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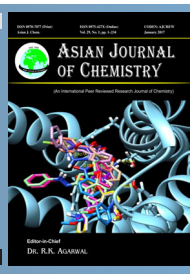

Physico-Chemical Study and Evaluation of Antimicrobial and Antioxidant Activities of *Artemisia judaica* L. Essential Oil, Growing in Illizi, Algeria

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Hydrodistilled volatile oil obtained from the aerial parts of *Artemisia judaica* L. cultivated near Illizi, Algeria, was analyzed by gas chromatography mass spectrometry (GC-MS). More than 20 compounds were identified, the major constituents of essential oil were piperitone (79.04 %), davanone (7.23 %) and (4E,6E)-2-methyl-2,4,6-octatriene (5.32 %). Isolated essential oil was tested for radical-scavenging ability using the stable 2,2-diphenylpicrylhydrazyl (DPPH) radical, the 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonate) (ABTS) radical and for reducing power ability with a test based on the reduction of ferric cations (FRAP). In all tests, oil shows a prominent antioxidant activity. The screening of antimicrobial activity of all the essential oils was evaluated against representatives of Gram-positive, Gram-negative bacteria and fungi, using the agar diffusion method. All tested microorganisms were inhibited by the essential oil of *A. judaica.*

Keywords: *A. judaica*, Essential oil, Physical proprieties, Antioxidant activity, Antimicrobial activity.

INTRODUCTION

Artemisia judaica L., belongs to the family Compositae (Asteraceae) and is a fragrant shrub that grows widely in the Arabian area [1-3], this sub-species is endemic in Algeria, Libya and Morocco was present in the mountains of the central Sahara. In Algeria, it is largely distributed in Tassili N'ajjer. This sub-spontaneous grass, which is used as traditional medicines to treat digestive diseases: aerophagia, flatulence and urinary decrease, analeptic drink for new mother after childbirth, bad breath, gumboils and urinary incontinence in Tassili N'ajjer [4]. It is commonly used before celebrations a spoonful of dried leaves is taken with a glass of water to prevent intestinal troubles. An infusion of the leaves is relaxing and helps bring on sleep. In the Sahara, the plant is greatly appreciated when added to green tea. Because of its prophylactic virtues, a branch is frequently attached to the wrists of babies and small children to ward off negative influences. In Djanet, when the grapes are ripe, several branches are hung in the vineyards to keep insects away [5].

Artemisia judaica L. is commonly used as tea by population of Saudi Arabia and in Egypt Sinai. In the traditional medicine of the Arabic area, *A. judaica* is used in the treatment of gastrointestinal disorders, enhanced eyesight, cardiovascular health, capillary strength and structure of connective tissue, appearance of skin and immune systems as well as decreased risk of atherosclerosis, cancer and arthritis [3,6,7].

As part of the study evaluation of the biological effectiveness of the essential oils from the medicinal plants, the study presented a study of the antioxidant and antibacterial activities associated with the chemical composition of essential oil isolated from *Artemisia judaica* L.

EXPERIMENTAL

The aerial parts of *A. judaica* (Fig. 1.) were collected from weddi tasset in Illlizi (Algeria), on April, 2014. The vernacular name of this plant is tiheradjeli (the Targui name on Algeria) or shih balady, baatharan or baethran (the Arabics names on Egypt and Saudi Arabia). Samples of the plants were identified by Prof. Amar Eddoud, Department of Agricultural Sciences, University of Kasdi Merbah-Ouargla, Algeria.

Essential oil extraction: The dried aerial parts of *A. judaica* were subjected to hydrodistillation in a modified Clevenger-type apparatus for 3 h. The essential oil was obtained with (0.82-1.3) % (w/w) of yield and was dried over anhydrous sodium sulfate and stored in sealed glass vials at 4 to 6 °C prior to analyses.

