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(RESEARCH ARTICLE)



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Phytochemical analysis and biological activity of the essential oil of field mugwort: *Artemisia campestris* L. subsp. glutinosa from the Algerian Sahara

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Abstract

This work focuses on the phytochemical study and biological activity (antimicrobial) of the aerial parts of the *Artemisia campestris* collected from the Ahaggar National Park in southern Algeria. After extraction of the essential oil, chromatographic and biological analyzes were carried out on this species.

The results show an average essential oil yield of 0.6 ± 0.02 ml per 100 g of dry plant. Chromatographic analysis of the essential oil of *Artemisia campestris subsp. glutinosa* is rich in monoterpene compounds (50.47%), particularly in hydrogenated forms (40.24% of α and β -pinene) and sesquiterpenes (35.75% of Spathulenol (8.47%), β -Eudesmol (4.67%), and Carvomenthene (3.37%)...

The study of antimicrobial activity revealed a remarkable antifungal activity for *Candida albicans* that could be exploited therapeutically.

Keywords: Essential oil; Artemesia campestris; GC/MS; Antimicrobial activity; Candida albicans

1. Introduction

Artemisia campestris is a Mediterranean species that originates from the high plains of the Maghreb. It grows widely in the high plateaus, but more rarely in the pre-Saharan region, and is absent from the northern Sahara, reappearing in the central Sahara mountains up to an altitude of 2000 m. It is quite common in rocky and sandy riverbeds, where it descends quite low in the tropical zone of hot areas of the Hoggar [1-3], but less so in the Tassili des Ajjer [4].

These highly fragrant aerial parts [5] are widely used in traditional medicine as an anti-venom and anti-inflammatory. The leaves are prepared as an infusion or decoction, ground into a powder, and sometimes added to food sauces or porridges as a purifier and regulator of the blood circulation of pregnant or postpartum women, hence the Arabic name "mother of breath", "um nefsa" [1,2].

2. Material and methods

2.1. Plant Material

The aerial parts of *Artemisia campestris L. subsp. Glutinosa* were collected during the month of September for several years from flowering branches in the Ahaggar region at Oued Tizouyeg (65 km north of Tamanrasset and at an altitude of 2095 meters). A voucher specimen was deposited, and after botanical identification, it was placed in the herbarium

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of the National Higher School of Agronomy of Algiers. To prevent putrefaction, the leaves and fruiting branches were carefully separated and dried on paper in a well-ventilated place, protected from light and humidity for ten days at room temperature in the pharmacognosy laboratory. They were then stored in dry containers until use.



Figure 1 Artemisia campestris L. subsp. glutinosa : general aspect (D. Boukhalfa)

2.2. Microbiological material

To determine the antimicrobial activity of the essential oil of this plant, five bacterial strains (*Escherichia coli, Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, and Enterococcus faecium*) and one mold (*Candida albicans*) were selected (Table 1).

The strains used are reference strains (American Type Culture Collection : ATCC) that are sensitive. All strains are pure and derived from the collection of the microbiology laboratory at the Research and Development Center (CRD), SAIDAL. The bacterial strains were maintained by subculturing on nutrient agar suitable for their growth for 24 hours in the dark at 37° C, while the only fungal strain tested was grown on Sabouraud nutrient medium for 24 hours at 37°C.

| Names of strains | N° ATCC | Forms | Taxon |
|------------------------|---------|-------------------------------------|--------------------|
| Staphylococcus aureus | 6538 | CG+ Aerobic / Facultative anaerobic | Micrococcaceae |
| Bacillus subtilis | 9372 | BG+ Strict aerobe | Bacillaceae |
| Pseudomonas aerugenosa | 9027 | BG- Strict aerobe | Pseudomonadaceae |
| Escherichia coli | 4157 | BG- Aerobic / Facultative anaerobic | Enterobacteriaceae |
| Enterococcus faecium | 6569 | BG+ Facultative anaerobic | Enterococcaceae |
| Candida | 24433 | yeast | Cryptococcaceae |

Table 1 Characteristics of the tested microbial (bacterial and fungal) strains

2.3. Physicochemical Equipment

2.3.1. Refractometer

The refractometer used to determine the refractive index of the essential oil is a CARL ZEISS instrument, reference 89717.

2.3.2. Hydrodistillation Apparatus:

Standardized apparatus for essential oil extraction in compliance with the European Pharmacopoeia 8th edition.

2.3.3. Physicochemical Analysis Equipment:

The gas chromatograph used in this study is a Hewlett-Packard (HP) Palo-Alto CA, USA (Agilent Technologies) 6800 plus.

- Injector: Split-splitless set at 250 °C, injection mode: Split 50:1. Sample is introduced with a micro- syringe.
- Column:
 - Type: Hewlett Packard-5MS, non polar.
 - \circ Dimensions: Length: 30 m, internal diameter (I.D.): 0.25 mm, film thickness: 0.25 μm
 - Stationary phase: 5% phenyl 95% dimethylpolysiloxane.
- Detector: The detector used is a mass spectrometer (MS) or triple quadrupole mass filter (QQQ) of the HP (Agilent Technologies) MSD 5973 type.

2.4. Extraction and determination of essential oil

The essential oil is stored in tinted glass bottles to protect it from heat and light, which are necessary for its preservation.

Table 2 Operating conditions

| Dry weight (gr) | Solvent (ml) | Extraction time | |
|-----------------|------------------------------|-----------------|--|
| 50 | Water + glycerine: (250+150) | 3 hours | |

2.5. Physical indices

Refractive index

The refractive index at 20°C and density are determined by methods conforming to AFNOR standards, 2011 [6].

• Relative density:

This is the ratio of the mass of a certain volume of essential oil at 20°C to the mass of an equal volume of distilled water at 20°C [6].

