



Comparative Studies of Chemical Compostion, Antimicrobial and Antioxidant Activity of Essential Oil of Some Species from Genus *Artemisia*

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Abstract

Background and Objective: Some species from genus *Artemisia* were used in ancient medicine since Pharaonic civilization, most species of this genus are grown in arid or desert zones in Egypt. The present study aimed to evaluate and compare the chemical constituents, antimicrobial and antioxidant potential of the essential oils of three species of *Artemisia* (*Artemisia sieberi*, *Artemisia judaica* and *Artemisia monosperma*) grown in Egypt. **Materials and Methods:** Chemical constituent of the essential oils of these species were analysed by GC-MS, antibacterial activities were carried out using disc-diffusion test and antioxidant properties were investigated with Iron, Fe (III) to Fe (II) reduction and DPPH radical scavenging capacity. **Results:** The results of chemical analysis revealed similarity between the three species in 20 compounds, the major compounds identified in essential oils were verbenol, (7.5 % and 11.51%) in *A. sieberi* and *A. monosperma*, β -caryophyllene oxide (1.25 % – 0.78%) and Methyl jasmonate (0.9 % and 1.21 %) in *A. sieberi* and *A. judaica*, respectively. While the major compound in *A. judaica* was Lilac alcohol C (9.6%) and camphor (4.5%). The antibacterial investigation exhibited significant and broad-spectrum antibacterial efficacy of *A. monosperma* and *A. judaica* against different strains of Gram-positive and Gram-negative bacteria. Whereas, *A. sieberi* showed higher antibacterial efficacy against the gram-positive bacteria but weak or no effect against the Gram-negative bacteria. The results of the antioxidant investigation showed that *A. sieberi* present the higher reduction capacity with an IC_{50} of 0.17 ± 0.03 g/L, followed by *A. judaica* with an IC_{50} of 0.58 ± 0.04 g/L and *A. monosperma* with an IC_{50} of 6.35 ± 0.41 g/L. However, the reducing capacity of ascorbic acid and quercetin were 0.091 ± 0.002 g/L and 0.026 ± 0.002 g/L respectively. **Conclusion:** The present study revealed that the essential oils of *A. sieberi*, *A. judaica* and *A. monosperma* possesses significant antioxidant and antibacterial activity, which attributed to the plenty of varied chemical compounds in these medicinal plants.

Keywords: *Artemisia judaica*, *Artemisia monosperma*, *Artemisia sieberi*, Disc Diffusion, Essential Oils, Radical Scavenging

1. Introduction

Medicinal plants and natural products have attracted the scientific interest all over the globe, medicinal plants are essential components of primary health care for up to 80% of the Earth's inhabitants, they are also intervened in 11% of up to 252 drugs of modern pharmaceutical industries¹.

Essential oils are important compounds used in traditional medicine extensively in industries. From 3000 known essential oils only 10% of them are commercially important in pharmaceutical, food, cosmetic, perfumery industries^{2,3}.

Generally, little knowledge is known about desert plants, which exists in harsh environmental condition. *Artemisia* is genus of small herbs and shrubs, belong to *Asteraceae*, comprises over 500 species, which are mostly found in Asia, Europe and North America. Number of these genus member of Anthemideae tribe which is famous with medicinal and ethnopharmacological properties is prescribed in the cosmetic, flavor and fragrance industries⁴. Interestingly, members from this genus are used in ancient Egyptian civilization as found in some medical papyri dating back to 1850 B.C.⁵

A. judaica L. is a perennial fragrant shrub which grows widely in the deserts and it is very common in Sinai Peninsula in Egypt, it is used as an anthelmintic drug in most North African and Middle-Eastern countries where it is known by the Arabic name of "shih"⁶. *A. sieberi* is traditionally used for the treatment of different ailments. Some studies analysed the chemical constituents of *A. sieberi* growing in Iran and France using gas chromatography–GC–mass spectrometry (GC–MS), and showed antimicrobial activity⁷. *A. monosperma* is growing in different regions of Egypt, it grows in desert and semi-desert climate, and have many medicinal properties⁸.

There are many factors influencing on the variations in the essential oils contents of plant species belonging to the same plant family, the climatic variation that occur over the course of a year is one of the major impacts, which is important to identify the most appropriate time of the year for optimal extractions in terms of yield and/or compound concentration. When different climatic factors in seasonal climates with two well-determined

seasons is modified, these variations could act on the plants and alter their metabolism^{9,10}.

