physics and Astronomy* **17**: 303-315.
10. Călin, J., Pop, G., Gruia, A.T. and Horhat, F.G. (2013). Chemical composition and antimicrobial activity of essential oils of lavender (*Lavandula angustifolia*) and Lavandin (*Lavandula x intermedia*) grown in Western Romania. *International Journal of Agriculture and Biology* **15**(4): 772-776.
11. Cristani, M., D'arrigo, M. and Mandalari, G. (2007). Interaction of four monoterpenes contained in essential oils with model membranes: Implications for their antibacterial activity. *Journal of Agricultural and Food Chemistry* **55**: 6300-6308.
12. Dahiya, P. and Purkayastha, S. (2012). Phytochemical screening and antimicrobial activity of some medicinal plants against multi-drug resistant bacteria from clinical isolates. *Indian Journal of Pharmaceutical Sciences* **74** (5): 443-450.
13. Douissa, F.B., Hayder, N., Chekir-Ghedira, L., Hammami, M., Ghedira, K., Mariotte, A.M., Dijoux-Franca, M.G. (2005). New study of the essential oil from leaves of *Pistacia lentiscus* L. (Anacardiaceae) from Tunisia. *Flavour and Fragrance Journal* **20**(4): 410-414.
14. Edris, A.E. (2007). Pharmaceutical and therapeutic potentials of essential oils and their individual volatile constituents: *Phytotherapy Research* **21**: 308-323.
15. Farzaneh, V. and Carvalho, I.S. (2015). A review of the health benefit potentials of herbal plant infusion and their mechanism of actions. *Industrial Crops and Products* **65**: 247-258.
16. Eliuz-Erdogan, A., Ayas, D. and Goksen, G. (2017). *In-vitro* phototoxicity and antimicrobial activity of volatile oil obtained from some aromatic plants. *Journal of Essential Oil Bearing Plants* **20** (3): 758-768.
17. Fadil, M., Farah, A., Bouchaib, I., Haloui, T., Lebrazi, S. and Rachiq, S. (2017). Intrapopulation variability of *Myrtus communis* L. growing in Morocco: Chemometric investigation and antibacterial activity. *Journal of Applied Research on Medicinal and Aromatic Plants* **7**: 35-40.
18. Hanamantagouda, M.S., Kakkalameeli, S.B., Naik, P.M., Nagella, P., Seetharamareddy, H.R. and Murthy, H.N. (2010). Essential oils of *Lavandula Bipinnata* and their antimicrobial activities. *Food Chemistry* **118**: 836-839.
19. Harkat-Madouri, L., Asma, B., Madani, K., Bey-Ould Si Said, Z., Grenier, D., Allalou, H., Remini, H., Adjaoud, A. and Boulekbache-Makhloufa, L. (2015). Chemical composition, antibacterial and antioxidant activities of essential oil of *Eucalyptus globulus* from Algeria. *Industrial Crops and Products* **78**: 148-153.
20. Hosseinzadeh, H., Khoshdel, M. and Ghorbani, M. (2011). Antinociceptive, anti-inflammatory effects and acute toxicity of aqueous and ethanolic extracts of *Myrtus communis* L. aerial parts in mice. *Journal of Acupuncture and Meridian Studies* **4** (4): 242-247.
21. Ignat, I., Volf, I. and Popa, V.I. (2011). A critical review of methods for characterisation of polyphenolic compounds in fruits and vegetables. *Food Chemistry* **126**: 1821-1835.
22. Jamoussi, B., Romdhane, M.; Abderraba, A., Hassine, B.B. and Gadri, A.E. (2005). Effects of harvest time on the yield and composition of Tunisian Myrtle oils. *Flavour and Fragrance Journal* **20**: 274-277.
23. Joana Gil-Chávez, G., Villa, J.A., Ayala-Zavala F., Basilio-Heredia, J., Sepulveda, D., Elhadi, M.Y. and González-Aguilar, G A. (2013). Technologies for extraction and production of bioactive compounds to be used as nutraceuticals and food ingredients: *Comprehensive Reviews in Food Science and Food Safety* **12**: 5-23.

24. Koutsoudaki, C., Krsek, M. and Rodger, A. (2005). Chemical composition and antibacterial activity of the essential oil and the gum of *Pistacia lentiscus* Var. chia. *Journal of Agricultural and Food Chemistry* **53(20)**: 7681-7685.
25. Longaray-Delamare, A.P., Moschen-pistorello, I.T. and Artico, L. (2007). Antibacterial activity of the essential oils of *Salvia officinalis* L. and *Salvia triloba* L. cultivated in South Brazil. *Food Chemistry* **100(2)**: 603-608.
26. Lis-Balchhin, M. and Deans, S.G. (1997). Bioactivity of selected plant essential oils against *Listeria monocytogenes*. *Journal of Applied Microbiology* **82**: 259-262.
