

Chemical Composition, Antibacterial and Antioxidant Activities of *Tagetes patula* L. Essential Oil Raised in Erbil, Iraq

Abstract

Background: Over the years, management of human pathogenic microorganisms has primarily relied on the use of synthetic antibiotics. In the recent past, *Tagetes patula* essential oils (EOs) and their phytochemistry and bioactivities have received great attention in research. **Purpose and Methods:** In this study, the component, antimicrobial activity, and antioxidant capacity (ferric-reducing antioxidant power assay) of EOs from five plant parts (shoot at vegetative growth stage [TPSV], shoot at flowering growth stage [TPSF], flower [TPF], fruit [TPS], and root [TPR]) of *T. patula* were investigated. The antibacterial activity against five gram-negative bacterial isolates (including *Serratia fonticola*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Proteus mirabilis*, and *Escherichia coli*) and five gram-positive bacterial isolates (including *Staphylococcus aureus*, *S. epidermidis*, *S. saprophyticus*, *Streptococcus agalactiae*, and *Streptococcus oralis*) was studied using broth microdilution method. FRAP assay was also used to evaluate their antioxidant activity. **Results:** One hundred and twenty-five compounds of the total EOs were identified, constituting a mixture of oxygenated monoterpenes (33%), monoterpene hydrocarbons (25%), oxygenated sesquiterpenes (19%), sesquiterpene hydrocarbons (12%), and furanocoumarins (8%). In this paper, for the first time, more than 60 new compounds were isolated from *T. patula* such as bergapten, sylvestrene, (E)- β -farnesene, (E)-epoxy-ocimene, (Z)-jasnone, γ -gurjunene, and γ -himachalene. The EOs of *T. patula* showed potent antibacterial activity against the studied bacteria with the highest growth inhibition observed in *E. coli* after 24 h of incubation (MIC value 0.08 and MBC value 0.32 μ L/mL). The TPS-EO had the highest mean value for ferric-reducing ability at the three test times, whereas TPR-EO had no activity. **Conclusion:** It was concluded that the potential biocidal activity of *T. patula* EOs could be substantially associated with their oxygenated constituents or the synergistic activity of their major and minor chemical components.

Keywords: *Tagetes patula*, essential oil, gas chromatography–mass spectrometry, antibacterial, antioxidant

Introduction

Tagetes is an important genus belonging to the Asteraceae family, native to Mexico and Central America,^[1] and widely cultivated in different parts of Kurdistan. However, the biological potency of the essential oil (EO) of this species has been broadly reported.^[2-5] The most important EOs in *T. patula* with pharmaceutical efficacy are piperitone, piperitenone, trans- β -ocimene, terpinolene, dihydrotagetone, cis-tagetone, limonene, β -caryophyllene, and allo-ocimene, α -terpinolene, trans-caryophyllene, (Z)-ocimenone, dl-limonene, piperitenone, β -pinene, and car-3-en-2-one.^[6,7] Although various antibacterial and antioxidant aspects of *T. patula* have been tested, the chemical constituents of different parts of its EO based

on experimental models have still not been explored. In this study, we investigated the effect of EO constituents, hydrodistilled from several parts of *T. patula*, and its antibacterial and antioxidant activities. However, to the best of our knowledge, this is the first publication that provides the list of more than 60 new compounds, which will be discussed in the following sections.

Materials and Methods

Plant material

The five different parts of *T. patula* were sampled freshly early morning in different periods, as shoots at vegetative growth (TPSV) were collected during July, whereas shoots at flowering stage (TPSF), flowers (TPF), fruits (TPS), and root (TPR) parts were sampled during August. All samples were placed into polythene bags and collected from different

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How to cite this article: Safar AA, Ghafoor AO, Dastan D. Chemical composition, antibacterial and antioxidant activities of *Tagetes patula* L. essential oil raised in Erbil, Iraq. J Rep Pharm Sci 2020;9:59-67.

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Received: 24 Jun 2019
Accepted: 12 Oct 2019
Published: 26 Jun 2020

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Access this article online

Website:
www.jrpsjournal.com

DOI: 10.4103/jrtps.JRTPS_68_19

Quick Response Code:



areas of Erbil Province (latitude: 36.2062; longitude: 44.0088 at 429 altitude). The collected parts were initially washed in tap water to remove soil and other contaminants and were cut into small pieces to be prepared for distillation. A voucher specimen was deposited by Dr. Abdullah Shakur Sardar at the herbarium of the College of Education, Salahaddin University-Hawler, Erbil, Iraq, under the voucher number (no. 7591).