2.6. Chemical analysis of essential oils :

This involves separation by gas chromatography/mass spectrometry (GC/MS).

- Injector: Set at 250°C, injection mode: Split 50:1. Injected volume: 0.2 $\mu l.$
- Analysis mode : Scan (from 34 to 450)
- Solvent used : Hexane, Solvent delay: 4 min
- Interface temperature: 280°C
- Ionization type : Electron impact
- Filament intensity: 70 eV
- Mass analyzer type : Quadrupole
- Quadrupole temperature: 150°C, Source temperature: 230°C
- Oven temperature: programmed to 60°C (8 min), at a rate of 2°C/min up to 250°C, for 10 minutes.
- Carrier gas: Helium purity: N 6, Carrier gas flow rate: 0.5 ml/min.

Each essential oil sample is injected three times, as well as the internal calibration solution containing a mixture of hexanes.

2.7. Biological methods: Method for evaluating antimicrobial activity:

We adopted the disk diffusion method on agar medium using sterile cellulose disks impregnated with essential oil called aromatograms [7].

Determination of minimum fungicidal concentration (MFC):

MFC is the lowest concentration of the essential oil capable of killing microorganisms after 48 hours of incubation to achieve 99.99% destruction of the initial inoculum.

Strains are considered resistant, slightly sensitive, sensitive, very sensitive, and extremely sensitive when the diameters of the inhibition zones are, respectively:

- Resistant strain (- or $D \le 6mm$)
- Sensitive strain (+ or $9mm \le D \le 14mm$)
- Very sensitive strain (++ or $15mm \le D \le 19mm$)
- Extremely sensitive strain (+++ or $D \ge 20$ mm), according to the criteria defined in the literature.

It should be noted that all fungal and bacterial tests were repeated three times. Positive (Gentamicin 20mg/ml) and negative (physiological water) controls were also prepared.

3. Results

The essential oil obtained after extraction is a clear yellow liquid with a strong characteristic odor.

3.1. Physical clues

Table 3 Yield, refractive index, and relative density

| Plant | | Average yield (ml /100 gdm) | IR _n ^{x20} | Density (g/ml) | |
|-------|---------------------------------------|--------------------------------|--------------------------------|-------------------|--|
| | Artemisia campestris subsp. glutinosa | 0.60±0.2 | 1.4768 ±0.0005 | 0.9344 | |

3.2. Analysis of the chemical composition of the essential oil:

Gas chromatography coupled with mass spectrometry analysis of the essential oil of the Wild Wormwood was performed under the analytical conditions mentioned above.

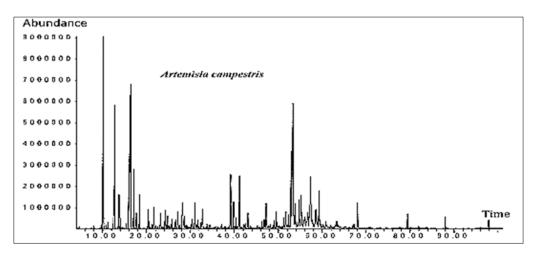


Figure 2 Chromatographic profile of the essential oil of Artemisia campestri

| Table 4 Chemical composition of the essenti | ial oil of Artemisia campestris |
|---------------------------------------------|---------------------------------|
|---------------------------------------------|---------------------------------|

| N° | Identified compounds | TR | IR | IR réf. | % |
|----|--------------------------------------------------------|-------|------|------------|------|
| 01 | ethanone,1-(2-méthyl-2-cyclopentèn-1-yl)- | 07.40 | 881 | - | 0.04 |
| 02 | 4- cis-heptanal | 07.97 | 897 | 893 | 0.08 |
| 03 | α-thuyene | 09.66 | 926 | 924 | 0.14 |
| 04 | α-pinene | 10.20 | 935 | 932 | 9.96 |
| 05 | camphene | 10.89 | 946 | 946 | 0.13 |
| 06 | verbenene | 11.25 | 952 | 967 | 0.18 |
| 07 | β-pinene | 12.74 | 977 | 974 | 6.06 |
| 08 | β-myrcene | 13.69 | 993 | 988 | 1.14 |
| 09 | 1,9-decadiene | 14.04 | 998 | 1003 | 0.34 |
| 10 | 1(7),5,8-o-menthatriene | 14.52 | 1005 | 1003 | 0.08 |
| 11 | α-terpinene | 15.34 | 1017 | 1014 | 0.22 |
| 12 | p- cymene | 16.21 | 1024 | 1024 | 9.42 |
| 13 | α-limonene | 16.42 | 1032 | 1029 | 5.51 |
| 14 | trans-β-ocimene | 17.04 | 1032 | - | 2.08 |
| 15 | cis- β-ocimene | 17.68 | 1050 | 1044 | 0.48 |
| 16 | γ-terpinene | 18.37 | 1059 | 1054 | 1.10 |
| 17 | α-terpinolene | 20.40 | 1087 | 1086 | 0.70 |
| 18 | benzene, 1-methyl-2-(1methylethenyl)- | 20.65 | 1088 | 1086 | 0.27 |
| 19 | rose furane | 21.17 | 1098 | 1095 | 0.15 |
| 20 | Perillene | 21.41 | 1102 | 1102 | 0.12 |
| 21 | Linalool | 21.69 | 1106 | 1107 | 0.76 |
| 22 | cis-rose oxyd | 22.10 | 1111 | 1111 | 0.21 |
| 23 | cyclopropane methanol,2-methyl-2-(4-methyl-3-pentenyl) | 22.53 | 1117 | 1111 | 0.10 |
| 24 | α-campholenal | 23.21 | 1126 | 1122 | 0.67 |
| 25 | neo-allo-ocimene | 23.50 | 1130 | 1128 | 0.09 |
| 26 | β-pinone | 23.91 | 1136 | 1137 | 0.11 |
| 27 | trans-pinocarveol | 24.26 | 1141 | 1141 | 0.87 |
| 28 | di hydro linalol | 24.78 | 1148 | 1134 | 0.49 |
| 29 | (+)-pinocarvone | 25.72 | 1161 | 1160 | 0.33 |
| 30 | α-phellandren-8-ol | 26.58 | 1173 | 1172 | 0.39 |
| 31 | terpinen-4 ol | 27.07 | 1180 | 1179 | 0.80 |
| 32 | Cryptone | 27.58 | 1187 | 1189 | 0.20 |
| 33 | p-cymen-8-ol | 28.17 | 1195 | 1196 | 1.91 |
| 34 | Myrtenol | 28.56 | 1201 | 1202 | 0.47 |
| 35 | l-verbenone | 29.13 | 1209 | 1204 | 0.19 |