The chemical composition of essential oils from the *Artemisia* genus has been extensively studied in several species from around the world, however, little studies is known about them in Egypt, many studies have shown that *Artemisia* species display significant intraspecific variations in the terpene constituents of their essential oils. In some cases, the variation in the volatile components of these plants may occur during plant growth at different altitudes. For the cultivated species, the quality and yield of essential oils from *Artemisia* species is influenced by the harvesting season, fertilizer and pH of soil, the choice and stage of drying conditions, the geographic location, the plant part, the plant genotype, or the extraction method¹¹.

In literature, an exhaustive survey have been conducted on different species from genus *Artemisia*, which showed that they have a vast range of biological activities including antimalarial, cytotoxic, antihepatotoxic, antibacterial, antifungal and antioxidant activity. Some very important drug leads have been discovered from this genus, notably artemisinin, the well known antimalarial drug isolated from the Chinese herb *A. annua*. Terpenoids, flavonoids, coumarins, caffeoylquinic acids, sterols and acetylenes constitute major classes of phytochemical constituents of that genus¹².

The aim of this study was to determine the potential variations occurring in the essential oils yield and chemical composition of three plants from genus *Artemisia*, grown in agro-climatic condition of Egypt in addition to their antioxidant and antimicrobial properties.

2. Materials and Methods

2.1 Plant Material

Flowering aerial parts of three species from genus *Artemisia*, *A. sieberi*, *A. monosperma* and *A. judaica* (Figure 1) were collected from South Sinia, Egypt, during the spring season 2016. Collected plants have been kindly verified and authenticated in the Desert Research Center, voucher specimens were deposited in the Herbarium of Desert Research Center.

*Artemisia monosperma**Artemisia sieberi**Artemisia judaica***Fig. 1.** The three plants under study.

2.2 Extraction and Analysis of Fixed Oil

30 grams of fresh areal parts from each plant under study were crushed and extracted with petroleum ether: diethyl ether (1:1) for 4 h in a Soxhlet apparatus. The extract was evaporated under reduced vacume, 1 ml concentrated extract was dissolved in 20 ml petroleum ether and 10 ml methanolic KOH was added. The mixture was shaken for 2 min. and allowed to stand for 10 min; the upper layer was removed and washed with water. These oils (like the methyl esters of the fatty acids) were analyzed by GC/MS using a Hewlett-Packard 6890/5972 system with HP-5MS capillary column (30 m\0.25 mm; 0.25 μ m film thickness). Constituents were identified by comparison of their retention indices with literature values¹³.

2.3 Extraction and Analysis of Essential Oils

Two ml of extract prepared in a soxhelt with petrolum ether: ether (1:1) as deccribed above were hydrodistllied for 4hours, the distillate was extracted by n-hexane,

seperated the organic layer in separating fynle and concentrated under reduced pressure to 1 ml and dried over anhydrous sodium sulphate. The compounds were analyzed using a Thermo GC-Trace ultra system (Thermo Co. USA), they were separated on 30m X 0.25 mm X 0.25 μ m Elite-5MS column (Thermo Scientific GC Column). The column temperature was increased from 40 °C to 220 °C at a rate of 4 °C/ min; injector temperature, 250 °C; injection volume, 1 μ l; helium carrier gas flow rate 20 ml/min; transfer temperature, 280 °C. MS parameters were as follows: EI mode, with ionization voltage 70 ev, ion source temperature. The constituents were identified by matching their mass spectra in the Wiley 275.L library and by comparison of their retention indices with literature values¹³. Retention indices were determined using retention times of n-alkanes that have been injected to the same instrument and under the same chromatographic conditions. Relative percentage amounts were calculated from the total area under the peaks by the software of the apparatus¹⁴.

2.4 Antioxidant Capacity

2.4.1 Fe (III) to Fe (II) Reduction Capacity

The reduction capacity of Fe (III) to Fe (II) was done as described previously (Abd Alla et al., 2016)¹⁵. Briefly, 1 ml of each concentration was mixed with 2.5 ml of phosphate buffer (0.2 mol/l, pH 7.0) and 2.5 ml of potassium hexacyanoferrate $K_3Fe(CN)_6$ solution and they were incubated for 30 min at 50°C. Then, 2.5 ml of trichloroacetic acid (10%) was added to this mixture to stop the reaction. Afterwards, 2.5 ml of this mixture was homogenized with $FeCl_3$ (0.5 ml, 0.1%) and distilled water (2.5 ml). The absorbance was measured at 700 nm and the concentration of the samples at which the absorbance of 0.5 (EC_{50}) was determined. Quercetin and Ascorbic acid were used as positive control for comparison.

