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Chemical composition of essential oil, FTIR, phytochemical profile of crude extract and biological activity of *Pistacia lentiscus* from Algeria

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Pistacia lentiscus L. (Anacardiacae) has been known in Algeria since ancient times for its medicinal properties. The purpose of the present study was to identify the chemical composition of the essential oil of *P. lentiscus* leaves growing in Chlef region using GC-MS. The plant organic fractions of the leaf powder were investigated by FTIR, determination of total phenolic and total flavonoids content, evaluation of antioxidant activity and antimicrobial activity of the methanolic extract. The essential oil was rich in thirty-nine compounds. Limonene (17.7%) and α-pinene (15.8%) were the major components detected. The FTIR results showed a fairly wide and significant characteristic band of the -OH hydroxyl function group. TPC and TFC were determined to be 173.79 µg GAE/mg, and 58.73 µg QE/mg, respectively. The antioxidant activity was found to be IC_{50} = 14.90 µg/mL. The antimicrobial results, MIC, MBC, and MFC measurements indicated that *P. lentiscus* exhibited significant antimicrobial and antifungal activities. Overall, these data indicate that *P. lentiscus* leaves may be used for pharmaceutical application, nutraceutical and functional food industries.

Keywords: *Pistacia lentiscus*; GC-MS; FTIR; secondary metabolites; antioxidant activity; antimicrobial activity.

Introduction

Medicinal plants are an extraordinary treasure trove of new preventive and therapeutic molecules, the most important elements of which are alkaloids, flavonoids, vitamins, tannins, essential oils, organic acids, resins, fatty acids, saponins and polysaccharides (Rawani et al., 2011). Essential oils from different plant species are known for their various biological activities and they can be used for food preservation and other pharmacological applications (Tiwari et al., 2009). This renewed interest has been reflected in a number of recent decades in the antimicrobial and antioxidant properties of a variety of essential oils and extracts using a wide range of *in vitro* and *in vivo* techniques (Burt, 2004; Holley & Patel, 2005). Algeria has a remarkable plant diversity, estimated at nearly 4000 taxa (Miara et al., 2018). However, the medicinal flora is losing importance as little research has been done on its significance (Baba Aissa, 2000; Hamel et al., 2018). Local plants include *P. lentiscus* L. (Anacardiacae), known by different names in different regions in Algeria. *P. lentiscus* is a branched, perennial shrub up to three meters high, with a strongly pungent, resinous odor. It has thick, shiny, dark-green evergreen leaves, bearing short auxiliary clusters of small fruits that turn black when ripe. Flowering takes place between April and June, and fruiting between October and November. This plant is particularly representative of the hottest environments in the Mediterranean climatic zone (Smail-Saadoun, 2005). Numerous studies on essential oils have been carried out on *P. lentiscus* leaves from different origins (Fernandez et al., 2000; Zrira et al., 2003). The aerial part is traditionally used as a stimulant due to its diuretic properties and for the treatment of hypertension, cough, sore throat, eczema, abdominal pain, kidney stones, and jaundice (Palevitch & Yaniv, 2000).

In order to promote Algerian medicinal plants, the present work was carried out with the aim of enhancing the value of *P. lentiscus* through characterization of the essential oil by gas chromatography-mass spectrometry (GC-MS), Fourier transform infrared spectroscopy (FTIR) to determine plant organic fractions, phytochemical screening, determination of total phenolic content (TPC) and total flavonoids contents (TFC), evaluation of the antioxidant and antimicrobial activity of methanolic extract.

Materials and methods

The *P. lentiscus* leaves (Fig. 1) were freshly harvested in Ghansou forest, the region of Taougrite, Chlef (Northwest Algeria, 36.2802810° N, 0.9336096° W) in September 2022. After drying for 7 days at room temperature, in a dry, airy and shady place, the samples were recovered in clean bags and stored away from light and moisture.

Fig. 1. Vegetative parts of *P. lentiscus*

The dried plant leaves (100 g) were steam distilled in a Clevenger apparatus with 1 L of deionized water for 3 h. The extracted essential oil was collected and dried over anhydrous sodium sulfate (Na_2SO_4) and stored in dark sealed vials at 4 °C before further studies.