| InterformationNon-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non-Non- | 36 | (4R,8R)-8,9-epoxy-pmenth-1-ene | 29.77 | 1218 | - | 0.12 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|-----------------------------------|-------|------|------|------|
| 38β-renealed31.0012.3013.4314.5039cuminaldehyde31.4331.4312.4212.800.1640carvone31.7012.4612.420.3641pipertone32.3612.5112.510.3242pimenth-1-en-7-al32.4712.6112.9012.870.1943p-cymen-7-036.4712.9412.950.1944partial aclohol35.7412.9412.950.1945carvacol36.2713.2513.2013.2146cis-3-hexenyl tiglate37.3413.3513.230.1747p-menth-1.4-dien-7-ol37.8413.6513.6513.6547p-mentha-1.4-dien-7-ol37.8413.6513.6513.6540catcate dictronelly39.0413.6513.6513.6541catcate dictronelly39.0413.6513.6513.6550accata de actronelly39.0413.6513.6513.6551catcate dictronelly43.6414.6514.6514.6552catcate dictronelly43.6414.6514.6514.6553medy Eagenyle43.6514.6514.6514.6514.6554b-catopedee43.6514.6514.6514.6514.6555g-catophyline43.6514.6514.6514.6514.6514.6556g-catophyline43.6514.6 | | | 30.29 | | 1223 | |
| 40carvone31.7012412420.3641piperitone32.36125512510.3242p-menth-1-en-7-al32.74126112760.9343p-cymen-7-ol35.43129912870.1244perilla alcohol35.74129112950.1945carvacrol36.27131213140.2346cis-3-hexenyl tiglate37.131325132413300.1747p-mentha-1,4-dien-7-ol37.8413361374132513460.6649acetate de tironellyl39.131355135412860.6650acetate de neryle39.81136513651.040.1251acetate de geranyle40.26132213460.400.1252acetate de geranyle41.14138513832.1853methyl Eugenol42.58140714100.1754f-caryophyllene43.55145514150.6155g-curvenene43.55145514150.6156acetare de geranyle45.61142514100.1157acaryophyllene45.61145514160.1158acetare de geranyle45.61142514460.6159acetare de geranyle45.61142514160.1150acaryophyllene45.61142514160.11 <td< td=""><td>38</td><td>β-citronellol</td><td>31.00</td><td>1236</td><td>1333</td><td>1.45</td></td<> | 38 | β-citronellol | 31.00 | 1236 | 1333 | 1.45 |
| 41piperitone32.3612.5512.510.3242p-menth-1-en-7-al32.4712.6112.600.3143p-cymen-7-ol35.4312.9912.870.1244perilla alcohol35.7412.9412.950.1945carvacrol36.2713.1213.140.2346cis-3-hexenyligate37.1313.2513.220.1847p-menth-1.4-dien-7-ol37.8433.3113.051.1448a-cubebene39.3113.5113.541.8650a-cubetene39.1313.5113.541.8151a-cubetene39.1313.511.3541.8152a-cubetene39.1313.511.3541.8153a-cubetene40.621.3721.3741.4054a-cupone40.621.3721.3141.4155a-cubetene40.621.411.411.411.4154p-caryophyllene43.651.4251.411.411.4155a-curuene4.621.421.411.411.411.4156a-caryophyllene4.621.421.411.411.411.411.4157a-caryophyllene4.621.421.411.411.411.411.411.4158g-caryophyllene4.621.421.411.411.411.411.411.411.411.41 <t< td=""><td>39</td><td>cuminaldehyde</td><td>31.43</td><td>1242</td><td>1238</td><td>0.16</td></t<> | 39 | cuminaldehyde | 31.43 | 1242 | 1238 | 0.16 |
| nnnnnnn1p-menth-1-en-7-al31.4112871287128712181p-gmen-7-ol35.43129412950.191acroacl35.74129412950.191carvacrol36.27131213140.231cis-3-hexenyl tiglate37.13132513220.181p-menth-1.4-dien-7-ol37.8433.831335134613451accubebene38.6239.81136513621.181accuta de atronellyl39.91136513541.181accata de atronellyl39.91136513621.181accata de atronellyl39.91136513621.181accata de atronellyl39.91136513641.181accata de atronellyl39.91136513621.181accata de atronellyl39.91136513641.181accata de atronellyl41.14138513821.181accata de atronellyl41.14138513821.181accata de atronellyl41.14138513821.181accata de atronellyl41.14138513821.181accata de atronellyl41.14138513821.181accata de atronellyl43.6514251.481.181accata de atronellyl <td>40</td> <td>carvone</td> <td>31.70</td> <td>1246</td> <td>1242</td> <td>0.36</td> | 40 | carvone | 31.70 | 1246 | 1242 | 0.36 |
| 43p-ymen-7-ol35.412912870.1244perilla alcohol35.74129412950.1945carvacrol36.27131213140.2346cis-3-hexenyl tiglate37.131325132213140.1747p-mentha-1.4-dien-7-ol37.8437.83132513450.1649acetate de cironellyl39.13135513541.1850acetate de neryle39.81136513.421.1451acetate de geranyle40.26137213740.1052acetate de geranyle41.14138513831.1853methyl Eugenol42.58142514160.1154β-caryophyllene43.65142514160.1155β-cubehene43.65142514160.1156acarophyllene45.59145514510.1157acarophyllene45.69142514160.1158germacrene-D45.69142514160.1159acubene45.691455145214160.1150acubene45.791455145514510.1159acubene45.891455145514510.1150acubene45.991455145514510.1151acubene45.991455145514510.1151acubene45.99 | 41 | piperitone | 32.36 | 1255 | 1251 | 0.32 |
| 44perila acohol35.74129412950.1945carvacrol36.27131213140.2346cis-3-hexenyl tiglate37.1313251322131447p-mentha-1.4-dien-7-ol37.84133513351356136148a-cubebene39.21313513551354136550acetate de cironellyl39.31135513541365136451acetate de aneryle39.91136513631365136452acetate de geanyle40.26137213740.0653acetate de geanyle41.14138513831383138354B-caryophylene43.65142514160.1155β-cubebene43.65142514160.1156acurumene46.901435142514160.1157carayophylene46.911455145214160.1158germacrene-D46.92147814840.3013315110.1459acurumene46.9214781484148815020.20141611150acurumene46.9214781484148815020.20141611150acurumene46.9214781484148815020.201416111111111111111111111111111111111111 | 42 | p-menth-1-en-7-al | 32.74 | 1261 | 1276 | 0.93 |
| 45carvacrol36.27131213140.2346cis3-hexenyl tiglate37.13132513220.1847p-mentha-1.4-dien-7-ol37.84133613330.1748a-cubebene36.52134613450.6049acetate di cironellyl39.1313551354136550acetate de neryle39.81136513740.1051a-copane40.26137213740.1052acetate de geranyle14.14138513831383131553methyl Eugenol41.44138514160.1054β-caryophyllene43.65141614160.1055β-cubebene43.65142514160.1156a-caryophyllene45.92147814160.1157a-morphene46.7014.7514.7514.1458germacren-D45.7914.7814.1414.1559a-curumene46.7014.7314.1414.1550a-curumene46.7014.1414.1414.1450a-curumene46.7014.1414.1414.1450a-curumene46.7014.1414.1414.1451a-curumene46.7014.1414.1414.1452a-curumene46.7014.1414.1414.1453a-curumene50.7115.1315.1415.14 | 43 | p-cymen-7-ol | 35.43 | 1299 | 1287 | 0.12 |
| 46sis3-hexenyltiglate3121312213221322132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241324132413241 | 44 | perilla alcohol | 35.74 | 1294 | 1295 | 0.19 |