2.4.2 DPPH Radical Scavenging Capacity

In this test, 0.5 ml of each concentration was homogenized with 0.5 ml of DPPH methanolic solution (0.04 g/L). Then, this solution was mixed vigorously and putting in darkness for 30 min at a temperature of 25 °C. Afterwards, The absorbance of the mixtures was measured at 517 nm¹⁵, and the percentage inhibition was calculated as:

$$\% \text{ Inhibition} = \frac{(A \text{ blank} - A \text{ sample})}{A \text{ blank}} \times 100$$

Quercetin and ascorbic acid was used as positive control and the concentration providing 50% inhibition (IC_{50}) was calculated from the graph of inhibition percentage plotted.

2.5 Antibacterial Testing

Ten bacterial strains (Gram-positive and Gram-negative) including referenced bacterial strains and clinically isolated strains were used to evaluate the antibacterial properties of the flowering aerial parts of *A. sieberi*, *A. judaica* and *A. monosperma*. The referenced bacteria strains were *Escherichia coli* ATCC 35218, *Staphylococcus aureus* ATCC 25923, *Klebsiella pneumonia* ATCC 700603, *Klebsiella pneumonia* ATCC 27736, *Staphylococcus epidermidis* ATCC 12228 and *Bacillus cereus* ATCC 10876. The clinical isolated strains were *S. aureus*, *Acinetobacter*

baumannii, *E. coli* and *Pseudomonas aeruginosa*. The disc diffusion method was employed in this investigation as reported by Abdallah et al, 2016¹⁵. Briefly, using sterile loop one colony from each of the over-night subcultures containing the above motioned microorganisms was dipped in to a tube containing sterile normal saline and adjusted to be equivalent to 0.5 McFarland standard (Approximately $1-2 \times 10^8$ CFU/ml). This adjusted microorganism was swabbed over a previously prepared sterile Mueller-Hinton agar. The dry volatile oils were reconstituted in Ether at concentration 500 mg/ml, and without delay 20 μ l from that concentration was dropped over 6 mm blank discs (Whatman No.1) and left to dry under aseptic conditions. The dried discs were loaded over the swabbed sterile Mueller-Hinton plates, Erythromycin (15 μ g/disc) was used as positive control, blank disc loaded with Ether only and dried with the tested discs was used as negative control. Mean zone of inhibition was calculated after overnight incubation at 35 °C.

3. Statistical Analysis

For quantitative data, One-way ANOVA analysis was used, $P \leq 0.05$ considered significant. SPSS version 11 was used in statistical analysis of quantitative data and for graph drawing.

4. Results

4.1 Chemical Compositions and Yields of Essential Oil

The yields of the Essential Oils (EO) from 50 g fresh aerial parts of the three tested species of genus *Artemisia* was found to be varied. The results showed that the EO yield varied significantly depending on the species. The optimal yield was observed in *A. judaica* (2.1%) followed by *A. sieberi* (1.8%) the lowest yield was observed in *A. monosperma* (1.2%). The chemical compositions of the essential oils for three species of *Artemisia* are illustrated in (Table 1). The compounds were identified by matching their MS fragmentation patterns with those reported by MS computerized data bank spectral libraries¹³. The results showed the major compounds of *A. sieberi*, which were Verbenol (11.51%) Lilac alcohol C (8.0%), Methyl jasmonate (0.9%), Eucalyptol (0.78%),

Table 1: Percentage composition and retention time of essential oils of the tested *Artemisia* spp.

No.	Compounds	Rt	<i>A. judaica</i>	<i>A. sieberi</i>	<i>A. monosperma</i>
1	p-Cymene	5.16	0.59	0.19	0.50
2	Eucalyptol	5.36	0.31	0.78	0
3	8 hydroxymenthol	5.4	.02	0.03	0
4	Geranyl- vinyl ether	5.6	0.09	0.03	-
5	Geranyl- isovalerate	5.78	-	0.21	0.10
6	trans-Isoeugenol	5.16	0.65	-	0.04
7	Lavandulyl-acetate	7.3	-	0.21	0.04
8	cis4-methoxy-thujane	7.2	-	0.26	0.09
9	Verbenol	7.4	0.36	11.51	7.54
10	Carvone oxide,	8.78	0.09	0.03	-
11	Camphor	8.29	4.6	0.47	0.26
12	(+)Borneol	8.99	-	0.53	0.32
13	Terpineol	9.28	-	0.13	0.37
14	α -santalol	9.85	-	-	0.04
15	Limonene	10	0.08	0.02	0.15
16	D Verbenone	10.39	0.34	0.25	0.25
17	Carvenone	12.17	0.72	-	2.81
18	4-Terpinenyl- acetate	13.1	-	0.13	0.04
19	Cis-p-mentha-7,8-dien-2-ol	13.27	0.09	0.29	0.14
20	5-Caranol	13.6	0.86	0.25	0.38
21	Eugenol	14.38	2.95	0.10	-
22	7-trans-sesquisabinene Hydrate	18.08	0.06	0.24	0.16
23	Caryophyllene oxide	20.64	0.72	1.25	0.08
24	Spathulenol	20.67	0.72	0.45	1.11
25	Nerolidol	20.72	2.5	0.45	0.50
26	Chrysanthenone	20.95	0	0.52	0
27	α -Santoline alcohol	22.80	0.62	-	0.39
28	Lilac alcohol C	21.17	9.06	8.0	6.5
29	Methyl jasmonate	22.57	1.21	0.96	0.64
30	6-epishyobunol	22.49	0.14	1.14	0.17
31	Trans- Z- Bisabolene Epoxide	27.30	1.6	2.35	0.39
32	α -Santonin	32.22	0.52	0.53	0.39
33	Epicederene -oxide	32	0.06	0.49	-
34	Aromadendrene oxide	34.73	2.4	0.18	0.44
35	Corymbolon	34.43	0.16	0.18	0.29
36	Isoaromadendrene epoxid	35.31	0.25	3.16	9.8
37	Thumbergol	37.2	-	0.55	-
38	Cedran-diol	38.44	0.12	1.38	0.42