All chemicals were of analytical grade. 2,2-Diphenyl-1-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), potassium persulfate, methanol, 2,2'-azino-*bis*(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), 2,3,5-triphenyl-1,3,4-triaza-2-azoniacyclopenta-

Fig. 1. Photo of *Artimisia judaica* L.

1,4-diene (TPTZ), dimethyl sulfoxide were supplied from Sigma-Aldrich.

Chromatographic analysis of essential oil: 0.2 µL of sample was injected on a gas chromatography (Hewlett-packar computerized system, Agilent model 6890 GC coupled to a Agilent 5973 N mass selective detector and equipped with an Agilent technologies capillary HP-5MS column (30 m, 0.25 mm i.d, 0.25 µm thickness), a split/splitless injector used in the split mode (200:1), using helium (20 mL/min). The initial temperature of the column was 40 °C which was heated gradually to 325 °C with a 2 °C/min. High purity helium was used as carrier gas at 36 cm/s. The quadrupole, source and transfer line temperatures were maintained at 150, 230 and 280 °C, respectively. A solvent delay of 3 min. Identification of components was assigned by matching their mass spectra of peaks with those obtained from authentic samples and/or the Wiley and NIST library data.

Organoleptic characterization of the essential oil: According Linden and Lorient [8], the organoleptic characteristics of essential oil concern the study of appearance (solid or liquid), colour and odour.

Physical characteristics: They are mainly the refractive index (n), the density (d) and the optical activity (α) for the essential oil.

Determination of relative density at 20 °C: The relative density of essential oil (d_{20}) is the ratio of the mass (g) of a certain volume of essentialn oil to the mass of an equal volume distilled water. The procedure involves weighing the empty pycnometer, filled with distilled water and filled with essential oil (AFNOR NF ISO279: 1999 (T75-111)).

Determining the refractive index: The refractive index is the ratio between the sinus of the angles of incidence and refraction of a light source has a predetermined wavelength, from the air in the essential oil maintained at a constant temperature (AFNOR NF ISO280: 1999 (T75-112)). It is measured using a Abbe refractometer NAR-2T (cat. NO.1220) equipped with LED lamp (light source) and digital thermometer. The correction to 20 °C is carried out by the following formula:

$$I_{20} = I_t + 0.00045\ (T - 20\ °C)$$

with: I_{20} = Refractive index at 20 °C; I_t = Index at room temperature or measurement; T = Room temperature.

Specific optical activity ($[\alpha]_T$): The specific rotation ($[\alpha]_T$) set to a temperature T measured for a given wavelength, expressed in g^{-1} mL dm^{-1}. Usually by measuring the value of a sample at 20 °C and using sodium D ray (Na) as light source.

Biot's law is the law which expresses the proportionality of the optical rotation of a medium to concentrations of optically active products (dextrorotatory or levorotatory).

$$\text{Law of biot: } [\alpha]_T = \alpha/(L.C)$$

In which: α = Angle of rotation in degrees observed; L = Length of the tank in dm; C = Concentration of the solution in g/mL; α = it was measured by Bellingham + Stanley polar meter Model D. The solvent diluent is hexane.

Determination of antioxidant activity: Three methods have been applied for the antioxidant assessment of the *A. judaica* essential oil in this study: the 1,1-diphenyl-2-picrylhydrazyl radical ($DPPH^{\bullet}$) assay [9], the 2,2′-azino-*bis*(3-ethylbenzothiazoline-6-sulphonate) radical cation ($ABTS^{+\bullet}$) assay [10] and the ferric reducing antioxidant power (FRAP) assay [11]. All measurements were performed in duplicate.