The analyses of essential oil were carried out in Centre for Scientific and Technical Research in Physical and Chemical Analysis (PTAPC-CRAPC)-Laghouat- Algeria by SHIMADZU GCMS-QP2020 Instruments, equipped with a fused Rxi®-5ms capillary column (Phase: Crossbond® 5% diphenyl / 95% dimethyl polysiloxane) its dimensions are: 30 m × 0.25 mm and 0.25 µm film thickness, this column has similar phase to the following columns: HP-1ms, HP-1msUI, DB-1ms, DB-5ms, DB-1msUI, Ultra-1, VF-1ms, ZB-1, ZB-1ms and considered also equivalent to USP G1, G2, G38 phases. A volume of 0.5 µL of sample was injected in split mode (1:50). Injector and detector temperatures

were maintained at 250 and 310 °C, respectively the column temperature was programmed at: 50 °C fixed for 2 min then increased to 310 °C with an increase increment of 3 °C/min, and then maintained at 310 °C for 2 min. The carrier gas used was helium (99.995% purity) with a flow rate of 1 mL/min. The mass spectrometer conditions were as follows: ionization voltage 70 eV, in source temperature 200 °C, and electron ionization mass spectra were acquired over the mass range of 45–600 m/z.

Linear retention indices (LRI) were calculated for separate compounds relative to a homologous n-alkanes serial (n-C_8-C_{33}). Components were identified by comparison of their calculated (LRI) with those in the literature (Babushok et al., 2011), (book of Adams Robert P, 2017, ed.4.1) as well as their mass spectra with those recorded by the NIST (National Institute of Standards and Technology) and Wiley libraries "NIST17.lib, W11N17MAI and FFNSC1.2.lib".

Infrared analysis of powdered *P. lentiscus* leaves was carried out using a Shimadzu FTIR – 8400 spectrometer, a technique used to identify functional groups present in a sample. We carried out Fourier transform infrared spectroscopy using the KBr technique over a wavelength range of 400–4000 cm^{-1}.

P. lentiscus leaves were ground into powder (10 g was macerated with 100 mL methanol (three times) at room temperature for 24 to 48 h. The extract was filtrated and evaporated under a vacuum to obtain crude extract (Ertaş et al., 2021).

The study included phytochemical analysis using methanol filtrate prepared from plant fine powder. Solubility, precipitation, and color reaction tests were required for identification of chemical families in the qualitative study of *P. lentiscus* leaves. Several chemical groups were characterized using the methods described by Bruneton (1999), Majob et al. (2003), Karumi et al. (2004), Edeoga et al. (2005), Oloyede (2005), N'Guessan et al. (2009).

Total polyphenols of the leaf extracts were determined by the Folin-Ciocalteu reagent following the method of Heilerová et al. (2003) using gallic acid as the standard phenolic compound. 0.2 mL of the extract was added with 2.5 mL of the diluted Folin-Ciocalteu reagent. The mixture was left to stand for 2 minutes in the dark. Subsequently, 2 mL of Na_2CO_3 solution (7.5%) was added to the set. The entire mixture was heated to 60 °C for 20 minutes, then allowed to cool (ice) to read the absorbance, which was measured at 750 nm against a blank without extract using a spectrophotometer (UV-1600 PC). The quantification of polyphenols was based on a linear calibration curve performed by gallic acid at different concentrations under the same conditions as the sample. Total phenolic content was expressed in µg gallic acid equivalent (GAE).

The $AlCl_3$ method was used to determine the extract content of total flavonoids (Huang et al., 2004) using quercetin as the standard flavonoid compound. A millilitre and a half of the extract were added to an equal volume of a 2% $AlCl_3$ solution. The mixture was vigorously stirred, and the absorbance was read at 430 nm, after 30 minutes of incubation at room temperature. A calibration curve performed by quercetin at different concentrations performed under the same operating conditions as the samples was used for the quantification of flavonoids. The amount of total flavonoid was expressed in µg quercetin equivalent (QE).

The DPPH free radical scavenging activity of *P. lentiscus* methanolic extract was performed using the developed method of Blois (1958), 250 µL of the sample solution at different concentrations was added to 1750 µL of DPPH methanol solution (0.1 mM), the mixture was kept at room temperature for 30 minutes in the dark, after which absorbance was measured at 517 nm using a spectrophotometer (UV-1600 PC). Ascorbic acid was used as the standard antioxidant compound.

The antiradical activity was calculated using the following formula:

DPPH free radical scavenging activity (%) =

[(Acontrol – Asample) /Acontrol] x100

Where aAcontrol is the absorbance of the DPPH solution and Asample is the absorbance of the DPPH solution after the addition of the sample.

