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Composition and Radical Scavenging Activity of Edible Wild *Pulicaria jaubertii* (Asteraceae) Volatile Oil

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Abstract
The objectives of this work were to determine chemical composition and evaluate the radical scavenging activity (RSA) of *P. jaubertii* volatile oil from outskirts of Sana'a city (PjSO), as well as RSA of *P. jaubertii* volatile oil from Hajja Province (PjHP), Yemen. The composition of PjSO volatile oil was described by infra-red (IR) spectroscopy and gas chromatography/mass spectrometry (GC/MS). RSA of investigated oils were estimated, using spectrophotometric DPPH (2.2`-diphenyl-1-picrylhydrazyl) method. A total of sixteen components, which represent 99.98% of the total composition of PjSO oil, were identified. GC/MS analysis showed that the dominant component of PjOS oil is carvotanacetone (98.34%). The carbonyl group of carvotanacetone was identified from the IR spectrum by the appearance of absorption band at ~1700 cm^{-1}. The obtained analytical data showed that the PjSO essential oil possess 1.3% (v/w) oil content. This indicated that the PjSO essential oil has a commercial potential for production of carvotanacetone. Furthermore, RSA results indicated that PjSO essential oil has a higher RSA in comparison with that of PjHP oil and slightly higher than that of ascorbic acid at higher concentrations. Our finding reveals that PjSO oil could serve as safe natural alternative for synthetic antioxidants in food and pharmaceutical industries.
Keywords: *Pulicaria jaubertii*, volatile oil composition, radical scavenging activity, carvotanacetone.

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INTRODUCTION

Pulicaria genus (Asteraceae), includes more than 80 species that occur throughout the world from Europe to North Africa and Asia (Williams *et al*., 2003). Arange of biological activities have been reported for some species of *Pulicaria,* like anti-inflammatory, antilukemic (Al-Yahya *et al*., 1984), potential anticancer chemo-preventive activity (Al-Yahya *et al*., 1988), cytotoxic activity (Al-Yahya *et al*., 1988; Ali *et al*., 2001; Fawzy *et al*., 2013), antibacterial activity (Fawzy *et al*., 2013; Hanbali *et al*., 2005; Ali *et al*., 2012; Al-Fatimi *et al*., 2015; Al-Naqeb, 2015), antioxidant [Al-Fatimi *et al*., 2015; Al-Naqeb, 2015; Algabr *et al*., 2010), antihistaminic (Mahfouz *et al*., 1973), antispasmodic activity (Tanira *et al*., 1996) and antifungal activity (Znini *et al*., 2013). In Morocco, *Pulicaria odora* L. is commonly used as a traditional cure to treat back-pain, intestinal disorders and menstrual cramps. It is also described to women after childbirth, as a component of the traditional remedy called "Mssakhen" (Ezoubeiri *et al*., 2005).

Despite its long historic uses, the chemical information of this plant is limited. The previous chemical analysis studies of essential oils of the genus species have reported the occurrence of acetylenic compounds (Schulte *et al*., 1968), monoterpenes (Hanbali *et al*., 2005; Hichri *et al*., 2009], sesquiterpenes (San Feliciano *et al*., 1989; Mossa *et al*., 1992; Dendougui *et al*., 2000; Aberkane *et al*., 2007; Ghouila *et al*., 2008; Stavri *et al*., 2008), a variety of sesquiterpene lactones (Hichri *et al*., 2009; Abdel-Mogib *et al*., 1990; Rustaiyan *et al*., 1991), diterpenes (Hichri *et al*., 2009; Abdel-Mogib *et al*., 1990; Das *et al*., 2005), sterol glycoside (Ghouila *et al*., 2008), flavonoids (Williams *et al*., 2003; Abdel-Mogib *et al*.,., 1989; Algabr *et al*., 2015), phenolic compounds (Ezoubeiri *et al*., 2005; San Feliciano *et al*., 1989) and derivatives of caryophyllane (Basta *et al*., 2007).