DPPH assay: The scavenging activity of $DPPH^{\bullet}$ was determined based on the tests described by Brand-Williams *et al.* [9], with some modifications. Various concentrations of essential oil in methanol (1 mL) were mixed with methanolic solution containing DPPH radicals (0.1 mM). After vigorous agitation, the mixture was incubated for 1 h in the dark at room temperature and then the absorbance is measured at 515 nm with a UV spectrophotometer screws (JASCO-V530). A solution containing 1 mL methanol and 2 mL of DPPH radicals was used as blank. The estimation of the antiradical activity is expressed by the value of the per cent inhibition (IC (%)) according to the following formula:

$$IC\ (\%) = [(A_0 - A_x)/A_0] \times 100$$

where A_0 is the absorbance of analytical blank and A_x is absorbance in the presence of the extract solution.

Different sample concentrations were used in order to obtain antiradical curves for calculating the IC_{50} (= EC_{50}, the effective concentration) values. Antiradical curves were plotted referring to concentration on the x axis and their relative scavenging capacity on the y axis. The IC_{50} value, defined as the concentration of antioxidant that causes a 50 % decrease in the $DPPH^{\bullet}$ absorbance or the extract concentration providing 50 % inhibition. A lower IC_{50} value indicates greater antioxidant activity. Evaluation of free radical-scavenging activity was performed with Trolox equivalent antioxidant capacity (TEAC) assay [12-14].

ABTS assay: The free-radical scavenging capacity was measured using the ABTS decolouration method [15], with some modifications. Briefly, ABTS was dissolved in water to get a 7 mM concentration. ABTS radical ($ABTS^{+\bullet}$) was produced by reacting this stock solution with a 2.45 mM $K_2S_2O_8$ solution and allowing the mixture to stand in the dark at room temperature for 12 to 16 h. The $ABTS^{+\bullet}$ solution obtained was blue-green colouration which can be stored at -20 °C. Before use, the formed solution was diluted with methanol to an absorbance of 0.70 ± 0.02 at 734 nm. Samples were separately dissolved in methanol. In order to measure the antioxidant activity of

essential oils, 10 µL of each sample at various concentrations was added to 990 µL of diluted $ABTS^{+\bullet}$. The absorbance was measured spectrophotometrically at 734 nm using a UV spectrophotometer screws (JASCO-V530). Methanol was used to zero the spectrophotometer; $ABTS^{+\bullet}$ solution was used as blank sample. The radical-scavenging activity of the tested samples, expressed as percentage inhibition of $ABTS^{+\bullet}$ [IC (%)], were calculated according to the formula:

$$IC\ (\%) = [(A_0 - A_x)/A_0]\times 100$$

where, A_x and A_0 were the absorbance at 734 nm of samples with and without essential oils, respectively.

IC_{50} values, defined as the inhibiting concentrations of substrate that causes 50 % loss of ABTS activity (colour), were calculated by regression analysis. A lower IC_{50} value indicates greater antioxidant activity. Evaluation of free radical-scavenging activity was performed with Trolox equivalent antioxidant capacity (TEAC) assay [12-14].

FRAP assay: This method measures the ability of antioxidants to reduce the ferric iron. It is based on the reduction of the complex of ferric iron and 2,3,5-triphenyl-1,3,4-triaza-2 azoniacyclopenta-1,4-diene (TPTZ) in the ferrous form under acidic conditions. The reducing power is determined by the method described by Binsan *et al.* [16]. The FRAP reagent was freshly prepared by mixing acetate buffer (300 mM, pH 3.6), TPTZ solution (10 mM TPTZ in 40 mM HCl) and $FeCl_3{\cdot}6H_2O$ (20 mM) in a ratio of 10:1:1 [11]. The FRAP solution was incubated at 37 °C for 30 min. In a volume of 150 µL were prepared different concentrations of the sample to which was added 2850 µL of FRAP solution, incubated 30 min in the dark. Complex formation ferrous tripyridyltriazine (coloured product) is measured by reading absorbance at 593 nm. The activity is expressed as Trolox equivalent (micromoles TE/g of extract).