Isolation of essential oils

Six hundred grams of fresh plant parts were submitted to hydrodistillation using a Clevenger-type apparatus to produce oil for 3 h. The process was performed separately for each plant part by using 4750, 3650, 4150, 3560, and 3910 g from TPSV, TPSE, TPF, TPS, and TPR, respectively, until the required amount of oil was obtained. The oil was separated from the water by adding anhydrous sodium sulfate (Na_2SO_4) and stored in tightly closed dark vials at 4°C until analysis.^[8]

Gas chromatography and gas chromatography–mass spectrometry analysis

The gas chromatography (GC) analysis of the oil was conducted using a ThermoQuest (UK) gas chromatograph with a flame-ionization detector (FID). The analysis was carried out using fused silica capillary DB-5 column (60 m × 0.25 mm; film thickness, 0.25 μm). The injector and detector temperatures were 250°C and 300°C, respectively. Nitrogen was used as carrier gas at a flow rate of 1 mL/min; oven temperature was programmed from 60°C to 250°C at a rate of 5°C/min, and finally held isothermally for 10 min. GC–mass spectrometry (MS) analysis was performed using a ThermoQuest–Finnigan gas chromatograph equipped with the above mentioned column, used under the same conditions coupled to a TRACE mass spectrometer (UK). Helium was used as the carrier gas. Ionization voltage was kept at 70 eV. Ion source and interface temperatures were kept between 200°C and 250°C, respectively. Mass range was scanned from 43 to 456 *m/z*.^[9,10]

Identification of compounds

The constituents of the volatile oils in different stages were identified by the calculation of their retention indices under temperature-programmed conditions for *n*-alkanes (C6–C24) and the oil on a DB-5 column. Identification of individual compounds was made by comparing their mass spectra library (Wiley and Adams) or with authentic compounds. For confirmed compounds, their GC retention indices were compared with authentic compounds or with those reported earlier.^[10] Each sample was then analyzed three times with GC–FID to obtain the percentage concentration of each constituent without performing any correction.

Bacterial strains

The following microorganisms were obtained from Rizgari Hospital in Erbil: *Serratia fonticola*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Proteus mirabilis*, *Escherichia coli*, and five gram-positive bacterial isolates including *Staphylococcus aureus*, *S. epidermidis*, *S. saprophyticus*, *Streptococcus galactiae*, and *Streptococcus oralis*. Each strain

was grown in a test tube containing 45 mL of sterile nutrient broth (Lab M, Heywood, England) at 37°C for 24 h. The bacteria identification was confirmed by VITEK 2 Compact (bioMérieux, Nürtingen, Germany) instrument.

Antibacterial susceptibility testing

To determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of EOs, the broth microdilution method was performed^[11] with some modifications. Ninety-six well-cultured plates were used. Stock solutions of EOs were diluted in dimethyl sulfoxide (DMSO) to give serial twofold dilutions that were added to each medium, resulting in concentrations ranging from 5 to 0.005 μL/mL. Ciprofloxacin was used as a positive control (500 μg/mL). The volume of dispensing extract was 100 μL per well along with 100 μL of Mueller Hinton broth. Twenty μL of bacterial culture at a density of 5×10^5 CFU/mL was added to the wells.^[11] Three control wells were maintained for each test batch: the positive control (antibiotic, Mueller Hinton broth and test organism), sterility control (Mueller Hinton broth and DMSO), and negative control (Mueller Hinton broth, test organism, and DMSO). The plates were incubated at 37°C for 24 h. The absorbance for each well was measured at 630 nm before incubating by enzyme-linked immunosorbent assay (ELISA) Reader (BioTech, Vermont, USA). Then, the plates were incubated under shaking conditions (100–120 rpm) at 37°C for 24 h. After the incubation time, the absorbance was remeasured to determine the final absorbance and was compared with the initial absorbance.^[12]

The MIC and MBC were confirmed by subculturing bacterial cells on the solid nutrient agar. The plates were incubated at 37°C for 24 h overnight. The lowest concentration of the EO required to inhibit visible growth of the tested microorganism was designated as the MIC, whereas the plates that did not show growth were considered to be the MBC. Using the values of MIC in the micro broth dilution assay method, the MIC index values (MBC/MIC) for both the EO and the standard control drug were calculated against the test strains. The tests were performed in triplicate. However, the EOs and the compounds with MICs less than 500 μg/mL were considered to be of interest.^[13]

Ferric-reducing antioxidant power assay

The Fe^{3+} reducing antioxidant power of the EOs was performed according to Pulido *et al.*,^[14] with modification in terms of the time interval. The reaction was evaluated at three different times (5, 25, and 50 min). Briefly, ferric-reducing antioxidant power (FRAP) assay reagent was freshly prepared and contained in 25 mL of 300 mM sodium acetate buffer (pH, 3.6), 2.5 mL of 20 mM 2,4,6-tripyridyl-S-triazine (TPTZ) (Sigma-Aldrich, UK) in 40 mmol/L HCl, and 2.5 mL of 20 mmol/L $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ in a ratio of 10:1:1 and warmed at 37°C. The FRAP reagents (2 mL) were mixed with 100 μL of each sample, then the mixture was incubated at 37°C. The absorbance was read at 593 nm after each 5, 25, and 50-min interval using a UV-Vis spectrophotometer (EMCLAB 11 UV, Duisburg, Germany). The FRAP value was determined by designing a standard curve produced by the addition of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ to the FRAP reagent. Antioxidant

Table 1: Essential oil composition of different parts and stages of *Tagetes patula* L. from Erbil