Camphor (0.47%) and, cis-4-methoxy-thujane (0.26%), Cis-p-mentha-7,8-dien-2-ol,(0.25%) α -Santonin(0.53%) and caryophyllene oxide (1.25%). Some compounds are present in minor amounts, Carvone oxide (0.03%) and Limonene (0.02%) whereas in *A. judaica*., the major compounds were Lilac alcohol C (9 %), Camphor (4.5%), Eugenol (2.5%), Nerolidol (2.5%), Bisabolene epoxide (1.6%), Methyl jasmonate (.21%), Spathulenol (0.74%), 5-Caranol (0.86%), santiolia alcohol (0.62%), p-Cymene (0.59%) and trans-Isoeugenol (0.65%).

Regarding *A. monosperma*, the major compounds were Verbenol (7.5%), Lilac alcohol C(6.5%), Terpeneol, Carvenone (2.5 %), Camphor (0.26%) Aromadendrene oxide (2.5%) and Spathulenol, (0.72%), Bisabolene epoxide (1.6%). The chemical analysis of the essential oils of *A. monosperma*, *A. judaica* and *A. sieberi*, showed 20 similar compounds with a high percentage, the essential oils of *A. judaica* recorded high ratio of oxygenated terpenoids than the others (*A. sieberi* and *A. monosperma*).

4.2 Fatty Acids

Fatty Acids Analysis of the three investigated species from genus *Artemisia* revealed the presence of varied bioactive fatty acids as shown in (Table 2), Linolic acids are present in the three species where Arachidonic acid, Erucic acid and Oleic acid are found in two species and not detected in other one. Whereas, Linolenic acid was found only in *A. sieberi*.

4.3 Antioxidant Activity

In the present study, the FRAP method and DPPH scavenging capacity was used to determine the antioxidant capacity of the tested *Artemisia* essential oils by reducing the ferric ion (Fe^{3+}) to the ferrous ion (Fe^{2+}), and reduction of DPPH. The results of this study showed that *A. sieberi* present the higher antioxidant activity, followed by *A. judaica* and *A. monosperma* (Table 3). However, the standards substances used in this study (Ascorbic acid and Quercetin) present an antioxidant activity of 0.033 ± 0.001 g/l and 0.017 ± 0.001 using DPPH reduction and 0.091 ± 0.002 g/l and 0.026 ± 0.002 g/l using FRAP method, respectively (Table 3).

4.4 Antibacterial Activity

The results of the antibacterial evaluation are presented in Figures 2-4 and Tables 4, 5. In general, *A. monosperma* and *A. sieberi* showed greater antibacterial activity against both of the Gram-negative and Gram-positive bacteria. The mean zone of inhibition of the essential oils of *A. monosperma* ranged between 23.0 ± 0.0 to 18.5 ± 1.5 mm, for Gram-positives, and 16.5 ± 0.5 to 10.0 ± 1.0 for Gram-negatives. Among all tested bacteria the most susceptible bacteria was *Satphylococcus aureus*. Mean zone of inhibition of the essential oils of *A. sieberi* ranged between 20.0 ± 0.0 to 17.5 ± 0.5 mm, for Gram-positives, and 17.0 ± 1.0 to 11.5 ± 0.5 for Gram-negatives. The most susceptible bacteria was *S. aureus*. While, *A. judaica*

Table 2: Fatty acid analysis of the tested Artemisia spp.