Scavenging effect values were expressed as IC_{50} (µg/mL), which represents the effective extract concentration of the sample antioxidant required to scavenge 50% of the DPPH radical in the mixture and calculated from the calibration curve. DPPH scavenging activity is best represented by a lower IC_{50} value.

The antimicrobial activity of *P. lentiscus* methanolic extract was tested on the following strains (American Type Culture Collection (ATCC) reference strains): *Escherichia coli* ATCC 8739, *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 6538, *Bacillus cereus* ATCC 14579, *Candida albicans* ATCC 10231, and *Candida albicans* ATCC 10237 using the diffusion well method according to a modification of the method described by Vardar-Ünlü et al. (2003).

The cells were resuspended in saline ($2x10^8$ cells/mL for bacteria (0.5 Mc Farland) and 10^6 cells/mL for *Candida*) and placed with a sterile cotton swab on a Petri dish containing Mueller-Hinton agar (MH) for bacteria and Sabouraud Dextrose Agar (SDA) for *C. albicans*. Wells of approximately 6 mm in diameter were made in the agar. Each well received 50 µL of the extract (we prepared a range of concentrations of 25, 50, 100, and 200 mg/mL dissolved in dimethylsulfoxide (DMSO)). The Petri dishes were incubated for bacteria at 35 ± 1 °C for 24 h and *C. albicans* at 37 °C for 24 h. Each experiment was repeated three times under the same experimental conditions. Antimicrobial activity was determined by measuring the diameter of the inhibition zone in millimeters (mm). Positive controls included amoxicillin (AMC) 30 µg, cephalexin (CN) 10 µg, cefazolin (CZ) 30 µg, and cefoxitin (FOX) 30 µg.

Minimum inhibitory concentration (MIC) was the lowest concentration of the methanolic extract that showed no visible bacterial growth (no color change of TTC) after the incubation period. The MIC was determined using the Mueller-Hinton broth microdilution method using 96-well plates (Okusa et al., 2007).

The minimal bactericidal concentration (MBC) and minimal fungicidal concentration (MFC) were considered as the lowest concentration of methanolic extract that killed 99.9% of microorganisms in culture on the agar plate after incubation period. The MBC and MFC were determined by plating directly the content of wells with concentrations higher than the MIC value. The MBC and MFC values were determined when there was no colony growth from the directly plated contents of the wells.

All bioactivity results are the mean of three independent studies. Data are reported as mean ± standard error (x ± SE).

Results

The yield of oil obtained by hydro-distillation of *P. lentiscus* leaves is given as 0.1 % on a dry weight basis. The chemical profile of volatile fractions and the relative content of detected components of *P. lentiscus* are reported in Table 1 and Figure 2. Thirty-nine compounds were identified, accounting for 96.49% of the total chemical composition. According to the global chromatographic analysis of *P. lentiscus* oil, there is a complex mixture that is mostly composed of mono- and sesquiterpenes. It was dominated by monoterpene hydrocarbons (66.62%) and sesquiterpenes hydrocarbons (16.98%), while oxygenated mono- and sesquiter-penes were only present in a small percentage (respectively 4.27% and 3.44%). The major components detected in the oil were limonene (17.70%), α-pinene (15.80%), myrcene (7.97%), β-pinene (7.23%) followed by caryophyllene (5.64%) and γ-terpinene (5.19%).

FTIR analysis was used to identify the functional groups present in *P. lentiscus* powder. The spectrum obtained shows several characteristic absorption bands, indicating the presence of different functional groups (Table 2, Fig. 3), three intense bands are observed, a fairly broad and important characteristic band in the frequency range 3271–3350 cm^{-1} which characterizes an elongation band of the hydroxyl function -OH, an elongation band characteristic of nitro compounds -NO appears in the frequency range 1539 cm^{-1} and an intense band at 1035 cm^{-1} shows the presence of an alkene (the double bond).

Methanolic extract of *P. lentiscus* leaves was rich in various secondary metabolites according to phytochemical analyses (Table 3). A strongly positive reaction was seen, pointing to the existence of phenolic compounds, flavonoids, tannins, quinones and terpenoids. A small amount of saponins, anthraquinones, reducing compounds, alkaloids, oses and holosides were also detected.