Pulicaria jaubertii is an aromatic wild plant. It is known as "Eter Elraee" in Arabic (Fawzy *et al.,* 2013), Anssif*,* Khawa and Mashmum in Sana'a, Taiz and Aden Provinces (in Yemen) respectively. In South Yemen Provinces, this plant with basil *(Ocimum basilicum)* and Shadab (*Ruta chalepensis*) is believed to be predominantly a defence mechanism against devils, pathogens and pests in childbirth and wedding occasions. It is used in folk medicine as diuretic, and as treatment for fever, urogenetic organs and pyritic conditions. For its flavour, It is agreeable as a spice, It is also used to perfume bread, soup and meat. Published studies from Saudia Arabia and Yemen documented that *P. jaubertii* show antimicrobial, antimalarial and insecticide properties (Dubaie and El-Khulaidi, 2005; Fawzy *et al*., 2013).

The objectives of this study were to determine the content, describe composition and to estimate RSA of the volatile oil of wild *P. jaubertii* which grown in Sana'a outskirts (PjSO), Yemen, as well as to determine the content and to evaluate RSA of the volatile oil *of P. jaubertii* from Hajja Province (PjHP), Yemen. Finally, and according to the best of our knowledge, there are very few of chemical and biological studies, which have been done previously on the volatile oil of *Pulicaria jaubertii* (Asteraceae) grown in Yemen, whether those grown in southern Yemen (Al-Fatimi *et al.,* 2015) or those that were grow in northern Yemen [270 km northwest of Sana'a] (Algabr *et al.,* 2010; Algabr *et al.,* 2012).

MATERIALS AND METHODS

Plant material

The plant samples (leafes, flowers and stems) of *Pulicaria jaubertii* collected in Feb. & Mar. 2014, from Hadda area, Sana'a outskirts, and Aljar area of Hajja Province (270 km northwest of Sana'a), Yemen. Their identification was clarified by Dr/ H. Ibrahim, the staff member of Plant Taxonomy Unit, Department of Biology, Faculty of Science, Sana'a University, Yemen, and according to Dubaie and El-Khulaidi, (2005). Voucher specimens have been deposited under the numbers Bot.Kh725a and Bot.Kh725b correspondingly, in the herbarium of the Department of Biology, Faculty of Science, Sana'a University, Sana'a, Yemen. Fresh herb of aerial parts (leafes, flowers and stems) of both plants were cut into small pieces and left to dry on the laboratory benches at room temperature (23-27 ºC) for 15 days. The dried plant materials were ground into fine powder using a mortar and pestle, then subjected to hydro distillation.

Volatile oils extraction

The fine powder of the dried plant material of PjSO (300 *g*) and PjHP (300 *g*) were separately hydro distilled for 3 hours using modifier Clevenger apparatus. Volatile oil extracts of PjSO and PjHP were dried separately over anhydrous sodium sulphate and then filtered off through Whatman filter paper (number 1). The purified volatile oil extracts were stored in dark at 4 °C.

Volatile oils analysis

IR analysis

The FT-IR spectrum of the neat (undiluted) essential oil of *P. jaubertii* (PjSO) was recorded on a Shimadzu-FTIR-410 Spectrometer (Japan) in the range 500 to 4000 cm^{-1}. The spectra were obtained by means of sodium chloride (NaCl) plate technique by placing a few drops of oil between the optically polished plates of sodium chloride that are placed in the light beam. The spectrum was plotted as intensity versus wave number (cm^{-1}).