Compound	<i>A. monosperma</i>	<i>A. sieberi</i>	<i>A. judaica</i>
Erucic acid	0.02	0.02	-
Arachidonic acid	0.03	-	0.08
Linolic acid	0.5	0.02	0.3
Linolenic acid	-	0.07	-
Oleic acid	0.12	-	1.4
Oleic acid, 3(octadecyloxy)propyl ester	0.41	-	-

Table 3: Antioxidant capacity of the essential oils of the tested Artemisia spp.

Measurement	<i>monosperma</i>	<i>A. sieberi</i>	<i>A. judaica</i>	Ascorbic acid	Quercetin
IC ₅₀ (g/L)	4.7 ± 0.12	0.09 ± 0.02	0.22 ± 0.02	0.033 ± 0.001	0.017 ± 0.001
EC ₅₀ (g/L)	$6..35\pm 0.41$	0.17 ± 0.03	0.58 ± 0.04	0.091 ± 0.002	0.026 ± 0.002

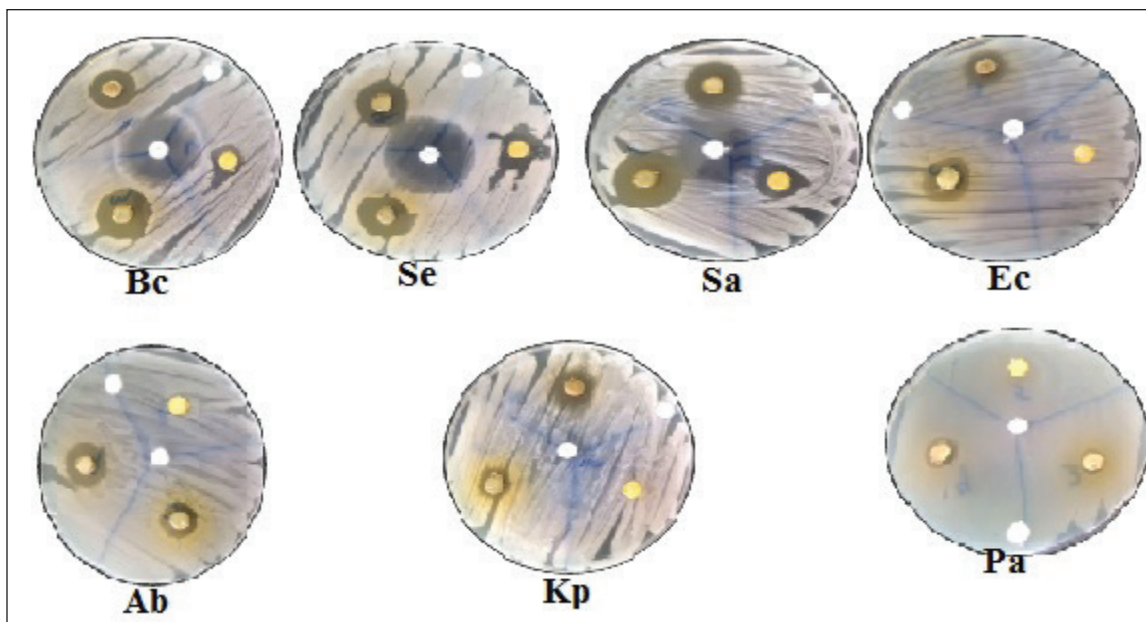


Fig. 2. Representative photo showing the effect of volatile oils on some bacterial strains*.

*The antibiotic disc (In the middle), the negative control (white disc in the corner), the volatile oils form *Artemisia* spp. (In yellow color). Ec = *Escherichia coli* ATCC 35218, Kp = *Klebsiella pneumonia* ATCC 700603, Ab = *Acinetobacter baumannii* clinical isolate, Pa = *Pseudomonas aeruginosa* clinical isolate, Sa = *Staphylococcus aureus* ATCC 25923, Se = *Staphylococcus epidermidis* ATCC 12228, Bc = *Bacillus cereus* ATCC 10876.

Table 4: Antibacterial activity of the tested plant's essential oils against some Gram-positive bacteria*

Tested plant	Mean zone of inhibition (mm)			
	Sa1	Sa2	Se	Bc
<i>A. monosperma</i>	23.0±0.0	22.5±0.5	18.5±1.5	20.5±0.5
<i>A. sieberi</i>	20.0±0.0	20.0±0.0	19.0±1.0	17.5±0.5
<i>A. judaica</i>	14.5±0.5	20.0±1.0	31.5±0.5	25.5±0.5
Erythromycin (15 µg/disc)	6.0±0.0	20.0±1.0	7.5±0.5	6.0±0.0

* Sa1 = *Staphylococcus aureus* ATCC 25923, Sa2 = *Staphylococcus aureus* clinical isolates, Se = *Staphylococcus epidermidis* ATCC 12228, Bc = *Bacillus cereus* ATCC 10876.