No.	Compounds/classification	RI ^a	TPSV		TPSF		TPF		TPS		TPR	
			RT ^b	Area%	RT	Area%	RT	Area%	RT	Area%	RT	Area%
1.	α -pinene	932	4.11	0.54	4.11	0.47	4.1	0.1	4.11	0.25		
2.	Camphene	946	4.36	0.09	4.37	0.06						
3.	Sabinene	969	4.78	1.23	4.79	1.27	4.77	0.3	4.78	0.52		
4.	β -pinene	974	4.86	0.06	4.86	0.07						
5.	Myrcene	988	5.07	0.31	5.08	0.26	5.06	0.11	5.07	0.43		
6.	α -phellandrene	1002	5.37	0.39	5.38	0.4			5.37	0.11		
7.	<i>p</i> -cymene	1020	5.79	0.25								
8.*	<i>o</i> -cymene	1022			5.81	0.15	5.78	0.11	5.79	0.1		
9.*	Sylvestrene	1025	5.89	9.85	5.91	8.74	5.86	3.4	5.88	5.61	5.88	0.13
10.	(Z)- β -ocimene	1032	6.05	10.02	6.07	9.09	6.03	8.36	6.06	10.21		
11.	(E)- β -ocimene	1044	6.27	1.04	6.27	1.06	6.25	0.7	6.26	1.95		
12.	Dihydro-tagetone	1046	6.36	2.61	6.36	0.84	6.34	0.63	6.35	0.72		
13.	γ -terpinene	1054	6.53	0.07	6.53	0.08			6.52	0.05		
14.	Terpinolene	1086	7.24	14.36	7.26	12.88	7.2	3.11	7.24	9.31		
15.*	Dihydro-linalool	1088			7.41	0.03						
16.	<i>p</i> -cymenene	1089	7.28	0.81								
17.	Linalool	1095	7.48	0.3	7.49	0.34			7.48	0.14		
18.*	α -pinene oxide	1099					7.38	0.13				
19.	<i>cis</i> -thujone	1101							7.57	0.11		
20.*	<i>trans</i> -vertocitral C	1105	7.58	0.19	7.58	0.14						
21.*	(2E,4E)-octadienol	1113	7.81	0.53	7.82	0.55	7.8	0.16	7.81	0.3		
22.	(Z)-epoxy-ocimene	1128	8.24	3.01	8.25	2.65	8.22	2.59	8.23	2.4		
23.	Allo-ocimene	1128	8.17	0.05	8.18	0.15			8.16	0.1		
24.	<i>cis-p</i> -mentha-2,8-dien-1-ol	1133	8.38	0.18					8.37	0.06		
25.*	(E)-epoxy-ocimene	1137	8.48	1.47					8.48	2.47		
26.	<i>trans</i> -sabinol	1137			8.38	0.15						
27.*	Geijerene	1138			8.49	1.48						
28.	(E)-tagetone	1139	8.58	3.44	8.59	3.1	8.77	1.27	8.57	2		
29.*	(E)-myroxide	1140					8.47	2.58				
30.	Camphor	1141	8.71	0.41	8.71	0.3	8.56	2.23				
31.	(Z)-tagetone	1148	8.78	4.47	8.8	4.51			8.78	1.78		
32.	Isoborneol	1155	9.04	0.1	9.05	0.14						
33.	Terpinen-4-ol	1174					9.42	0.61				
34.*	(E)-isocitral	1177	9.38	0.49	9.39	0.45			9.43	0.54		
35.	<i>p</i> -cymene-8-ol	1179	9.69	1.25					9.67	0.63		
36.	<i>cis</i> -pinocarveol	1182			9.44	0.53						
37.	α -terpineol	1186	9.8	0.52					9.79	0.08		
38.*	<i>trans-p</i> -mentha-1(7),8-dien-2-ol	1187			9.67	0.18						
39.*	2-allyl-phenol	1189			9.69	0.75	9.68	2.35				
40.	Myrtenol	1194	9.97	0.06	9.8	0.19			9.97	0.1		
41.*	Methyl chavicol	1195					9.79	0.52				
42.*	<i>trans</i> -4-caranone	1196	10.07	0.28					10.05	0.31		
43.	γ -terpineol	1199	10.11	0.48								
44.*	<i>cis</i> -4-caranone	1200			9.98	0.28	9.96	2.3	10.24	0.16		
45.	<i>trans</i> -carveol	1215			10.27	0.08						
46.	<i>cis</i> -sabinene hydrate acetate	1219			10.51	0.05						
47.*	Coahuilensol methyl ether	1219	10.58	0.18	10.59	0.09			10.55	0.12		
48.	(Z)-ocimenone	1226	10.82	6.57	10.85	8.09			10.82	5.33		
49.	(E)-ocimenone	1235	11.04	6.61	11.07	8	10.82	12.08	11.03	3.77		
50.*	Car-3-en-2-one	1244					11.02	3.92				
51.	Piperitone	1249	11.43	6.53	11.45	5.78	11.39	2.52	11.4	1.79		
52.*	Perilla aldehyde	1269	11.8	0.14	11.8	0.09	11.91	0.66				
53.*	Neo-3-thujanol acetate	1273	11.98	0.07								
54.*	<i>p</i> -menth-1-en-7-al	1273			11.88	0.15						
55.	Isobornyl acetate	1283	12.15	0.44	12.16	0.34			12.14	0.21		