GC/MS analysis

Gas chromatography/mass spectrometry (Electron impact) analysis of the studied volatile oil was achieved by Shimadzu gas chromatography. Gas chromatography was equipped with DB-5 wax cross–linked fused silica capillary column (30 m long × 0.25 mm internal diameter) covered with film thickness (0.5µm) of polydimethylsiloxane. Temperature of the oven was automatic, from 40 ^{0}C for three minutes with an increase of 4 ^{0}C/min to 250 ^{0}C and isothermally for 10 minute at 250 ^{0}C. Injections were performed with injector temperature of 200 ^{0}C and ion source temperature rest at 250 °C. The injection volume was 1 µL of the oil. Flow rate of a carrier gas (Helium), was fixed at 1 mL/minute. The type of mass spectrometer was an electron impact (EI) (70 eV), computerized from m/e 40 to m/e 500. Retention indices were calculated using standards n-alkanes (C_5-C_{30}) and then compared with the data available in literature (Adams, 1995).

Assay of radical scavenging activity

Radical scavenging activity (RSA) of the volatile oils of *P. jaubertii* (PjSO and PjHP) was estimated by the spectrophotometric DPPH assay method (Đorđević *et al*., 2007). The stable radical 2.2`-diphenyl-1-picrylhydrazyl (DPPH) was used to estimate the electron donation ability of the investigated volatile oils by measuring their ability to reduce DPPH radicals (deep purple) into the neutral nonradical form (pale yellow). The control solution (DPPH solution) and six samples of increasing concentrations of the volatile oils were prepared by diluting 0, 10, 20, 40, 60, 80 and 100 µg of each volatile oil with methanol to a total volume of 1 mL. To each sample, 2 mL of 90 µM methanol solution of DPPH was added. Samples mixtures were incubated for one hour period at room temperature and after that, the absorbance of investigated samples were read against the absorbance of the control solution at 517 nm. A parallel RSA assay on ascorbic acid with the same set of concentrations was also performed. Inhibition percent of DPPH radical (I %) was calculated as $I\% = 100 (A° - A)/A°$ (Bhatt and Negi, 2012), where A° is the absorbance of the control solution (DPPH solution) and A is the absorbance of individual investigated samples. The test was carried out in triplicate.

RESULTS

Volatile oils content

Based on the dry plant weight of sample, the aerial part (flowers, leaves and stems) of *Pulicaria jaubertii* (Asteraceae) Gamal-Eldin (PjSO and PjHP), yielded 1.34% and 0.18% (v/w) oils content, respectively. Pale yellow volatile oils with a distinguishing perfumed aroma, were obtained.

Volatile oils analysis

GC/MS analysis

A total of eighteen chemical components with retention time between 12.76 and 34.40 minutes were recognized in the gas chromatogram of PjSO volatile oil (Figure 1). Sixteen of these components, which represent 99.98% of the total composition were quantified and identified. These components are listed in Table 1 along with their retention time (RT), composition percentage (%), and their calculated retention indices (RI) values as well as the corresponding RI values from literature.

IR analysis

The FTIR spectrum of *P. jaubertii* (PjSO) volatile oil (Figure 2) was recorded in the region (500 - 4000 cm^{-1}). It showed a band (medium & sharp) at 3020 cm^{-1} and some bands (medium & sharp) at 2965-2850 cm^{-1}. Single absorption band (*strong & sharp*) at ~1700 cm^{-1}, a band (weak & sharp) at ~1600 cm^{-1}, two equivalent bands (weak & sharp) at 1380 cm^{-1} and 1360 cm^{-1} and some broad and sharp bands in the range from ~750 to ~ 670 cm^{-1} were also observed in IR spectrum of PjSO volatile oil.

Radical scavenging activity

Both volatile oils of *P. jaubertii* (PjSO and PjHP) were screened for their possible Radical scavenging activity (RSA). Results of RSA of both *P. jaubertii* volatile oils in addition to L-ascorbic acid were tabulated (Table 2). Data were expressed as means ± S.D.

Growth location influence

The effect of plant growth location on the chemical composition and volatile oil content was recorded (Table 3). It showed a comparison between the composition and the volatile oil content of PjSO (current study) and those of the volatile oil of PjHP (Algabr *et al.,* 2012). Furthermore, results of the effect of plant growth location on the RSA of both oils were recorded (Table 2).