Calculation of Trolox equivalent antioxidant capacity (TEAC): The free radical-scavenging activity of each sample was expressed as Trolox equivalent antioxidant capacity (TEAC), which was obtained by comparing the absorbance change at 515 nm for DPPH essay, at 734 nm for ABTS essay and at 593 nm for FRAP essay, in a reaction mixture containing a sample of plant extract or test material with that containing Trolox. This index is defined as the millimolar concentration of a Trolox solution whose antioxidant capacity is equivalent to 1 mg of the extract [15].

Antimicrobial screening: The antimicrobial activities were determined by using the drop agar diffusion method [17]. The microorganisms tested were the fungi *Candida albicans* ATCC 10231 and the bacteria *Escherichia coli* ATCC 8739, *Salmonella typhimurium* ATCC 14028, *Staphylococus aureus* ATCC 6538, *Enterococcus feacium* ATCC 19434 and *Streptocoque B (Streptococcus agalactiae).* The oils were diluted in 10 % DMSO/sterile H_2O solution. A suspension of the tested microorganisms was spread on the appropriate solid media plates and incubated overnight at 37 °C (for the bacteria) or 25 °C (for *conidia* of filamentous fungi) After 1 day, 4-5 loops of pure colonies were transferred to saline solution in a test tube for each bacterial strain and adjusted to the 0.5 McFarland turbidity standard (about 108 cells/mL) [18]. Sterile cotton dipped into the bacterial suspension and the agar plates were streaked three times, each time turning the plate at a 60° angle and finally rubbing the swab through the edge of the plate. Sterile paper discs (Glass Microfibre filters, Whatman; 6 mm in diameter) were placed onto inoculated plates and impregnated with the diluted solutions (15 µL/disc). Ampicillin (10 µg/disc) was used as positive control for all strains except *C. albicans* for which nystatin (100 µg/disc) was used. Inoculated plates with discs were placed in a 37 °C (or 25 °C for conidia) incubator. After 24 h of incubation, the results were recorded by measuring the zones of growth inhibition surrounding the disc. Clear inhibition zones around the discs indicated the presence of antimicrobial activity. The test was run in duplicate.

RESULTS AND DISCUSSION

Chemical composition of essential oil: The chromatographic analysis of *A. judaica* essential oil shown in Table-1, Thirteen compounds could be identified in the oil, the major compounds, which were identified by GC-MS, were piperitone (79.04 %), davanone (7.23 %) and (4E,6E)-2-methyl-2,4,6-octatriene (5.32 %).The chemical composition of essential oil of *A. judacia* collected from Illizi was compared with essentials oils of the same species taken from Egypt and Libya.

TABLE-1
CHEMICAL COMPOSITION OF ESSENTIAL OIL OF *A.judaica*

N	TR	Component	%
1	9.501	1R-α-Pinene	0.41
2	10.135	Non identifier	0.35
3	14.597	*p*-Cymene	0.84
4	21.111	**(4E,6E)-2-Methyl-2,4,6-octatriene**	**5.32**
5	23.778	Cyclohexaneacetaldehyde, 2-Methylene	1.08
6	30.740	**Piperitone**	**79.04**
7	43.573	(–)-Germacrene D	1.41
8	44.468	Bicyclogermacrene	0.77
9	44.697	Davana ether (isomer 1)	0.40
10	45.916	Davana ether (isomer 2)	1.18
11	46.335	Myristicin	0.95
12	46.992	Davana ether	0.56
13	49.173	Spathulenol	0.47
14	50.273	**Davanone**	**7.23**
-	-	**Monoterpens hydrocarbons**	**1.25**
-	-	**Oxygenated monoterpenes**	**79.04**
-	-	**Sesquiterpenes hydrocarbons**	**2.18**
-	-	**Oxygenated sesquiterpenes**	**9.84**
-	-	**Phenylpropanoid**	**0.95**
-	-	**Other compounds**	**6.4**