Table 1: Continued

No.	Compounds/classification	RI ^a	TPSV		TPSF		TPF		TPS		TPR	
			RT ^b	Area%	RT	Area%	RT	Area%	RT	Area%	RT	Area%
56.	Bornyl acetate	1287					12.15	0.5				
57.*	<i>trans</i> -verbenyl acetate	1291			12.33	0.11						
58.*	Carvacrol	1298	12.63	0.14	12.66	0.11						
59.*	Neo-dihydro carveol acetate	1299			12.78	0.16						
60.	Terpinene-4-ol acetate	1299	12.77	0.17								
61.*	Silphiperfol-5-ene	1326			13.18	0.05	13.17	0.42	13.17	0.12		
62.	Piperitenone	1340	13.67	6.37	13.7	6.68	13.66	6.34	13.64	1.78		
63.	Piperitenone oxide	1366	14.28	0.11	14.3	1.87	14.27	1.53	14.27	0.84		
64.*	Longicyclene	1371							14.46	0.09	14.22	0.86
65.*	Silphiperfol-6-ene	1377					14.46	0.33				
66.	Geranyl acetate	1379	14.62	0.13	14.62	0.1			14.62	0.06		
67.*	α -isocomene	1387					14.76	0.17				
68.	β -elemene	1389							14.87	0.2	14.89	0.97
69.*	7-epi-sesquithujene	1390	14.83	0.08	14.84	0.07						
70.*	(Z)-Jasmone	1392	15.04	0.16	15.04	0.22	15.04	0.64	15.07	0.2		
71.	Cyperene	1398									15.11	12.76
72.*	β -longipinene	1400			15.19	0.23			15.18	0.16		
73.*	α -funebrene	1402	15.15	0.08								
74.*	β -isocomene	1407					15.26	0.19				
75.*	Longifolene	1407							15.27	0.12		
76.	α -gurjunene	1409									15.44	0.67
77.	(E)-caryophyllene	1417	15.59	4.54	15.61	6.43	15.61	20.59	15.68	26.62	15.59	5.96
78.*	<i>cis</i> -carvyl propanoate	1420	15.65	0.92								
79.*	α - <i>trans</i> -bergamotane	1432									15.93	0.21
80.	Aromadendrene	1439									16.01	0.77
81.*	α -himachalene	1449									16.29	0.41
82.	α -humulene	1452	16.43	0.13					16.42	0.64		
83.	Geranyl acetone	1453							16.34	0.05		
84.	(E)- β -farnesene	1454			16.44	0.49	16.43	0.73			16.46	8.98
85.*	<i>trans</i> -carvyl propanoate	1454	16.54	0.16								
86.*	γ -decalactone	1464					16.52	0.81				
87.	γ -gurjunene	1475									16.94	1.44
88.*	γ -himachalene	1481									17	1.81
89.	Germacrene D	1484	17.09	0.89	17.1	0.96	17.09	1.64	17.11	3.97	17.1	0.15
90.*	<i>cis</i> -eudesma-6,11,diene	1489									17.16	0.37
91.*	α -zingiberene	1493							17.36	0.12		
92.*	α -selinene	1498									17.44	0.12
93.	α -muurolene	1500									17.54	0.52
94.	Bicyclogermacrene	1500	17.47	0.38	17.47	0.9	17.47	0.69	17.47	1.23		
95.	(E,E)- α -farnesene	1505			17.69	0.31	17.69	0.28	17.69	0.56		
96.	β -bisabolene	1505	17.71	0.18							17.74	9.44
97.	δ -cadinene	1522							18.09	0.1		
98.*	Italicene epoxide	1547	18.79	0.31	18.79	0.13			18.79	0.26	18.79	0.31
99.	(E)-nerolidol	1561			19.02	0.19	19.03	0.18				
100.	epi-longipinanol	1562	18.94	0.11	18.94	0.03			18.93	0.04	18.94	0.42
101.*	Germacrene d-4-ol	1574			19.35	0.06						
102.	Spathulenol	1577	19.43	0.3	19.43	0.33						
103.	Caryophyllene oxide	1582	19.52	0.78	19.53	0.57	19.53	6.51	19.54	4.89	19.52	2.54
104.*	Thujupsan-2 α -ol	1586							19.76	0.05		
105.*	β -atlantol	1608									20.1	0.81
106.	Humulene epoxide II	1608							20.12	0.1		
107.*	anti-syn-syn-helifolen-12-al ^c	1619									20.22	0.27
108.*	2-epi- α -cedren-3-one	1626									20.36	0.31
109.*	Muurola-4,10(14)-dien-1- β -ol	1630									20.52	0.16