Table 1. Volatile oil *components of wild P. jaubertii* grown in Hadda area of Sana'a province (Sana'a outskirts), Yemen.

NC[a]	CC[b]	RT[c] (min.)	CP[d] (%)	RI[e]	
				CRI[f]	LRR[g]
1	1,8-Cineole	12.76	0.01	1032	1033
2	*trans*-Linalool oxide	14.42	0.02	1083	1088
3	Chrysanthenone	16.45	0.42	1121	1123
4	Camphor	16.96	0.01	1145	1143
5	Carvomenthone	18.99	0.09	1177	1181
6	p-Menth-1(7)-en-2-one	21.20	0.72	1236	1238
7	Carvotanacetone	21.81	98.34	1248	1246
8	Thymol	22.69	0.11	1288	1290
9	Carvacrol	23.22	0.01	1295	1298
10	Ascaridole epoxide	23.32	0.01	1305	-----
11	2́, 4́-Dimethoxy-3́-methylacetophenone	23.46	0.01	1312	1312
12	Methyl eugenol	25.94	0.06	1398	1401
13	(E)-γ-Methylionone	26.70	0.09	1481	1479
14	β-Bisabolene	28.38	0.02	1507	1509
15	Geranyl isobutyrate	28.53	0.03	1519	1514
16	Unknown	31.02	0.01	1573	-----
17	β- Caryophyllene oxide	31.27	0.01	1584	1581
18	Unknown	34.40	0.01	1616	-----

Notes: [a]Numbers of components. [b]Chemical components which are arranged based on their elution from a DB-5 column. [c]Retention time in minute. [d]Composition percentage. [e]Retention indices. [f]Calculated retention indices relative to C5-C30 n-alkanes. [g]Literature retention indices (Adams, 1995; Algabr *et al*., 2012; Fawzy *et al*., 2013).