Total phenolic, flavonoids, and antioxydant activity of P. lentiscus. The total phenolic and flavonoids content in *P. lentiscus* methanolic extract was 173.79 ± 0.15 µg GAE/mg, and 58.73 ± 0.08 µg QE/mg),

respectively (Table 4). *P. lentiscus* methanolic extract showed a significant increase in antioxidant activity, even at very low concentrations, and the DPPH scavenging capacity reached 97.46% at 62.5 µg/mL concentration. As shown in Table 4, the antioxidant capacity of *P. lentiscus* was (IC_{50} = 14.90 ± 0.09 µg/mL), which remains inferior to ascorbic acid used as reference antioxidant (IC_{50} = 3.25 ± 0.06 µg/mL).

Table 1
Chemical composition of the essential oil of *P. lentiscus* leaves growing in Algeria

No.	Component	R. time	Similarity R	%	Index
1	Tricyclene	8.154	96	0.38	915
2	α-Pinene	8.639	99	15.80	927
3	Camphene	9.156	97	1.85	940
4	Sabinene	10.171	97	0.79	966
5	β-Pinene	10.299	97	7.23	969
6	Myrcene	10.944	98	7.97	985
7	α-Phellandrene	11.452	96	1.82	998
8	α-Terpinene	11.986	97	2.39	1010
9	ρ-Cymene	12.329	97	2.03	1018
10	Limonene	12.560	96	17.70	1023
11	E-β-Ocimene	13.417	98	1.29	1042
12	Isopentyl butanoate	13.766	99	0.65	1050
13	γ-Terpinene	13.882	97	5.19	1052
14	Terpinolene	15.215	95	2.18	1082
15	2-Nonanone	15.378	98	0.62	1085
16	2-Nonanol	15.797	82	0.26	1095
17	Isopentyl isovalerate	16.030	96	0.32	1100
18	Terpinen-4-ol	19.324	95	3.02	1171
19	α-Terpineol	19.937	97	0.98	1184
20	Carvone	22.363	96	0.27	1237
21	Isoamyl hexanoate	22.708	97	0.26	1245
22	Bornyl acetate	24.300	97	1.49	1280
23	2-Undecanone	24.661	98	1.07	1288
24	β-Elemene	28.973	92	0.45	1386
25	Caryophyllene	30.138	97	5.64	1414
26	Isoamyl Benzoate	30.802	97	0.51	1430
27	α-Humulene	31.534	97	1.06	1447
28	γ-Muurolene	32.496	97	0.65	1471
29	(-)-Germacrene D	32.675	97	3.17	1475
30	Viridiflorene	33.257	91	0.38	1489
31	α-.Muurolene	33.460	97	0.89	1494
32	(E,E)- α – Farnesene	33.769	95	1.03	1501
33	γ-Cadinene	34.001	96	0.39	1507
34	Δ- Cadinene	34.386	95	3.32	1517
35	Caryophyllene oxide	36.684	88	0.51	1576
36	1-epi-Cubebol	38.411	92	0.29	1622
37	τ- Cadinol	38.922	93	1.30	1636
38	Alloaromadendrene epoxide	39.077	95	0.27	1640
39	τ- Muurolol	39.381	93	1.07	1648
	Total identified (%)			96.49	
	Essential oil content (%, v/w)			0.1	
	Monoterpene hydrocarbons			66.62	
	Oxygenated monoterpenes			4.27	
	Sesquiterpene hydrocarbons			16.98	
	Oxygenated sesquiterpenes			3.44	
	Others			5.18	