Table 1: Continued

No.	Compounds/classification	RI ^a	TPSV		TPSF		TPF		TPS		TPR	
			RT ^b	Area%	RT	Area%	RT	Area%	RT	Area%	RT	Area%
110.	allo-aromadendrene epoxide	1639	20.77	0.27	20.8	0.14			20.8	0.52	20.78	0.53
111.*	Selina-3,11-dien-6- α -ol	1642					20.81	0.52				
112.*	14-hydroxy-(Z)-caryophyllene	1666					21.18	0.13				
113.*	Helifolenol B	1679									21.63	0.1
114.*	Germacra-4(15),5,10(14)-trien-1 α -ol	1685							21.9	0.08		
115.*	(Z)- α -trans-bergamotol	1690									21.9	0.14
116.	2-pentadecanone	1697							22.02	0.1		
117.*	14-hydroxy-4,5-dihydro-caryophyllene	1706			22.36	0.04						
118.*	(Z)- α -atlantone	1717									22.49	0.8
119.*	6S,7R-bisabolone	1748									23.15	0.27
120.*	(E)- α -atlantone	1777									23.89	0.42
121.	<i>n</i> -nonadecane	1900							26.22	0.22		
122.*	Phytol	1942					26.74	0.22				
123.*	Bergapten	2056									26.84	39.68
124.*	<i>n</i> -heneicosane	2100							30.15	0.41		
125.*	Oleic acid	2141	30.46	0.61								
	Total No. & percentage (%)		59	-(96.22%)	63	(94.14%)	42	-(93.16%)	58	-(95.19%)	31	(92.33%)
	Monoterpene hydrocarbon	%	41%		39%		18%		30%		0.5%	
	Oxygenated monoterpene	%	47%		48%		39%		27%		0%	
	Sesquiterpene hydrocarbon	%	2%		3%		4%		8%		40%	
	Oxygenated sesquiterpene	%	8%		9%		34%		35%		13%	
	Oxygenated diterpene	%	0%		0%		1%		0%		0%	
	Furanocoumarins (FCs)	%	0%		0%		0%		0%		43%	
	Others	%	2%		2%		5%		1%		4%	

^aRI, Retention indices relative to C6–C24, *n*-alkanes on the DB-5 column

^bRT, Retention time

*Compounds identified for the first time in *Tagetes patula*

capacity based on the ability to reduce ferric ions of samples was calculated from the linear calibration curve and expressed as $\mu\text{mol Fe}^{+2}$ per gram of fresh weight ($\mu\text{mol Fe}^{+2}/\text{g FW}$).

Statistical analysis

For analyzing antibacterial activity, the experiment was performed in a completely randomized design (CRD) with three replicates for each treatment, including a control to assess the efficiency of EOs against the tested strains. For analyzing antioxidant activity, statistical analysis was carried out using factorial CRD between the EOs and the time interval. All results were expressed as mean \pm standard error (SE). These evaluations were performed by two-way analysis of variance, and statistical significance between mean values was carried out by the least significant difference (LSD) test using the Statistical Package for the Social Sciences software of SPSS, version 18, for Windows (SPSS, Chicago, Illinois). The values of $P < 0.01$ were considered statistically significant.