| Yp-mentha-1.4-ident-7-ol37.84133613330.1748a-cubebene38.52134613450.0649actate de citronellyl39.13135513542.1850actate de neryle39.81136513621.0451a-copaene40.26137213740.0652actate de geranyle41.14138513832.1853methyl Eugenol42.58140714100.1754β-caryophyllene43.66141614150.6055β-cubebene43.65142514610.1156a-caryophyllene43.65142514610.1157a-morphene45.79145914590.1458germacrene-D46.70147514780.3159a-curcumene46.70147514840.6050a-curcumene47.211483148710.260a-murolene49.00151315140.1461y-cadinene49.01151315140.1462S-Cadinene49.01151315141514151463acyophylene A-ethenyl-50.60152215221524151464a-cucurene50.711542154415141514151465acyophylene A-ethenyl-50.61152315451544151466(-)-carvomenthene52.81 | 45 | carvacrol | 36.27 | 1312 | 1314 | 0,23 |
| 48a c. cubebene38.5213.4613.450.0649acetate de citronelly3.1351.3541.351.3541.35550acetate de neryle3.011.3551.3641.0451a copane4.0261.3221.3740.0652acetate de geranyle4.1441.3851.3831.31553methyl Eugenol4.2581.4071.4101.15754β-caryophyllene4.3651.4251.4611.1155β-cubebene4.3651.4251.4611.1156acarophyllene4.5191.4591.4141.41557a-morphene4.6701.4751.4781.41458gernacrene-D4.6701.4751.4481.6159acurcumene4.6191.4141.4981.611.61450a-murolene4.6191.4151.4141.4151.41450acurcumene4.6191.4151.4141.4151.41450acurcumene4.6191.4151.4141.4151.41451a-murolene4.6101.4141.4141.4151.41452acurcumene4.6141.4141.4141.4151.41453acurcumene4.6141.4141.4141.4151.41454a-curcumene4.5141.4141.4141.4141.41454a-curcumene4.5141.5141.514< | 46 | cis-3-hexenyl tiglate | 37.13 | 1325 | 1322 | 0.18 |
| 49acetate de cirronellyl39.1331.3513.542.1850acetate de neryle39.81136513641.0451a-copaene40.26137213740.1052acetate de geranyle41.14138513832.1853methyl Eugenol42.0514.014.150.0154β-caryophyllene43.0614.1614.150.0155β-cubebene43.0514.2514.160.1156a-caryophyllene43.0514.5514.160.1157a-morphene46.0714.5714.840.3158germacrene-D46.0214.7514.940.3159a-currumene49.0214.9414.940.3250a-currumene49.0214.9414.9414.9450a-currumene49.0214.9414.9414.9461y-cadinene49.0414.9414.9414.9414.94623-Cadinene49.0414.9414.9414.9414.9463y-cadinene49.0414.9414.9414.9414.9464y-cadinene50.0414.9414.9414.9414.9465inclinellelelelelelelelelelelelelelelelelel | 47 | p-mentha-1,4-dien-7-ol | 37.84 | 1336 | 1333 | 0.17 |
| NoSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSectorSector </td <td>48</td> <td>α- cubebene</td> <td>38.52</td> <td>1346</td> <td>1345</td> <td>0.06</td> | 48 | α- cubebene | 38.52 | 1346 | 1345 | 0.06 |
| 1accopaen40.26137213740.4052acetate de geranyle41.14138513832.1853methyl Eugenol42.58140714100.1754β-caryophyllene43.06141614150.0055β-cubebene43.05142514010.1156α-caryophyllene45.09145014540.1457α-amorphene46.70147514780.3158germacrene-D46.92147814840.3659α-curcumene47.21148314871.0260α-murolene49.00151315140.1461γ-cadinene49.00151315140.1462δ-Cadinene50.09153115421.0263cyclocetne, 4-ethenyl-50.09153215220.0264(-calacorene50.75154215450.0265nerolidol (E)52.3615701.531.640.0264(+)-carvomenthene53.82158515778.4765Globulol53.82158515778.4766Globulol54.3916461.641.641.6467Globulol54.6816101.5115721.5268Salvialenone54.6816101.511.511.5169Globulol54.6816101.611.511.51 <td>49</td> <td>acetate de citronellyl</td> <td>39.13</td> <td>1355</td> <td>1354</td> <td>2.18</td> | 49 | acetate de citronellyl | 39.13 | 1355 | 1354 | 2.18 |
| 52acetate de geranyle41.141.3851.3832.1853methyl Eugenol42.58140714100.1754β-caryophyllene43.06141614150.0155β-cubebene43.651425142514160.1156α-caryophyllene43.65142514260.1157α-amorphene45.191450145214320.3158germacrene-D46.70147514780.3659α-curcumene46.72148314921.0260α-murolene48.14149815020.2061γ-cadinene49.00151315110.11626-Cadinene49.00151315110.1163cyclocetene, 4-ethenyl-50.09153315360.1464α-calacorene50.75154215440.0065nerolidol (E)52.36157015450.6066(+)-carvomenthene52.361570154713767Salvialenone53.82158515778.3768Salvialenone53.821585157215227010-eij-y-eudesmol54.6816101171caryophylene oxide55.1316481606172y-eudesmol55.1316481606117310-eij-y-eudesmol55.131618160611< | 50 | acetate de neryle | 39.81 | 1365 | 1365 | 1.04 |
| S3methyl Eugenol42.58140714100.1754β-caryophyllene43.06141614150.6055β-cubebene43.65142514610.1156α-caryophyllene45.19145014540.1457α-amorphene46.70147514780.3158germacrene-D46.92147814840.6659α-curcumene47.21148314871.0260α-muurolene48.14149815020.2061γ-cadinene49.00151315110.4162δ-Cadinene49.00151315140.4163cyclooctene, 4-ethenyl-50.09153115360.1464α-calacorene50.75154215440.0165nerolidol (E)52.36157015320.4164salationone53.28157515450.6065salvialenone53.2815951.578.4768Salvialenone53.8215951.571.5769Globulol54.391604-0.207010-epi-γ-eudesmol54.6816102.51.316181606712-yeudesmol55.13161816062.51.3161816062.51.3 | 51 | α-copaene | 40.26 | 1372 | 1374 | 0.40 |
| 54 β -caryophylene43.06141614150.6055 β -caryophylene43.06142514210.1156 α -caryophylene43.05142514240.1157 α -amorphene45.191450145214420.3158germacrene-D46.92147814840.3659 α -curcumene47.21148314971.0260 α -murolene48.14149815020.2061 γ -cadinene49.00151315110.4162 δ -Cadinene49.00151315140.4163cyclooctene, 4-ethenyl-50.09153115140.4164 α -calacorene50.75154215440.1065nerolidol (E)52.36157015650.6066(+)-carvomenthene52.9115791.578.4768Salvialenone53.82158515778.4769Globulol54.391604.1.527010-epi- γ -eudesmol54.681610.1.5271carvophylene oxide55.13161816062.3272 γ -eudesmol55.35162516251.522 | 52 | acetate de geranyle | 41.14 | 1385 | 1383 | 2.18 |
| 55β- cubebene43.65142514610.1156α-caryophyllene45.19145014540.1457α-amorphene46.70147514780.3158germacrene-D46.92147814840.3659α-curcumene47.21148314871.0260α-muurolene48.14149815020.2061γ-cadinene49.00151315110.4162δ-Cadinene49.00153115120.7463cyclooctene, 4-ethenyl-50.09153115360.1464α-calacorene50.75154215440.0165nerolidol (E)52.36157015650.6066(+)-carvomenthene53.28157515423.7767(4) spathulenol53.821595-1.3768Salvialenone54.881610-1.527010-epi-γ-eudesmol54.68161816062.3271caryophylene oxide55.33164816062.3272γ-eudesmol56.85163516291.521.52 | 53 | methyl Eugenol | 42.58 | 1407 | 1410 | 0.17 |