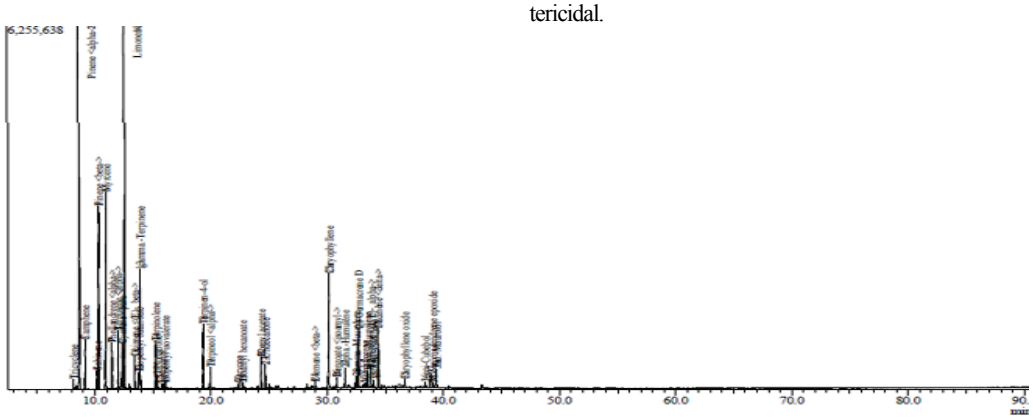


Fig. 2. GC-MS chromatogram of *P. lentiscus* essential oil

Table 2
Peak correspondence of P. lentiscus powder FTIR spectra

Wavenumber (cm^{-1})	Function group	Abbreviation	Vibration modes
3271–3350	O-H of the hydroxyls group	v(O-H)	stretching
2920	C-H of -CH_2- of alkanes	vas(CH_2)	stretching (asymmetric)
2850	C-H of -CH_2-	vs(CH_2)	stretching (symmetric)
1614	N-H of amide I	δ(N-H)	bending
1539	N-O of nitro compounds	vas(N-O)	stretching (asymmetric)
1446	C-C of aromatics	v(C-C)	stretching
1319	N-O of nitro compounds	vs(N-O)	stretching (symmetric)
1234	-CH_2- of methylenes	δ(CH_2)	bending
1147	C-O of esters	v(C-O)	stretching
1035	=C-H of Alkenes	v(C-H)	bending
763	C-H aromatic ring	–	deformation

Table 3
Phytochemical screening of *P. lentiscus* methanolic extract

Compounds		*P. lentiscus*
Phenolic compounds		+++
Flavonoids		+++
Tannins (Gallic)		+++
Saponins		+
Quinones		+++
Anthraquinones		+
Terpenoids		+++
Reducing compounds		+
Alkaloids	Mayer	+
	Wagner	+
Oses and holosides		+

Note: (+++) strongly positive reaction, (++) positive reaction, (+) weakly positive reaction.

The results of antimicrobial activity, MIC, MBC and MFC of the methanol extract of leaves of *P. lentiscus* are illustrated in (Tables 5 and 6, Figures 4 and 5). Significant antibacterial and antifungal activity was observed in *P. lentiscus* with different inhibitory diameters. The bacterial and fungal strains tested were sensitive to all concentrations of 25, 50, 100 and 200 mg/mL. *P. lentiscus* showed the highest activity against *C. albicans* ATCC 10237 and *E. coli* ATCC 25922 with a diameter of 24.0 and 19.7 mm respectively. The antibiogram results of this study showed that there are strains such as *S. aureus* ATCC 6538 and *B. cereus* ATCC 14579 which are resistant to the FOX antibiotic, and highly sensitive strains such as *E. coli* ATCC 8739 and *E. coli* ATCC 25922. The minimum inhibitory concentration (MIC) values for the methanolic extract reveal the lowest concentration against *E. coli* ATCC 8739, *E. coli* ATCC 25922, *B. cereus* ATCC 14579 and *C. albicans* ATCC 10237 with a MIC value of 12.5 mg/mL. The MBC and MFC values were found to be <50 mg/mL for all the tested strains. The MBC/MIC ratio was <2 for *S. aureus* ATCC 6538, <4 for the other strains. The MFC/MIC ratio was <2 for *C. albicans* ATCC 10231, and 4 for *C. albicans* ATCC 10237. Based on these findings, it was believed that the leaves of *P. lentiscus* assayed in a methanolic extract were bactericidal.

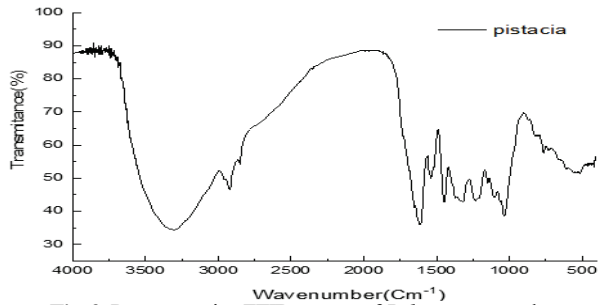


Fig. 3. Representative FTIR spectra of *P. lentiscus* powder

Discussion

The yield of essential oil obtained from the leaves of *P. lentiscus* (0.1%) in this study is in accord with previous works (Castola et al., 2000; Dob et al., 2006), while Benhammou & Atik Bakkara (2009) have found that the oil yield was very low in the order of 0.05% and 0.07% in Tlemcen region. The quantity found is low compared to those described in the literature in Morocco 0.23% (Aouinti et al., 2013), Italy 0.45% (Barra et al., 2007), Turkey 0.30% (Duru et al., 2003).