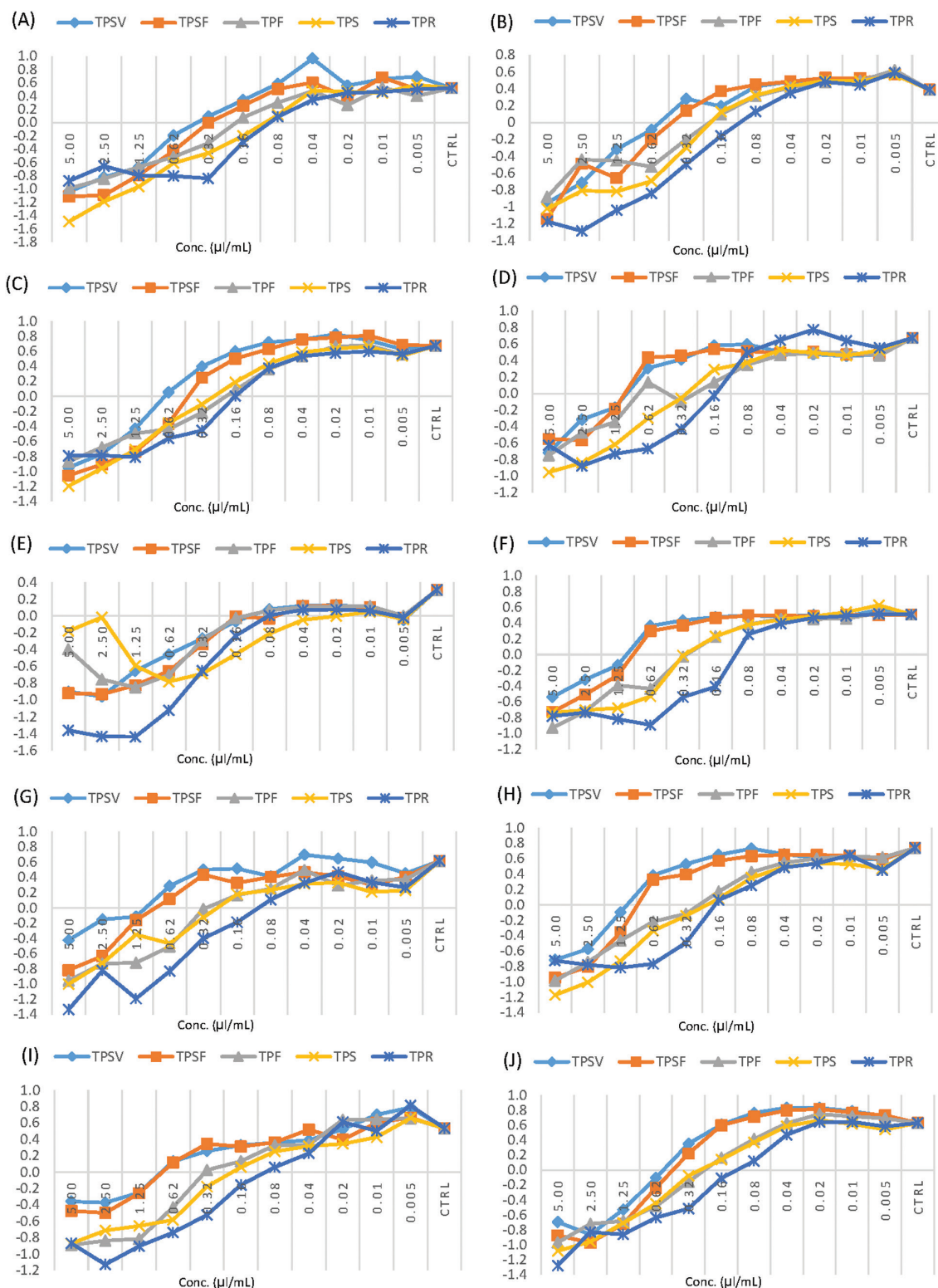
Results and Discussion

Chemical constituents of essential oils

The obtained volatile components from different parts of *T. patula* (TPSV, TPSF, TPF, TPS, and TPR) are shown in

Table 1. The components are listed in order of their elution on the DB-5 column. All compounds and their percentages were identified by comparing and matching the mass spectra and GC retention indices of the unknown compounds with those of reference. The maximum oil yield was found in TPSV (0.057%) followed by TPS (0.042%), TPSF (0.037%), TPF (0.022%), and lowest in TPR (0.012%). In total, 125 chemical compounds were identified from the EO of studied species. The total amount of identified EOs at TPSV and TPSF were 59 and 63 compounds representing 96.22% and 94.14%, respectively, whereas 42, 58, and 31 compounds were isolated from the TPF, TPS, and TPR parts expressing 93.16%, 95.19%, and 92.33%, respectively [Table 1].

The chemical constituents of EOs as in Table 1 were revealed to be variable and similar among *T. patula* parts, and the percentage of each component also showed high variation. Monoterpene hydrocarbons characterized by terpinolene, (Z)- β -ocimene, sylvestrene, (E)-ocimene, (Z)-ocimene, piperitone, piperitenone, (Z)-tagetone, (E)-tagetone, and sesquiterpene (E)-caryophyllene were the most prolific components of TPSV and TPSF with quantitatively variation. Similar compositions are cited in studies with the EO constituents from the aerial part of *T. patula*.^[4,15] In addition, the EO chemical profiles of TPF and TPS closely resembled



(Figure 1) Antibacterial activity of different concentrations of EOs from *T. patula* on: A) *S. fonticola*, B) *K. pneumoniae*, C) *A. baumannii*, D) *P. mirabilis*, E) *E. coli*, F) *S. aureus*, G) *S. epidermidis*, H) *S. saprophyticus*, I) *S. agalactiae*, J) *S. oralis*

Figure 1: Antibacterial activity of different concentrations of essential oils from *Tagetes patula* on: (A) *Serratia fonticola*, (B) *Klebsiella pneumoniae*, (C) *Acinetobacter baumannii*, (D) *Proteus mirabilis*, (E) *Escherichia coli*, (F) *Staphylococcus aureus*, (G) *Staphylococcus epidermidis*, (H) *Staphylococcus saprophyticus*, (I) *Streptococcus agalactiae*, and (J) *Streptococcus oralis*

each other, with at least 20 components occurring in both parts. Among the components, (E)-caryophyllene, (E)-ocimene, (Z)- β -ocimene, piperitenone, (Z)-ocimene, caryophyllene

oxide, sylvestrene, (E)-myroxide, car-3-en-2-one, germacrene D, terpinolene, and (E)-epoxy-ocimene were the highest constituted oil. Our results resemble the composition reported

by previous studies with some differences in the quantitative data.^[1,7,16,17]