| 56α-caryophylene45.19145014540.1457α-amorphene46.70147514780.3158germacrene-D46.92147814840.3659α-curcumene47.211483140710260α-murolene48.14149815020.2061γ-cadinene49.00151315110.4162δ-Cadinene49.00151315140.4163cyclooctene, 4-ethenyl-50.09153115320.4164α-calacorene50.75154215440.1065nerolidol (E)154715450.410.4166(+)-carvomenthene52.36157015473.3767(+) spathulenol53.28158515778.4768Salvalenone54.8916041.5215227010-epi-γ-eudesmol54.6816101.521.5271caryophylene oxide55.13161816062.3272γ-eudesmol56.89163516291.52 | 54 | β-caryophyllene | 43.06 | 1416 | 1415 | 0.60 |
| 57α-amorphene46.70147514780.3158germacrene-D46.92147814840.3659α-curcumene47.21148314871.0260α-muurolene48.14149815020.2061γ-cadinene49.00151315110.4162δ-Cadinene49.00151315140.4163cyclooctene, 4-ethenyl-50.09153115360.1464α-calacorene50.75154215440.1065nerolidol (E)52.36157015650.6066(+)-carvomenthene53.2815751.378.4767Salvalenone53.8215951.311.3168Salvalenone54.391610-1.327010-epi-γ-eudesmol54.6816102.321.5271caryophylene oxide55.13162816291.32 | 55 | β- cubebene | 43.65 | 1425 | 1461 | 0.11 |
| 58germacrene-D46.92147814840.3659α-curcumene47.21148314871.0260α-muurolene48.14149815020.2061γ-cadinene49.00151315110.4162δ-Cadinene49.00151315120.7463cyclocetne, 4-ethenyl-50.09153115360.1464α-calacorene50.75154215440.1065nerolidol (E)52.36157015650.6066(+)-carvomenthene53.28158515778.4767(+) spathulenol53.8215951.378.4768Salvialenone54.3916041.321.327010-epi-γ-eudesmol54.6816102.321.3271caryophylene oxide55.13161816062.3272γ-eudesmol55.13161816291.32 | 56 | α-caryophyllene | 45.19 | 1450 | 1454 | 0.14 |
| 59 α-curcumene 47.21 1483 1487 1.02 60 α-murolene 48.14 1498 1502 0.20 61 γ-cadinene 49.00 1513 1511 0.41 62 δ-Cadinene 49.00 1513 1514 0.41 62 δ-Cadinene 49.00 1513 1514 0.41 63 cyclooctene, 4-ethenyl- 50.09 1531 1536 0.14 64 α-calacorene 50.09 1532 1544 0.10 65 nerolidol (E) 52.36 1575 1542 1544 0.10 65 nerolidol (E) 52.36 1570 1565 0.60 66 (+)-carvomenthene 52.32 1575 1.47 0.43 67 (+)spathulenol 53.82 1585 1.577 8.47 68 Salvialenone 54.39 1.604 1.23 1.37 69 Globulol 54.39 1.610 <td< td=""><td>57</td><td>α-amorphene</td><td>46.70</td><td>1475</td><td>1478</td><td>0.31</td></td<> | 57 | α-amorphene | 46.70 | 1475 | 1478 | 0.31 |
| 60α-muurolene48.14149815020.2061γ-cadinene49.00151315110.4162δ-Cadinene49.00152215220.7463cyclooctene, 4-ethenyl-50.09153115360.1464α-calacorene50.75154215440.1065nerolidol (E)52.36157015650.6066(+)-carvomenthene52.3115753.3767(+) spathulenol53.28158515778.4768Salvialenone53.2815021.521.527010-epi-γ-eudesmol54.3916041.521.5271caryophylene oxide55.13161816062.3272γ-eudesmol56.08163516291.52 | 58 | germacrene-D | 46.92 | 1478 | 1484 | 0.36 |
| 61γ-cadinene49.00151315110.4162δ-Cadinene49.00152215220.7463cyclooctene, 4-ethenyl-50.09153115360.1464α-calacorene50.75154215440.1065nerolidol (E)52.36157015650.6066(+)-carvomenthene52.9115792.373.3767(+) spathulenol53.2815951.5778.4768Salvialenone53.8215951.521.3769Iobulol54.3916042.201.5131.527010-epi-γ-eudesmol54.6816101.521.5271caryophylene oxide55.13161816062.3272γ-eudesmol56.08163516291.42 | 59 | α-curcumene | 47.21 | 1483 | 1487 | 1.02 |
| A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A | 60 | α-muurolene | 48.14 | 1498 | 1502 | 0.20 |
| 63cyclooctene, 4-ethenyl-50.09153115360.1464α-calacorene50.75154215440.1065nerolidol (E)52.36157015650.6066(+)-carvomenthene52.9115791.5773.3767(+) spathulenol53.82158515778.4768Salvialenone53.821595.1371.3769Globulol54.391604.2.27010-epi-γ-eudesmol54.6816101.521.5271caryophylene oxide55.13161816062.3272γ-eudesmol56.08163516291.43 | 61 | γ-cadinene | 49.00 | 1513 | 1511 | 0.41 |
| 64 α-calacorene 50.75 1542 1544 0.10 65 nerolidol (E) 52.36 1570 1565 0.60 66 (+)-carvomenthene 52.91 1579 - 3.37 67 (+) spathulenol 53.28 1585 1577 8.47 68 Salvialenone 53.82 1595 - 1.37 69 Globulol 54.39 1604 - 0.20 70 10-epi-γ-eudesmol 54.68 1610 - 1.52 71 caryophylene oxide 55.13 1618 1606 2.32 72 γ-eudesmol 56.08 1635 1629 1.43 | 62 | δ-Cadinene | 49.56 | 1522 | 1522 | 0.74 |
| 65 nerolidol (E) 52.36 1570 1565 0.60 66 (+)-carvomenthene 52.91 1579 3.37 67 (+) spathulenol 53.28 1585 1577 8.47 68 Salvialenone 53.82 1595 1.37 69 Globulol 53.82 1595 1.37 69 Globulol 54.39 1604 2.42 70 10-epi-γ-eudesmol 54.39 1604 2.42 71 caryophylene oxide 55.13 1618 1606 2.32 72 γ-eudesmol 56.08 1635 1629 1.43 | 63 | cyclooctene, 4-ethenyl- | 50.09 | 1531 | 1536 | 0.14 |
| 66(+)-carvomenthene52.911579-3.3767(+) spathulenol53.28158515778.4768Salvialenone53.821595-1.3769Globulol54.391604-0.207010-epi-γ-eudesmol54.681610-1.5271caryophylene oxide55.13161816062.3272γ-eudesmol56.08163516291.43 | 64 | α-calacorene | 50.75 | 1542 | 1544 | 0.10 |
| 67(+) spathulenol53.28158515778.4768Salvialenone53.821595-1.3769Globulol54.391604-0.207010-epi-γ-eudesmol54.681610-1.5271caryophylene oxide55.13161816062.3272γ-eudesmol56.08163516291.43 | 65 | nerolidol (E) | 52.36 | 1570 | 1565 | 0.60 |
| 68 Salvialenone 53.82 1595 - 1.37 69 Globulol 54.39 1604 - 0.20 70 10-epi-γ-eudesmol 54.68 1610 - 1.52 71 caryophylene oxide 55.13 1618 1606 2.32 72 γ-eudesmol 56.08 1635 1629 1.43 | 66 | (+)-carvomenthene | 52.91 | 1579 | - | 3.37 |
| 69 Globulol 54.39 1604 - 0.20 70 10-epi-γ-eudesmol 54.68 1610 - 1.52 71 caryophylene oxide 55.13 1618 1606 2.32 72 γ-eudesmol 56.08 1635 1629 1.43 | 67 | (+) spathulenol | 53.28 | 1585 | 1577 | 8.47 |
| 70 10-epi-γ-eudesmol 54.68 1610 - 1.52 71 caryophylene oxide 55.13 1618 1606 2.32 72 γ-eudesmol 56.08 1635 1629 1.43 | 68 | Salvialenone | 53.82 | 1595 | - | 1.37 |
| 71 caryophylene oxide 55.13 1618 1606 2.32 72 γ-eudesmol 56.08 1635 1629 1.43 | 69 | Globulol | 54.39 | 1604 | - | 0.20 |
| 72 γ-eudesmol 56.08 1635 1629 1.43 | 70 | 10-epi-γ-eudesmol | 54.68 | 1610 | - | 1.52 |
| | 71 | caryophylene oxide | 55.13 | 1618 | 1606 | 2.32 |
| 73 (+)-epi-bicyclosesquiphellandrene 56.70 1646 - 1.43 | 72 | γ-eudesmol | 56.08 | 1635 | 1629 | 1.43 |
| | 73 | (+)-epi-bicyclosesquiphellandrene | 56.70 | 1646 | - | 1.43 |