The GC–MS chromatograms of the essential oil of *P. lentiscus* shows that 67 compounds were identified, the major components detected in the oil were limonene (17.7%), α-pinene (15.8%). Similar results were also reported by Ismail et al. (2012) showing that the major components detected in the oil were α-pinene (20.6%), limonene (15.3%), β-pinene (9.6%). The results revealed by the study of (Ben Douissa et al., 2005) showed also the abundance of α-pinene 17%, δ-terpinene (9%) and terpen-4-ol (12%), while a low amount of limonene was present. However, other reports show that β-myrcene was the major compound of essential oils from Algeria (Mecherara-Idjeri et al., 2008) and France (Castola et al., 2000). On the other hand, Dob et al. (2006) showed that longifolene was the main component of Algiers and Tizi-Ouzou oils (12.8% and 16.4%, respectively), while α-pinene was the major constituent of the Oran oil (19.0%). According to Drioiche et al. (2023) spathulenol (18.57%), germacrene D (17.54%), bicyclogermacrene (12.52%), and terpinen-4-ol (9.95%) dominated. Chaabani et al. (2020) also reported the domination of germacrene D (16.58%) of the essential oil extracted from *P. lentiscus* leaves in Tunisia.

Table 4
Total phenolic content (TPC), Total flavonoid content (TFC) and IC_{50} values of DPPH assay of *P. lentiscus* leaves extract

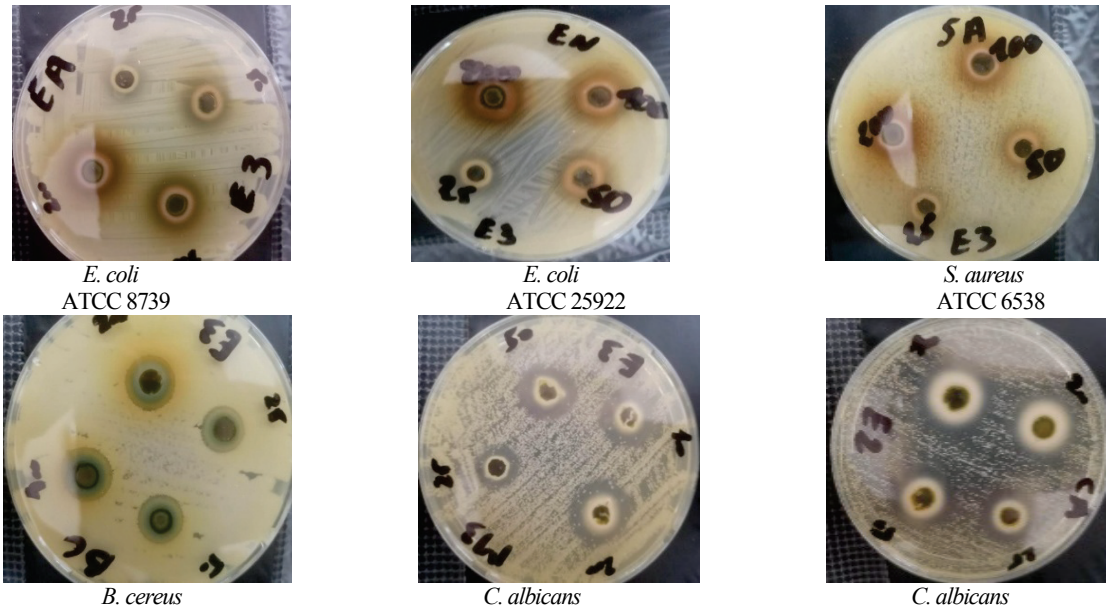
Methanolic extract	Yield, %	TPC, µg GAE/mg extract	TFC, µg QE/mg extract	IC_{50}, µg/mL	
				extract	ascorbic acid
P. lentiscus	37.8	173.79 ± 0.15	58.73 ± 0.08	14.90 ± 0.09	3.25 ± 0.06