Conversely, the composition of the TPR oil was considerably different from the rest of the aerial parts. Bergapten (39.68%) proved to occur in very high concentrations followed by cyperene (12.76%), β -bisabolene (9.44%), (E)- β -farnesene (8.98%), and (E)-caryophyllene (5.96%). The consistency of the oil was also notably different from the oil from aerial parts due to it forming a solid crystalline substance. It is interesting to note that thiophenes, the main constituents isolated by several previous studies^[18-20] are absent in our oil, similar to the finding in a study by Romagnoli *et al.*^[9]

Correspondingly, more than 60 new compounds were isolated in this study for the first time in *T. patula*, which include bergapten, sylvestrene, (E)- β -farnesene, (E)-epoxy-ocimene, (Z)-jasmone, γ -gurjunene, γ -himachalene, β -bisabolene, (E)-myroxide, geijerene, and italicene epoxide. Consequently, the variations of oil components between the plant parts and their ratios might be affected by several factors including used plant part as well as the developing stage.^[4,21]

Antibacterial activity of essential oils of *Tagetes patula*

The antibacterial activity of different EOs of *T. patula* (TPSV, TPSF, TPF, TPS, and TPR) against all tested bacteria is shown in Figure 1. In general, the EOs showed high-to-mild antibacterial activity against all tested bacterial strains. The TPF and TPR EOs showed considerably more activity than the other parts. Minimum antibacterial activity was shown by both TPSV and TPSF EOs. In general, all the EOs were able to inhibit the tested bacteria with different ratios. The results of the determination of the antimicrobial activity of all five EOs of *T. patula* are presented as MIC and MBC values [Table 2]. The values of the MIC are those obtained after 24 h incubation at 37°C; MBC was determined by streaking out a sample on Mueller Hinton agar followed by incubation for a further 24 h at 37°C. The range of MIC and MBC of EOs recorded was between 0.16 and 0.64 $\mu\text{L/mL}$. In this investigation, the lowest MIC and MBC were recorded against *E. coli* by TPS EO with the values 0.08 and 0.32 $\mu\text{L/mL}$, respectively. According to

the comparison between the effects of EOs and the positive control, ciprofloxacin antibiotic (CIP), the results showed a relatively significant difference between them. On the basis of this study, we can consider that the EOs of *T. patula* possessed strong-to-mild antibacterial activity against tested gram-positive and gram-negative bacteria strains. This observation is in agreement with other studies.^[15,22]

EOs are natural plant products that contain a complex mixture of components; therefore, they have multiple antimicrobial properties. Most of these compounds are derived from oxygenated terpenoids, particularly phenolic terpenes, phenylpropanoids, and alcohols.^[23,24] Our results support the notion that the strong biological activity of *T. patula* EO against the test pathogenic organisms is attributed to the presence of terpinolene, (Z)- β -ocimene, sylvestrene, (E)-ocimenone, (Z)-ocimenone, piperitone, piperitenone, (E)-caryophyllene, (Z)-tagetone, (E)-tagetone, caryophyllene oxide, car-3-en-2-one, germacrene D, (Z)-epoxy-ocimene, (E)-epoxy-ocimene, and (E)-myroxide in the aerial parts, and bergapten, cyperene, β -bisabolene, (E)- β -farnesene, (E)-caryophyllene, caryophyllene oxide, γ -himachalene, and γ -gurjunene in the root part. Likewise, major compounds such as piperitone, terpinolene, β -caryophyllene, piperitenone, dihydrotagetone, *cis*-tagetone, limonene, allo-ocimene, limonene, (Z)- β -ocimene, E-caryophyllene, piperitone, *P*-cymen-8-ol, (E)- β -ocimene, (Z)-tagetone, (Z)-tagetone, (E)-tagetone, (E)-tagetone, δ -elemene, linalool, and α -terthienyl obtained from other countries have been found to show significant biological activities including gram-positive and gram-negative bacteria strains.^[5,6,9,15,25-27] Moreover, a number of EOs with low activities due to their high hydrocarbon content can also be used to interact with each other, acting as synergistic agents to increase their bioactivities.^[23]

Antioxidant activity of essential oil of *Tagetes patula*

The FRAP assay is a simple and reproducible method, which can be applied to the study of the antioxidant capacity of pure dietary antioxidants.^[14] The antioxidant activity results of five *T. patula* EO parts (TPSV, TPSF, TPF, TPS, and TPR), which

Table 2: Minimum inhibition concentration ($\mu\text{L/mL}$) and minimum bacterial concentration ($\mu\text{L/mL}$) of *Tagetes patula* essential oils against test bacterial strains