27. Magiatis, P., Melliou, E., Skaltsounis, A.L., Chinou, I.B., Mitaku, S. (1999). Chemical composition and antimicrobial activity of the essential oils of *Pistacia lentiscus* var. chia: *Planta Medica* **65(8)**: 749-752.
28. Mohamadi, Y., Lograda, T., Ramdani, M. and Figueredo, G. and Chalard, P. (2021). Chemical composition and antimicrobial activity of *Myrtus communis* essential oils from Algeria. *Biodiversitas Journal of Biological Diversity* **22(2)**: 222-238.
29. Owlia, P., Saderi, H., Rasooli, I. and Sefidkon, F. (2009). Antimicrobial characteristics of some herbal oils on *pseudomonas aeruginosa* with special reference to their chemical compositions. *Iranian Journal of Pharmaceutical Research* **8(2)**: 107-114.
30. Ponce, A.G., Fritz, R., Del Valle, C. and Roura, S.I. (2003). Antimicrobial activity of essential oils on the native microflora of organic Swiss chard. *Lebensmittel-Wissenschaft und Technologie. LWT-Food science and Technology* **36 (7)**: 679-684.
31. Puva'ca, N., Lika, E., Tufarelli, V., Bursi'c, V., Peli'c, D.L., Nikolova, N., Petrovi'c, A., Prodanovi'c, R., Vukovi'c, G., Levi'c, J. (2020). Influence of different tetracycline antimicrobial therapy of mycoplasma (*Mycoplasma synoviae*) in laying hens compared to tea tree essential oil on table egg quality and antibiotic residues. *Sustainability* **12**: 3420.
32. Puva'ca, N., Stana'cev, V., Glamo'ci'c, D., Levi'c, J., Peri'c, L., Stana'cev, V. and Mili'c, D. (2013). Beneficial effects of phyto-additives in broiler nutrition. *World's Poultry Science Journal* **69**: 27-34.
33. Rasooli, I., Bagher-Rezaei, M. and Allameh, A. (2006). Ultrastructural studies on antimicrobial efficacy of thyme essential oils on *Listeria monocytogenes*. *International Journal of Infectious Diseases* **10(3)**: 236-241.
34. Romero-Rocamora, C., Ramasamy, K., Meng-Lim, S., Madjeed, A.B.A. and Agatonovic-Kustrin, S. (2020). HPTLC based approach for bioassay-guided evaluation of antidiabetic and neuroprotective effects of eight essential oils of the Lamiaceae family. *Journal of Pharmaceutical and Biomedical Analysis* **30**: 178.
35. Salvagnini, L.E., Oliveira, J.R.S., Dos Santos, L.E., Moreira, R.R. and Pietro, R.C.L.R. (2008). Evaluation of the antibacterial activity of *Myrtus communis* L. (Myrtaceae) leaves. *Revista Brasileira de Farmacognosia* **18 (2)**: 241-244.
36. SPSS (1995). *SPSS for Windows*, 6.1.2. SPSS Inc., Chicago, IL.
37. Stein, S., Mirokhin, D., Tchekhovskoi, D. and Mallard, G. (2002). *The NIST Mass Spectral Search Program for the NIST/EPA/NIH Mass Spectra Library*; Standard Reference Data Program of the National Institute of Standards and Technology. Gaithersburg, MD, USA.
38. Tajkarimi, M.M., Ibrahim, S.A. and Cliver, D.O. (2010). Antimicrobial herb and spice compounds in food. *Food Control* **21**: 1199-218.
39. Usai, M., Marchetti, M., Culeddu, N. and Mulas, M. (2018). Chemical composition of myrtle (*Myrtus communis* L.) berries essential oils as observed in a collection of genotypes. *Molecules* **23(10)**: 2502.
40. Zrira, S., Elamrani, A. and Benjlali, B. (2003). Chemical composition of the essential oil of *Pistacia lentiscus* L. from Morocco-a seasonal variation. *Flavour and Fragrance Journal* **18(6)**: 475-480.
41. Yadegarinia, D., Gachkar, L., Rezaei, M.B., Taghizadeh, M., Astaneh, S.A. and Rasooli, I. (2006). Biochemical activities of Iranian *Mentha piperita* L. and *Myrtus communis* L. essential oils. *Phytochemistry* **67 (12)**: 1249-55.
42. Zomorodian, K., Moein, M., Lori, Z.G., Ghasemi, Y., Rahimi, M.J., Bandegani, A., Pakshir, K., Bazargani, A., Mirza-Mohammadi, S. and Abbasi, N. (2013). Chemical composition and antimicrobial activities of the essential oil from *Myrtus communis* leaves. *Journal Essential Oil bearing plants* **16(1)**: 76-84.

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