The essential oil obtained from the leaves of *A. judaica* Egyptian which picked from the north coas and Sinai Peninsula, was pale yellow with a pleasant and distinct odour (1.4 ± 0.05 g/100 g fresh leaves). The major compounds, which were identified in the the north coas, were piperitone (45.0 %), *trans*-ethyl cinnamate (20.8 %), ethyl-3-phenyl propionate (11.0 %), *cis*-ethyl cinnamate (5.64 %) and methyl cinnamate (1.06 %). in the Sinai Peninsula. It is reported that the volatile oil composition of samples collected from the Sinai Peninsula, is rich in piperitone (27-46 %), *cis*-ethyl cinnamate (5-6 %), *trans*-ethyl cinnamate (8-13 %), camphor (16-23 %), chrysanthenone (5-6 %) and ethyl-3-phenyl propionate (0.2-0.5 %). Camphor and chrysanthenol were detected in low concentrations (0.38 and

0.14 %, respectively), *trans*-ethyl cinnamate and ethyl-3-phenyl propionate were found in high concentrations (20.81 and 11 %, respectively) [18].

The results of El-Massry *et al.* [19] were in close agreement with those of Saleh [2], who reported that the volatile oil of *A. judaica*, grown in the desert of Egypt, was a mixture of esters, ketones and aldehydes in which piperitone was the major component.

In contrast the essential oil of the aerial parts of *A. judaica* of Libya, yield 0.62 % (w/w), was lemon yellow in colour and had a strong smell. The dominant components of the essential oil of *A. judaica* from Libya were: piperitone (30.2 %), davana ether 2 (7.9 %), *cis*-chrysanthenol (9.1 %) and the remarkable presence of davana ether (3.0 %) and davana ether 1 (2.8 %) [20].

The composition of the essential oil of the aerial parts of *A. judaica* from Algeria, was studied by Charchari [21], it was characterized by piperitone (53.5 %), chrysanthenone (9.8 %) and *cis*-chrysanthenyl acetate (7.4 %). Additionally to Charchari [21], Dob and Chelghoum [22] noted that the essential oil of *Artemisia judaica* L. growing spontaneously in In-Amenas in southern Algeria, was isolated from the aerial parts by hydrodistillation in 0.70 % yield and the presence of piperitone (61.9 %), terpinen-4-ol (4.6 %) and bornyl acetate (3.0 %) in its essential oil.

Through the results of the literature review listed above, it is noted that the extracted essential oil from *A. judaica* showed a variation at their chemical compositions of essential oil, depending on geographical origin. But we can say that, the quality of the investigated oil was somewhat similar to that of the Libyan chemotype. And the similarities were in the presence of considerable proportions of piperitone, davana ether, davana ether 1, davana ether 2, davanone and the spathulenol. However the essential oil obtained from the aerial parts of *A. judaica.* collected from Illizi, Algeria indicates the presence of other chemotypes cited for the first time for this species with a considerable proportion, the compounds that appear for the first time are: (4E,6E) -2-methyl-2,4,6-octatriene (5.32 %), cyclohexaneacetaldehyde, 2-methylene (1.08 %) and the myristicin (0,95 %). The result of GC-MS analysis indicates that, the Algerian *A. judaiaca* essential oils contain the higher proportion of piperitone and davanone then the Egyptian en Libyan *A. judaica*.

Physical characteristics: The appearance, colour and odour of essential oil will be determined in order to assess the quality both economically and scientifically. Essential oils are usually liquid at room temperature, aromatic odour, rarely coloured when they are fresh. The organoleptic and physical characteristics of the volatile oil obtained from the aerial parts of *A. judaica* collected from Illizi, Algeria were obtained in Table-2.