Test bacteria	EOs concentration ($\mu\text{L/mL}$)									
	TPSV		TPSF		TPF		TPS		TPR	
	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
<i>Serratia fonticola</i>	0.32	0.64	0.32	0.64	0.16	0.32	0.16	0.64	0.16	0.64
<i>Klebsiella pneumoniae</i>	0.64	1.25	0.64	1.25	0.32	0.64	0.32	1.25	0.16	2.5
<i>Acinetobacter baumannii</i>	1.25	2.5	0.64	1.25	0.32	1.25	0.32	1.25	0.32	2.5
<i>Proteus mirabilis</i>	1.25	2.5	1.25	2.5	0.32	0.64	0.32	2.5	0.32	1.25
<i>Escherichia coli</i>	0.16	0.64	0.16	0.32	0.16	0.64	0.08	0.32	0.16	0.64
<i>Staphylococcus aureus</i>	1.25	2.5	0.64	1.25	0.32	1.25	0.32	1.25	0.16	0.32
<i>Staphylococcus epidermidis</i>	0.32	1.25	1.25	2.5	0.32	1.25	1.25	2.5	0.16	0.64
<i>Staphylococcus saprophyticus</i>	0.32	2.5	1.25	5.0	0.32	2.5	1.25	5.0	0.32	2.5
<i>Streptococcus agalactiae</i>	0.64	1.25	0.64	1.25	0.32	1.25	0.32	1.25	0.16	1.25
<i>Streptococcus oralis</i>	0.32	0.64	0.64	1.25	0.32	1.25	0.64	1.25	0.16	0.64

Table 3: Antioxidant capacity of essential oils from different parts of *Tagetes patula*, determined by the ferric-reducing antioxidant power assay at 5, 25, and 50 min of reaction

Plant part	FRAP value ($\mu\text{mol/g}$)		
	After 5 min	After 25 min	After 50 min
TPSV	81.56 \pm 4.52	98.69 \pm 5.47**	100.64 \pm 5.68**
TPSF	57.38 \pm 4.87	68.43 \pm 5.90	71.20 \pm 6.13
TPF	86.19 \pm 1.41	103.28 \pm 1.70**	105.46 \pm 1.77**
TPS	222.88 \pm 11.85**	248.17 \pm 13.04**	259.69 \pm 14.34**
TPR	0.00	0.00	0.00
Ascorbic acid	76.33 \pm 0.91	76.33 \pm 0.91	76.33 \pm 0.91
LSD value	EO: 11.597	Time: 6.35	EO*Time: 20.09

**Significant at $P < 0.01$

FRAP assay expressed as μM of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

Significantly different at $P < 0.01$, level of confidence based on LSD's multiple range test. Mean values denoted with a double star within the same column were observed to differ significantly (three replications \pm standard error (SE))

were recorded at three different times to evaluate the reducing power of ferric tripyridyltriazine (Fe^{+3} -TPTZ) complex to its ferrous (Fe^{+2} -TPTZ) blue-colored form with an absorption maximum at 593nm^[14] are shown in Table 3. FRAP value was significantly different depending on the plant parts and the time lapse. After 5-min reaction, the TPS-EO (222.88 \pm 11.85) showed a significantly potent FRAP reduction, that is, three times greater than positive control ($P < 0.01$). Similar results were found after 25 and 50 min of reaction. In TPSV and TPF, at 5 min of reaction, results were markedly similar to the positive control (ascorbic acid), but they significantly showed FRAP reducing activity after 25 min (98.69 \pm 5.47 and 103.28 \pm 1.70, $P < 0.01$) and 50 min (100.64 \pm 5.68 and 105.46 \pm 1.77, $P < 0.01$), respectively. The TPR-EO of this species did not show antioxidant activity [Table 3].

Similar results have also been reported by other studies.^[7,28] The strong antioxidant properties of the aerial part EOs of *T. patula* might be attributed to a comparatively high content of oxygenated terpenoids components or the synergistic activity between a variety of major and minor constituents. Furthermore, the differences in the antioxidant reactivity of these compounds affected the EOs ranking by the time of the reaction. Our results are in agreement with those findings that the antioxidants follow diverse kinetic behavior with time-dependent increase in their ferric-reducing ability.^[14] Formerly, Henriquez *et al.*^[29] emphasized that the time of reaction is one of the most important factors regarding the quantitation of the biological antioxidant potency of the plant extracts. However, our results showed that the antioxidant activity of the EOs depends on (1) the part of the plant and (2) the time of the reaction.

Conclusion

This study showed that chemical characteristics, antimicrobial and antioxidant efficacy of EOs obtained from *T. patula* vary among the analyzed plant parts. The difference in chemical composition (qualitatively and quantitatively) of our investigation and the reported data was likely due to plant parts and environmental conditions. Among the recorded new compounds in the study, bergapten,

sylvestrene, (E)- β -farnesene, (E)-epoxy-ocimene, (Z)-jasnone, γ -gurjunene, γ -himachalene, β -bisabolene, (E)-myroxide, geijerene, and italicene epoxide were the major chemical constituents. *E. coli* (MIC = 0.08 $\mu\text{L/mL}$) was the most affected microorganism by *T. patula* EOs. Also, among all EOs isolated from the tested plant, TPS had the highest antioxidant capacity at three different test times. One possible mechanism of the biological efficacy of these EOs appears to be related with the presence of either the high amount of oxygenated terpenoids (more than 50%) and fewer hydrocarbons in the aerial parts or with the synergistic activity of some major and minor components. Therefore, the plant could be a potential candidate source of natural antibacterial and antioxidant agents.

Acknowledgements

We are thankful to the director and the head of Pathological Analysis Department of Rizgari General Hospital for providing bacteria strains and lab facility for this research work.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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