Table 5: Antibacterial activity of the tested plant's essential oils against some Gram-negative bacteria

Tested plant	Mean zone of inhibition (mm)					
	Ec1	Ec2	Kp1	Kp2	Ac	Pa
<i>A. monosperma</i>	13.0±0.0	16.5±0.5	12.5±0.5	11.5±0.5	14.5±0.5	10.0±1.0
<i>A. sieberi</i>	15.5±1.5	16.5±0.5	15.0±1.0	14.5±0.5	17.0±1.0	11.5±0.5
<i>A. judaica</i>	6.0±0.0	6.0±0.0	6.0±0.0	6.0±0.0	8.0±0.0	6.0±0.0
Erythromycin (15 µg/disc)	6.0±0.0	24.0±0.5	6.0±0.0	7.0±1.0	31.5±0.5	25.5±0.5

* Ec1 = *Escherichia coli* ATCC 35218, Ec2 = *Escherichia coli* clinical isolate, Kp1 = *Klebsiella pneumonia* ATCC 700603, Kp2 = *Klebsiella pneumonia* ATCC 27736, Ac = *Acinetobacter baumannii* clinical isolate, Pa = *Pseudomonas aeruginosa* clinical isolate.

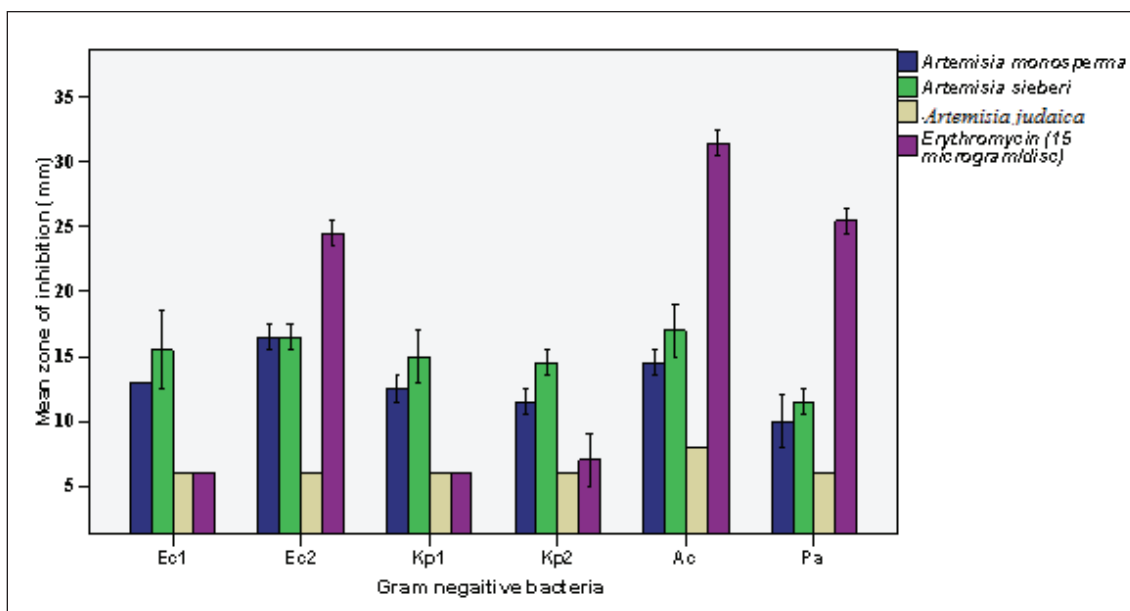


Fig. 3. Susceptibility of the Gram-negative bacteria to essential oils and to Erythromycin*.

* Ec1 = *Escherichia coli* ATCC 35218, Ec2 = *Escherichia coli* clinical isolate, Kp1 = *Klebsiella pneumoniae* ATCC 700603, Kp2 = *Klebsiella pneumoniae* ATCC 27736, Ac = *Acinetobacter baumannii* clinical isolate, Pa = *Pseudomonas aeruginosa* clinical isolate.

showed no antibacterial effect on the Gram-negative bacteria (6 mm), only weak effect recorded against *Acinetobacter baumannii* (8 mm). However, it showed higher antibacterial activity against the Gram-positives only. Surprisingly, *A. judaica* exhibited mean zone of inhibition ranged between 31.5 ± 0.5 to 14.5 ± 0.5 mm against the Gram-positive bacteria only, which lead to assuming that this plant has a great antibacterial and narrow spectrum effect against the Gram-positive bacteria in particular.