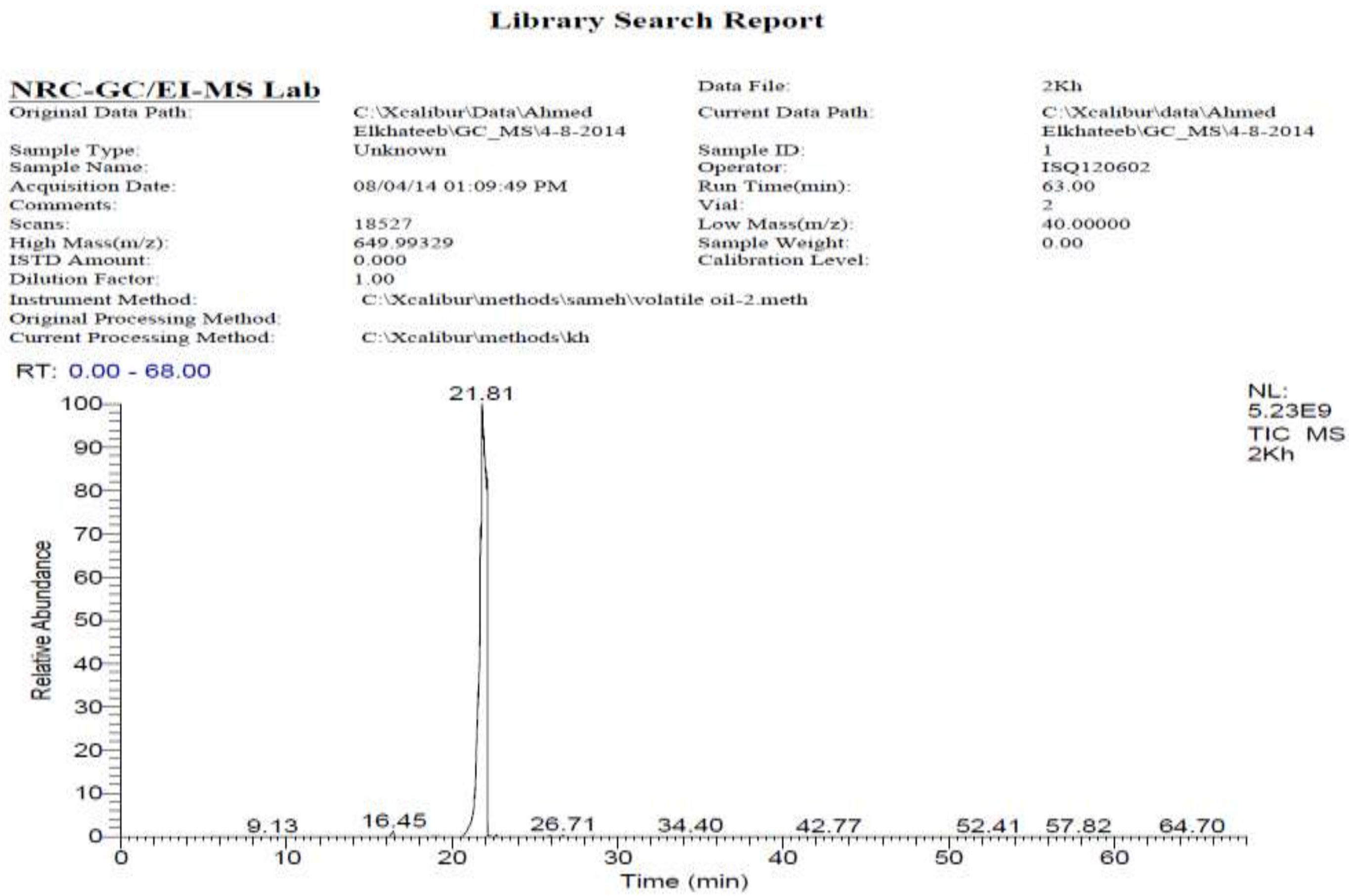

Fig. 1. Gas chromatogram of volatile oil of wild *P. jaubertii* grown in Hadda area of Sana'a province (Sana'a outskirts), Yemen.