Table 5
Antimicrobial activity of *P. lentiscus* methanolic extract

Strains	Inhibition zone diameter, mm							
	Concentration of methanolic extract leaves, mg/mL				antibiotics			
	25	50	100	200	AMC	CN	CZ	FOX
E. coli (ATCC 8739)	12.0 ± 0.66	15.7 ± 0.44	17	17.3 ± 0.44	28	22	29	22
E. coli (ATCC 25922)	15.7 ± 0.44	18.0 ± 0.66	19.0 ± 0.66	19.7 ± 1.11	20	20	28	22
S. aureus (ATCC 6538)	11.7 ± 0.44	13	15	16	17	15	13	R
B. cereus (ATCC 14579)	12.7 ± 1.11	13.7 ± 0.44	14.7 ± 0.44	15.3 ± 1.11	14	25	10	R
C. albicans (ATCC 10231)	12.3 ± 1.55	15.7 ± 0.44	17.3 ± 0.44	19.0 ± 0.66	–	–	–	–
C. albicans (ATCC 10237)	19.3 ± 1.77	19.7 ± 1.77	24.0 ± 0.66	24.0 ± 1.33	–	–	–	–

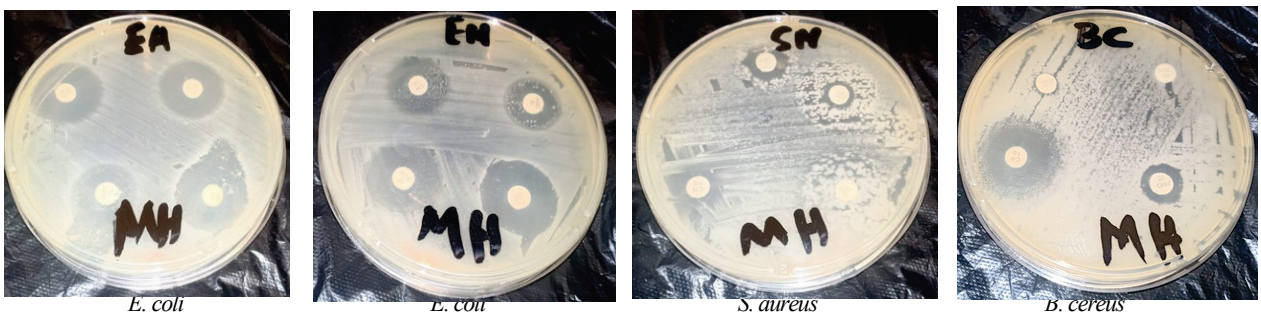
Table 6
The MIC, MBC, and MFC (mg/mL) of *P. lentiscus* methanolic extract

Strains	MIC, mg/mL	MBC, mg/mL	MFC, mg/mL	MBC/MIC ratio	MFC/MIC ratio
E. coli (ATCC 8739)	12.5	<50	–	<4	–
E. coli (ATCC 25922)	12.5	<50	–	<4	–
S. aureus (ATCC 6538)	25.0	<50	–	<2	–
B. cereus (ATCC 14579)	12.5	<50	–	<4	–
C. albicans (ATCC 10231)	25.0	–	<50	–	<2
C. albicans (ATCC 10237)	12.5	–	50	–	4



E. coli ATCC 8739 | *E. coli* ATCC 25922 | *S. aureus* ATCC 6538
B. cereus ATCC 14579 | *C. albicans* ATCC 10231 | *C. albicans* ATCC 10237

Fig. 4. Antibacterial activity of *P. lentiscus* methanolic extract against the tested strains, diameter of inhibition zone (mm) for the concentration range of 25, 50, 100, and 200 mg/mL



E. coli ATCC 8739 | *E. coli* ATCC 25922 | *S. aureus* ATCC 6538 | *B. cereus* ATCC 14579

Fig. 5. Antibacterial activity of antibiotics against the tested strains: amoxicillin (AMC) 30 µg, cefalexin (CN) 10 µg, cefazolin (CZ) 30 µg and cefoxitin (FOX) 30 µg

These differences between the yield and main components of the oils extracted from *P. lentiscus* can be explained by differences in climate conditions, geographical location, harvesting period and distillation techniques (Lahlou, 2004). It should also be noted that the production of essential and aromatic oils from plants is the result of a series of physiological, biochemical, metabolic and genetic regulations (Costa et al., 2003).

The FTIR analysis of *P. lentiscus* powder shows that the plant has characteristic peaks with different intensities, three intense bands are observed, a fairly broad and important characteristic band in the frequency range 3271–3350 cm^{-1} which characterizes an elongation band of the hydroxyl function -OH. These findings aid in a better comprehension of the plant's chemical composition and potential properties. Our observations are in accordance with previous work on *P. lentiscus* for extracts (Mehenni et al., 2016; Mokhfi et al., 2024) and for essential oils (Beraich et al., 2024).