| 74 | β-eudesmol | 57.31 | 1657 | 1654 | 4.67 |
|------|----------------------------------------------------------------------------------------|--------|------|------|-------|
| 75 | α-bisabolol oxide | 57.70 | 1664 | 1666 | 0.78 |
| 76 | trans-Zalphabisabolene epoxide | 58.51 | 1678 | - | 4.06 |
| 77 | Valerenol | 60.08 | 1707 | - | 0.21 |
| 78 | Farnesol | 60.27 | 1711 | 1727 | 0.16 |
| 79 | 2,6-diisopropylnaphthalene | 60.80 | 1721 | 1728 | 0.50 |
| 80 | 1H-3a,7-methanoazulène, octahydro- 1,4,9,9-tetra-methyl- | 61.90 | 1742 | - | 0.21 |
| 81 | vulgarol A | 62.93 | 1761 | - | 0.19 |
| 82 | bicyclo[5.2.0]nonane,4-methylene-2,8,8-trimethyl-2-vinyl- | 63.26 | 1767 | - | 0.41 |
| 83 | (3E)-5-isopropylidene-2,7-dimethyl -6-oxa- 1,3,7,10 -undécatetraene | 63.58 | 1774 | - | 0.24 |
| 84 | 1H-cycloprop[e]azulene, decahydro-1,1,7- trimethyl-4-methylene-, [1aR- (1a.alpha.,4 | 64.01 | 1782 | - | 0.15 |
| | a. alpha., 7.alpha. 7a. beta. , 7b.alph a.)]- | | | | |
| 85 | 8 methyltricyclo [5.3.1.0(3,8)]undecane-2,6-dione | 66.96 | 1839 | - | 0.17 |
| 86 | 6-methyl-2-tridecanone | 67.25 | 1845 | - | 0.16 |
| 87 | cis,cis-5,9-tetradécadiene | 68.02 | 1860 | - | 1.07 |
| 88 | ethyl ester de l'acide hexadecanoique | 74.54 | 1947 | - | 0.07 |
| 89 | heneicosane | 79.36 | 1947 | 2020 | 0.44 |
| 90 | Tricosane | 88.02 | 2297 | 2300 | 0.37 |
| 91 | heptacosane | 103.42 | 2645 | 2647 | 0.07 |
| 92 | tricosane, 2-méthyl- | 110.36 | - | - | 0.11 |
| 93 | 9-hexacosene | 116.84 | - | - | 0.09 |
| 94 | (s)(+)-Z-13-methyl-11-pentadecen-1-ol acetate | 120.97 | - | - | 0.58 |
| Tota | al (%) | | | | 96,07 |