To our best of knowledge, this is the first study, which is reported the physical properties of *A. judaica* essential oil from the extreme south of Algeria. The refractive index of essential oils is generally high. It is superior to that of water at 20 °C = 1.3356, this shows their rich components that deviate polarized light. A refractive index was varying essentially with the content in monoterpenes and oxygenated derivatives. High content in monoterpenes give a high index. For some authors, the low

TABLE-2
PHYSICAL AND ORGANOLEPTIC CHARACTERISTICS OF ESSENTIAL OIL OF *A. judaica*

		Essential oil of *A. judaica*
Organoleptic characteristics	Aspect	Clear liquid
	Colour	Yellow
	Odour	Fort and distinct odour
Physical characteristics	Density (d)	0,4608
	Refractive index (n at 20 °C)	1.48172 ± 0.00106
	Specific optical activity ([α] at 17 °C)	+ 62,774639

essential oil refractive index indicates its low refraction of light which could favour its use in cosmetic products [23,24]. Table-2 showed that *A. judaica* essential oil has a high refractive index and this is due to his riches in monoterpenes and oxygenated derivatives.

Essential oils are mixtures of terpene compounds, aromatic or other compounds and the optical activity of the essential oil obtained, is normally the results of all optical activities are in this mixture and are levorotatory and dextrorotatory compounds and from this base may conclude that *A. judaica* essential oil is richer in dextrorotatory molecules than that of levorotatory molecules.

Antioxidant activities: Several assays have been frequently used to estimate antioxidant capacities in fresh fruits and vegetables and their products and foods for clinical studies including 2,2-azino*bis*(3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS) [10], 2,2- diphenyl-1-picrylhydrazyl (DPPH) [9], ferric reducing antioxidant power (FRAP) [11]. These techniques have shown different results among crop species and across laboratories, the aim of this research was to compare the efficiency of ABTS, DPPH and FRAP assays to estimate antioxidant activities. The results of the antioxidant activity of *A. judaica* essential oil are summarized in Table-3, it was found that the essential oil showed different antioxidant capacities.

TABLE-3
ANTIOXIDANT ACTIVITY OF *A. judaica* EXPRESSED IN TEAC AND IC_{50}

Variables	DPPH	ABTS	FRAP
TEAC (µmol/g)	12.572	105.371	86.28 ± 3.2
IC_{50} (mg/mL)	3.63 ± 0.17	2.09 ± 0.17	–

Averages ± Standard deviation were obtained from two different experiments.

Comparing IC_{50} and TEAC values (Table-3), the essential oils obtained from *A. judaica* showed an antioxidant activity in the ABTS essay most important than in the DPPH essay. This is due to sensitive of DPPH method to acidic pH unlike the ABTS method has the extra flexibility in that it can be used at different pH levels [25]. In order to compare results given earlier, the study tested the ability of *A. judaica* essential oil of the reducing power of the ferric ion (Fe^{3+}) to corresponding ferrous ions (Fe^{2+}).

In general, the antioxidative effectiveness of essential oil depends on the content of phenolic compounds and the reaction

TABLE-4
ANTIMICROBIAL ACTIVITY OF *A. judaica* ESSENTIAL OIL

Name of bacterial strain	Inhibition diameter (mm)[a]		
	Ampicillin/Nystatin (10 µg/100 µg)	*A. judaica*	Dilution ratio[b]
Escherichia coli ATCC 8739	12.00 ± 1.0	15.00 ± 0.0	1
Salmonella typhimurium ATCC 14028	17.33 ± 1.5	12.00 ± 1.4	1
Staphylococcus aureus ATCC 6538	44.30 ± 0.5	20.50 ± 2.1	1/8
Enterococcus faecium ATCC 19434	45.30 ± 1.5	15.50 ± 0.7	1/32
Streptocoque B (Streptococcus agalactiae)	34.30 ± 0.5	13.75 ± 0.3	1/16
Candida albicans ATCC 10231	42.00 ± 1.0	12.75 ± 0.3	1/16

[a]Including disc diameter of 6 mm, Averages ± Standard Deviation were obtained from two different experiments.
[b]The essential oil was diluted in 10 % DMSO/sterile H_2O solution.