The analysis of plant powder could show a combination of different natural components, while extracts could offer a more concentrated view of specific functional groups. Comparisons with the literature show that the results we obtained are in agreement with the data available for essential oils and extracts of *P. lentiscus*, validating the presence of these functional groups in our powder sample. The significant presence of these functional groups is necessary for the characterization of bioactive compounds in the plant.

Phytochemical screening shows that *P. lentiscus* is rich in secondary metabolites, and these results are in line with what has been demonstrated in previous phytochemical studies (Bammou et al., 2015; Beghlal et al., 2016; Mechqoq et al., 2022).

Total phenolic and flavonoid content in *P. lentiscus* methanolic extract was 173.79 ± 0.15 µg GAE/mg, and 58.73 ± 0.08 µg QE/mg, respectively. Previous studies of total phenolic content of *P. lentiscus* revealed higher values than those we have obtained (Amessis-Ouchemoukh et al., 2014; Bouriche et al., 2016; Belhachat et al., 2017; Belabbas et al., 2023), on the other hand, Azib et al. (2019) showed a lower value 95.8 mg GA Eq/g. Our result for total flavonoids content of *P. lentiscus* was inconsistent with previous studies, which report lower values than those we obtained (Cheurfa & Allem, 2015; Bouriche et al., 2016; Belhachat et al., 2017; Azib et al., 2019; Belabbas et al., 2023). According to Djidel et al. (2013) and Bakli et al. (2020), reported values were 82.3 mg Q Eq/g and 278.5 mg R Eq/g, respectively.

The results obtained during the antioxidant activity by DPPH method of *P. lentiscus* methanolic extract showed that this plant possesses a very important antioxidant activity by an IC_{50} value 14.90 µg/mL. Various studies on *P. lentiscus* in different regions and using the free radical DPPH have reported similar results (Amessis-Ouchemoukh et al., 2014; Pacifico et al., 2014; Ghenima et al., 2015; Salhi et al., 2019). Furthermore, Hemma et al. (2018) showed a low scavenging ability compared to our result, evaluating the methanolic extract of *P. lentiscus* leaves and reporteing IC_{50} = 0.121 mg/mL.

The methanolic extract of *P. lentiscus* had efficient antimicrobial activity against all tested strains and for all concentrations.These results are confirmed by the majority of previous studies demonstrating the ability of various *P. lentiscus* extracts to inhibit pathogenic microorganisms (Salhi et al., 2019; Bakli et al., 2020; Alhadad et al., 2022; Belabbas et al., 2023). Inhibition diameters vary from one study to another due to the resistance of the bacterial and fungal strains tested. According to (Bammou et al., 2015) no activity has been shown against *E. coli* and *S. aureus* by *P. lentiscus* methanolic extract. In the work of Bammou et al. (2015) and Beldi et al. (2020), the essential oil of *P. lentiscus* showed no inhibitory effect against some bacterial strains (*E. coli*, *S. aureus*, *Pseudomonas aeruginosa* and *Klebsiella pneumonia*), these results are unlike the work of Aouinti et al. (2013) and Selmi et al. (2020). Findings of the present work have shown that the minimum inhibitory concentrations (MIC),determined by the lowest concentration 12.5 mg/mL, were recorded with *E. coli* ATCC 8739, *E. coli* ATCC 25922, *B. cereus* ATCC 14579 and *C. albicans* ATCC 10237.

To the best knowledge of Belabbas et al. (2023), the MIC values of *P. lentiscus* leaf phenolic extract values ranged between 2.5 mg/mL and above 20 mg/mL for *E. coli*. Also, Drioiche et al. (2023) revealed that the MIC of *P. lentiscus* aqueous extract values were between 1.2 and 2.5 mg/mL against *E. coli*, *S. aureus* and *C. albicans*. Bakli et al. (2020) reported good antifungal activity against *C. albicans* with MIC 0.1 mg/mL by ethyl acetate fraction from ethanolic extract of *P. lentiscus*. The antimicrobial potential of *P. lentiscus* extract in this study could be linked to its richness in flavonoids which have antimicrobial activity against *E. coli*, *S. aureus*, *B. cereus* and *C. albicans* (Araruna et al., 2012; Soni, 2013).

Conclusion

This study provides information on aromatic compounds in the essential oil of *P. lentiscus* and provides insights into the secondary metabolites and bioactivities of the methanolic extract. Based on the results obtained, *P. lentiscus* can be considered as a source of chemical substances with great potential for use as ingredients in various industrial applications such as functional foods, pharmaceuticals and cosmeceuticals.

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