3.3. Testing for antimicrobial activity

Table 5 Antimicrobial activity of essential oils of Artemisia campestris

| | Qualitative tes | Quantitative test | | |
|-------------------------|--------------------------------------|-----------------------|------------|----------------|
| Micro-organisms | Diameter of in | | | |
| | Essential oils Negative Controls Ger | | Gentamycin | Essential oils |
| | | (Physiological water) | | MFC |
| P. aeruginosa ATCC 9027 | 14 | - | 37 | - |
| E. coli ATCC 4157 | 10 | - | 25 | - |
| S. aureus ATCC 6538 | 15 | - | 36 | - |
| E. feacium ATCC 6569 | 15 | - | 31 | - |
| C. albicans ATCC 24433 | 23 | - | 25 | > 2% |

4. Discussion

4.1. To. Yield and Physical Indices

The essential oil yield of *Artemisia campestris* from Hoggar is slightly higher than that of the Naama region (0.3% MS) and Djelfa (0.29%) (8). It is almost identical to those of the northern Algerian Sahara (In Amenas (0.70% MS) (9), the Boussaada region (0.66%) (10), and Tunisia (Matmata region (Tunisia, 0.41-0.65%) (11) However, it is low (0.6 ml % DM); when compared to those from Morocco (Ouarzazate region (Morocco) (1.2%) (12).