5. Discussion

The strong fragrance of leaves and flower of genus *Artemisia* is associated to high concentration of sesquiterpenes, and other constituent in their essential oils which was determined in the current study. In our study the yield of Essential Oils (EO) are varied according to species, where *A. judaica* have higher amount of EO yields than *A. monosperma* and *A. sieberi*. Similar results were obtained by van Wyk, and Wink⁶.

The EO yields of *A. monosperma* detected in the present study were higher than that detected by El Zalabani *et al.*¹⁶ in plant grow in Libya, where the yield

of the essential oils was 0.16 % v/w., this higher yield of essential oils related to the tolerance level of these plants under drought conditions, plants that grow in such harsh conditions are adapted by means of accumulating some chemical compounds. When plant exposed to mild or severe drought condition, plant exhibit arrange of specific responses, to reduce the water loss or optimize water uptake. Among of these responses, closure of stomata, and decrease the rate of photosynthesis^{17,18}. Upon exposure to osmotic stress due to high temperature and drought, plant accumulate number of osmolytes for maintenance a turgor presuer in the cell.

The composition of essential oils for species of *Artemisia* were analyzed and showed that there are similar in 20 compound, the results showed the major compounds are, Verbenol, p-Cymene, Lilac alcohol C, Methyl-jasmonate, camphor, Cis-p-mentha-7,8-dien-2-ol, Limonene, verbenon, α -Santonin and Caryophyllene oxide with different concentration.

From the investigation on the basis of chemotaxonomy, there is similarity in major compounds of the essential oils from those three species. It was concluded that most of the essential oils are rich in oxygenated monoterpenes and monoterpene

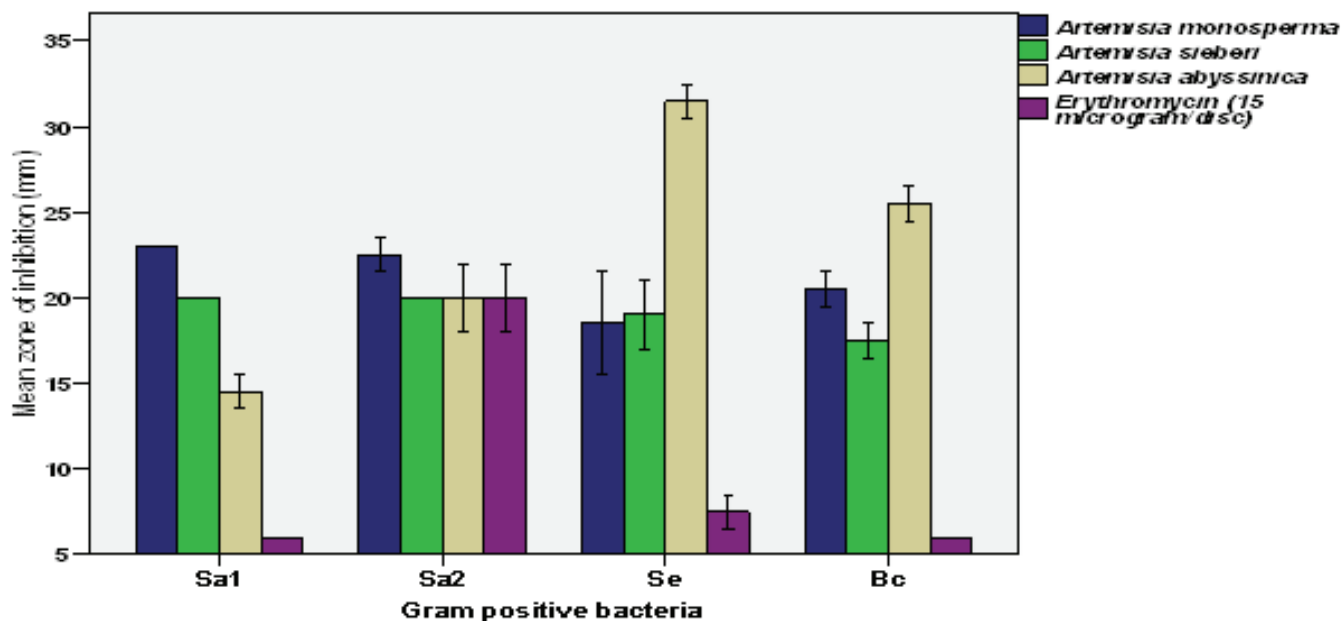


Fig. 4. Susceptibility of the Gram-positive bacteria to essential oils and to Erythromycin*.

* Sa1 = *Staphylococcus aureus* ATCC 25923, Sa2 = *Staphylococcus aureus* clinical isolates, Se = *Staphylococcus epidermidis* ATCC 12228, Bc = *Bacillus cereus* ATCC 10876.

hydrocarbons compounds. However, sesquiterpene is found as a major group of compounds in those three species.