activity of the phenol towards the chain-carrying peroxyl radicals and on the stability of the phenoxyl radical formed in the reaction. Although the essential oil obtained from *A. judaica* growing in Illizi is lacking to phenolic constituents, but it is showing an activity antioxidant relatively strong. Our results are not agree with the results of El-Massry *et al.* [19]. They reported that the Egyptian *A. judaica* volatile oil showed antioxidative activity, determined by thiocyanate and scavenging effect on 1,2-diphenyl picrylhydrazyl (DPPH) methods. Its activity may be due to the presence of 2,6-dimethyl phenol (1.39 %) and camphor (0.38 %). We can explain the activity antioxidant of *A. judaica* essential oil growing in Illliz region, with the presence of (4E,6E) -2-methyl-2,4,6-octatriene, cyclohexaneacetaldehyde, 2-methylene or the Myristicin, The first two compounds have only nine carbonate, they are not terpene or phenol.

The antioxidant activities of essential oils from aromatic plants are mainly attributed to the active compounds present in them. This can be due to the high percentage of main constituents, but also to the presence of other constituents in small quantities or to synergy among them [26,27].

Antimicrobial activity: The antimicrobial activity of essential oils obtained from *A. judaica* was evaluated by a paper disc diffusion method. The data show that the essential oil of *A. judaica* exhibited strongly all the tested strains, but in variable degree. The results presented in Table-4, reveal that *A. judaica* essential oil inhibited strongly the growth of *E. faecium* and *S. aureus.* The study used antibiotic ampicillin and the antifungal nystatin as positives probe.

The antimicrobial activities have been mainly explained through the presence of oxygenated sesquiterpenes and monoterpenes. The synergistic effect of essential oil components is a promising field that could lead to the optimization of a given bioactivity [28]. The essential oils of *A. judaica* showed antibacterial activity higher than the ampicillin, against all the tested strains. The results indicated that all the Gram-positive bacteria were the most sensitive strains tested to the essential oils of *A. judaica, especially E. faecium* (with dilution ration (1/32)) and *S. aureus*. The same results indicate by Janackovic *et al.* [20] in the essential oil extracted from the *A. judaica* Libyan and they reported that the essential oil of *A. judaica* exhibited higher antifungal potential than bifonazole against *A. versicolor*, *A. ochraceus*, *A. niger* and *Penicillium* species. Considering that the essential oils of *A. judaica* have the highest content of oxygenated compounds, it is expected to have the best antibacterial and antifungal effect. Oxygenated monoterpenes exhibit high antimicrobial activity on whole cells. In contrast, hydrocarbon derivatives have lower antimicrobial activity because of their lower solubility and diffusion through the medium [20].

On the other hand, the results (Table-4) by *A. judaica* essential oils are similar to the results obtained with *C. schoenantus* essential oil, which characterized by the high proportion of piperitone [29], so we can explain the high antimicrobial activity registered of *A. judaica* essential oil and *C. schoenantus* essential oil by the high proportion of piperitone.

Conclusion

To the best of our knowledge, the physical properties, the antimicrobial and the antioxidant activities and of the Algerian *A. judaica* essential oils have never been reported. Therefore, this work is the first report on the physical, chemical and biological characteristics of this herb of Illizi. The result of GC-MS analysis indicates that the Algerian *A. judaiaca* essential oils contain the higher proportion of piperitone and davanone then the Egyptian and Libyan *A. judaica*. Among identified components in *A. judaica* essential oil, (4E,6E)-2-methyl-2,4,6-octatriene, cyclohexaneacetaldehyde, 2-methylene and the myristicin were reported for the first times in this species. The presence of these components and other are possible to be reason for the high antioxidant activities showing in the DPPH, ABTS and FRAP tests. The antimicrobial activities of *A. judaica* essential oil was studied *in vitro* on five bacterial strains and one fungal strain, all microbial strains were inhibited by this oil.

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