The refractive index of this oil is low (1.4768 ± 0.0005) and complies with AFNOR purity standards [6], which could promote its use in cosmetic products.

4.2. Gas Chromatography-Mass Spectrometry

From a phytochemical point of view, ninety-four compounds were identified, representing 96.07% of the essential oil of *Artemisia campestris*, which is rich in:

- Monoterpenes (50.47%): of which 40.24% are monoterpene hydrocarbons (MH)(α-pinene (9.96%), p-cymene (9.42%), β-pinene (6.06%), α-limonene (5.51%), and β-ocimene (2.56%) and 10.23% are monoterpene oxygenated compounds(MO) (p-cymen-8-ol (1.91%), β-citronellol (1.45%), citronellyl acetate (2.1:8%)...).
- Sesquiterpenes represent 35.75% : of which 18.18% are sesquiterpene hydrocarbons (SQH) (+)carvomenthene (3.37%), (+)-epi-bicyclosesquiphellandrene (1.43%), α -curcumene (1.02%), ...) and 17.46% are oxygenated sesquiterpenes (SQO) (+) spathulenol (8.47%), β -eudesmol (4.67%), trans-Z-. α -bisabolene epoxide (4.06%)...
- Other compounds include alkanes (heneicosane, tricosane, heptacosane, etc.) and alkenes (1,9-decadiene, 9-hexacosene), etc.

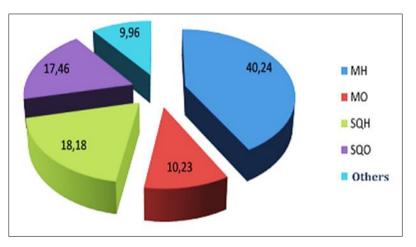


Figure 3 Distribution by chemical class of the essential oil of Artemisia campestris

The essential oil of this species showed a richness in hydrogenated monoterpenes with a predominance of the α and β -pinene couple. The other most important compounds are α -limonene, β -eudesmol, and β -ocimene. Several alkanes were also counted, although at relatively low levels (the most important being cis,cis-5,9 tetradecadiene), as well as acids and ester acids (ethyl hexadecanoic acid ester).

Compared to literature data, the essential oil of *Artemisia campestris* from the Ahaggar region is compositionally very different from those of other regions of Algeria, notably Djelfa (8), the latter being particularly rich in spathulenol (58.2%). Other compounds are present in variable amounts, such as caryophyllene oxide, β -caryophyllene, β -guaiene, p-menth-1-en-8-ol, and α -copaene.

It is also different from that of In Amenas (9), whose major compound is (Z, E) farnesol (10.3%), followed by cedrol (5.4%) and verbenone (3.8%).

However, this species is compositionally very close to those of certain regions in Tunisia, Italy (13), and Turkey, with a predominance of the α and β -pinene couple (11,14), such as the essential oil of *Artemisia campestris* from Matmata

(Tunisia). In fact, the α , β -pinene couple predominates, although the proportions are significantly higher compared to our sample, limonene and p-cymene are also present in both species with almost similar amounts.

In general, the compounds in common with all these species are the α and β -pinene couple, spathulenol, α -limonene, β -eudesmol, and β -ocimene.

These variations in yield and chemical composition seem to depend closely on the harvesting, extraction, and separation conditions as well as geographic variations.

4.3. Antimicrobial activity

The essential oil of *Artemisia campestris* is less active against all the studied bacteria and fungi, except for *Candida albicans*.

We observe that the essential oil of *Artemisia campestris* has weak activity against both Gram-positive and Gramnegative bacteria.

Our results seem to be consistent with those found with the essential oil of the same species from southern Tunisia (Matmata) (11) and those of Naili MB and al. (2010) (15), who tested the antibacterial activity of the methanolic extract of *Artemisia campestris* leaves. They found that the extract was more effective against Gram-positive bacteria (*Staphylococcus aureus*) than against Gram-negative bacteria (*Escherichia coli*).

These results tend to justify its use by the local population as an anti-flu and hemostatic agent, but above all as an antiseptic and healing agent during circumcision of children.

Like most Saharan aromatic species, the essential oil of *Artemisia campestris* shows a very pronounced activity against *Candida albicans*.

5. Conclusion

The essential oil of *Artemisia campestris* from Hoggar is mainly composed of hydrogenated monoterpenic compounds (40.24%), with the main ones being α -Pinene (9.96%), p-Cymene (9.42%) and β -Pinene (6.06%). The study of antimicrobial activity revealed strong antifungal activity against *Candida albicans*, which is often involved in digestive and gynecological fungal infections. This oil could indeed find its usefulness in various areas of health applications, particularly in infectiology. These results should be supplemented by more extensive studies to determine the toxicity and possibly the galenic forms of administration of this oil.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors and all co-authors declare that they have no conflicts of interest in relation to this document, and the material described is not in publication or intended for publication elsewhere.

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

Statement of informed consent:

The studies presented in this manuscript do not involve any information on individuals.

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