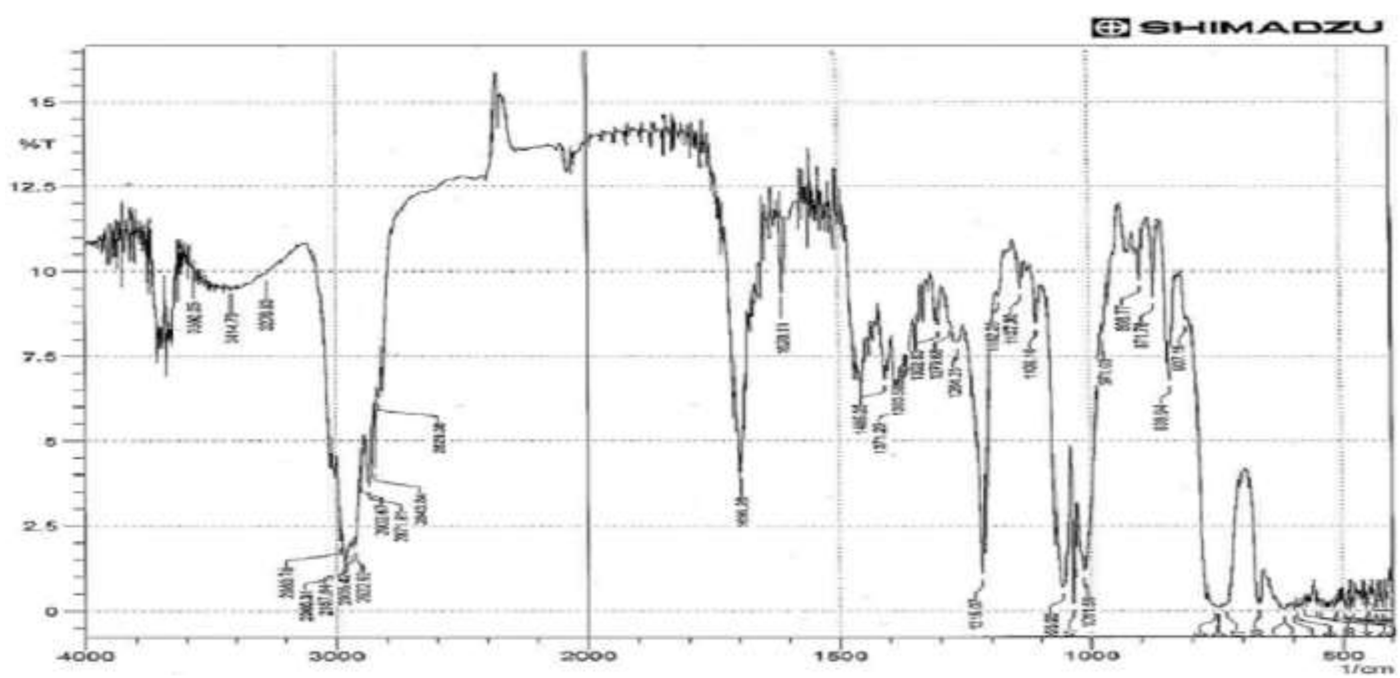

Fig. 2. FTIR Spectrum of volatile oil of wild *P. jaubertii* grown in Hadda area of Sana'a province (Sana'a outskirts), Yemen.

Table 2. Radical scavenging activities of volatile oils of wild PjSO and PjHP, Yemen against stable radical DPPH.

SC[a] (µg/ml)	Absorbance (A) and Radical scavenging activity[b]					
	The investigated oils				Ascorbic acid	
	A[c] at 517 nm		RSA[d] %		A at 517 nm	RSA %
	PjSO[e]	PjHP[f]	PjSO	PjHP		
0	0.4308	0.4308	0.00	0.00	0.4308	0.00
10	0.2210 ± 0.0031	0.3194 ± 0.0025	48.70 ± 0.72	25.86 ± 0.58	0.0386	91.04
20	0.1028 ± 0.0026	0.2341 ± 0.0038	76.14 ± 0.61	45.66 ± 0.88	0.0380	91.18
40	0.0631 ± 0.0034	0.1583 ± 0.0023	85.35 ± 0.79	63.25 ± 0.53	0.0377	91.25
60	0.0529 ± 0.0017	0.1453 ± 0.0018	87.72 ± 0.39	66.27 ± 0.42	0.0350	91.88
80	0.0432 ± 0.0019	0.1298 ± 0.0027	89.97 ± 0.44	69.87 ± 0.63	0.0341	92.08
100	0.0283 ± 0.0015	0.1213 ± 0.0022	93.43 ± 0.35	71.84 ± 0.51	0.0336	92.20

Notes: [a]Sample concentration (*volatill oils & ascorbic acid*). [b]Data were expressed as means ± S.D. [c]Absorbance. [d]Radical scavenging activity. [e]*Pulicaria jaubertii* from Sana'a Outskirts. [f]*Pulicaria jaubertii* from Hajja Province.

Table 3. The influence of growth location on volatile oils composition of *P. jaubertii* from two different locations in Yemen.

Chemical profile and volatile oils content			Growth location effect on chemical profile and content of volatile oil of *P. jaubertii*	
			PjSO[a] (Present study)	**PjHP[b] (previous study)[c]**
Chemical Composition	Oxygenated Monoterpenes	Main (%) Component	Component 7, representing 98.34 of the total components	Component 7, representing 63.96
		ROMT (%)	Eight components, representing 1.31	Six components, representing 5.70
	Phenolic and Aromatic Components (%)		Four components, representing 0.19	Six components, representing 8.10
	Sesquiterpenes Hydrocarbons (%)		One component representing 0.02	Four components, representing 5.112
	Oxygenated Sesquiterpenes (%)		Component 17, representing 0.01	Component 17, representing 0.852
	Others (%)		Ionone, representing 0.09	Four components, representing 11.33
Detected Components			18 Components, representing 100% of the total components	26 Components, representing 98.36% of the total components
Identified Components			16 Components, representing 99.98% of the total components	21 Components, representing 92.89% of the total components
Unknown Components			2 Components, representing 0.02% of the total components	4 Components, representing 4.89% of the total components
Oil Content (v/w%)			1.34	0.15