Our data was in contradiction with that determined by Mohammad hosseini *et al.*¹⁹, the essential oils of *A. sieberi* from Iran, were mainly composed Camphor (22.0%), 1,8-cineole (19.3%), cis-davanone (15.0 %), camphene (4.6%), terpinene-4-ol (3.2%). While in *A. monosperma*, the identified compounds were Verbenol, Lilac alcohol C, Terpeneol, Carvenone, Trans-sabinene-hydrate, Bornyl acetate, Camphor, iso-eugenol, p-cymene, α -Phellandrene, and Limonene. Moreover, similar data was reported by El Zalabani *et al.*¹⁶.

Negahban *et al.*²⁰ reported that, the essential oils of *A. sieberi* containing camphor and camphene have a potential effect against *Callosobruchus maculatus*, *Sitophilus oryzae* and *Tribolium castaneum*. On the other side, Farzaneh *et al.*²¹ established that, the essential oils of *A. sieberi* containing β -thujone (19.8%), α -thujone (19.5%), and camphor (19.5%) being its major components are slightly more effective against *Tiarospora phaseolina*, *Fusarium moniliforme* and *Fusarium solani* but had high antifungal activity against *Rhizoctonia solani*.

Whereas, our result clearly indicates that the composition of the essential oils varies significantly due to drastic conditions and drought stress in which the plant grows and survives, some compounds were detected in other chemical forms like thujone which was found as cis-4-methoxy-thujane, verbenol and Lilac alcohol C were accumulated in higher amounts to adapt to drought stress, this was confirmed by Putievsky *et al.*²² who established that *Pelargonium graveolens* plants which grow under moisture stress stress yielded essential oil richer in citronellol. He was also reported, as a crop plant accumulates amino acid proline when subjected to stress, citronellol accumulation in the test crop during summer could be a similar mechanism for adaptation to stresses²².

Regarding the antioxidant testing, the results showed that the ability of these essential oils to reduce iron and DPPH was less than that of ascorbic acid and quercetin because they are pure products and are known as antioxidant substances²³. Furthermore, the results showed a difference in the antioxidant capacity between the tested *Artemisia* species, this can be explained by the differences in chemical compositions and the harvested origin. These results are supported by a study carried out for different species of the genus *Artemisia*

and showed a difference in the antioxidant capacity²⁴. In this study, *A. judaica* has a similar antioxidant capacity to that reported in Ethiopia with an IC₅₀ of 0.289 mg/ml²⁵. Moreover, the earlier studies have reported the antioxidant capacity of essential oil of other *Artemisia* species^{26,29}.

Our study is in conformity with the study of Guetat.³⁰ who reported that *A. monosperma* and *A. sieberi* as well as another two species *A. scoparia*, *A. judaica* showed high antibacterial activity. However, it disagrees with their findings with the Gram-negatives. Our results suggests that *A. sieberi* has higher antibacterial activity against the Gram positives and weak or no activity with the gram negative bacteria, this claim was confirmed by Mahboubi and Farzin³¹, who cited that the Gram-positive bacteria and fungi were more sensitive towards oil of *A. sieberi* than Gram negative ones.

6. Conclusion

Genus *Artemisia*, family asteraceae, tribe anthemideae, famous with important medicinal plants, which are currently the area under discussion of phytochemical consideration due to their chemical and biological diversity. Three species of *Artemisia* show more than thirty compounds identified from essential oils, 20 compounds are similar and some compounds are different, the major compounds are Lilac alcohol C, verbenol and camphor, three species of *Artemisia* showed high antimicrobial and antioxidant activity, the antibacterial and antioxidant activity are attributed to the richness of phytochemical components of essential oil of these plants. There is a variety of composition of essential oils between three species, finally recommended by study the mechanism of action of essential oil in antimicrobial and antioxidant.

7. Acknowledgment

The authors were grateful to king Abd-Alaziz University, Faculty of Metrology, Environment and Arid Land Agriculture for supporting in analysis of GC-MS, and also we are grateful to Desert Research Center, Centre Lap for approval and support.

8. Competing Interest

The authors have declared that no competing interest exists.

9. Significance Statement

The current study found that the essential oils of three medicinal plant species from the genus *Artemisia*, which are growing in the arid zone in Egypt, namely *A. sieberi*, *A. judaica* and *A. monosperma*, are rich in chemical compounds of potential bioactive properties, confirming the use of some species from genus *Artemisia* in the traditional medicine since the ancient Pharaonic civilization. The study also highlights some similarities in chemical constituents between species of this genus as well as some significant antibacterial and antioxidant properties.

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