Notes: [a]*Pulicaria jaubertii* from Sana'a Outskirts. [b]*Pulicaria jaubertii* from Hajja Province. [c]Algabr *et al*., 2012

DISCUSSION

GC/MS analysis showed that the dominant component (98.34%) is the oxygenated monoterpene carvotanacetone whereas, the remaining oxygenated monoterpenes (eight components), four aromatic compounds (including phenolic compounds), one ionone, one sesquiterpene hydrocarbons and an oxygenated sesquiterpene are found in trace amounts (1.31%, 0.19%, 0.09%, 0.02% and 0.01%), respectively. GC/MS analysis results revealed that the volatile oil of *P. jaubertii* (PjSO) has a commercial potential for the production of oxygenated monoterpene carvotanacetone. Each one of the chemical components of PjSO volatile oil, was quantified by GC and identified by comparing their mass fragmentation with analogous spectral data from a data already available in the GC/MS computer libraries (NIST and Wiley libraries) as well as by matching their calculated retention indices (RI) with the reported RI values considered on the same columns polarities (Adams, 1995).

With respect to chemical composition of volatile oil extract of *P. jaubertii*, from Jazan, South of Saudi Arabia (Fawzy *et al*., 2013), Aljar area of Hajja province, North Yemen (270 km west Sana'a) (Algabr *et al.,* 2012) and Lahj province, South Yemen (Al-Fatimi *et al*., 2015), the presence of about 53 volatile constituents, including oxygenated monoterpenes (as major group), in addition to traces amount of monoterpene hydrocarbon, sesquiterpene hydrocarbons as well as oxygenated sesquiterpene, were previously reported and indicate that the oxygenated monoterpene carvotanacetone is the main components (98.59%, 64.0% and 93.5%, respectively). The presence of carvotanacetone as main component, has been also recorded in volatile oils of *Pulicaria undulate* from South Yemen (91.4%) and Sudan (55.87%) (Ali *et al*.,, 2012; El-Kamali *et al*., 2009), *P. mauritanica* from Morocco (87.3%) (Cristofari *et al*., 2011) and *P. inuloides* from North Yemen (47.3%) (Al-Hajj *et al*., 2014).

Results of previously published works and the results of GC/MS analysis of our study, reveal that the volatile oil from PjSO (present study), containing a quantity of carvotanacetone (98.34%), similar to the far end those of the quantity, which found in the volatile oil of *P. jaubertii* leaves from southern Saudi Arabia (98.6%), higher than those amount of oil from PjHP (64.0%) (Algabr *et al*., 2012) and the highest quantity among those which present in volatile oils of Yemeni *Pulicaria*.

A useful step in the analysis of IR spectrum is to look for any absorption bands in the region of stretching vibration (~ 4000 - 1500 cm^{-1}). Characteristic absorption bands were assigned in the IR spectrum of volatile oil of PJSO by simple check and attribution to extensive charts of distinctive group frequencies. IR spectral analysis results of the PjSO volatile oil, reveal the presence of mainly oxygenated terpenes (mono- and/or sesquiterpene), with feature structure containing carbonyl group. However, absorption band at ~1700 cm^{-1} was detected in IR spectrum of PjOS volatile oil. This band is characteristic to carbonyl groups of α,β-unsaturated ketone (carvotanacetone). The conjugation between C=C and C=O groups in such compounds, reduces the double-bond character of carbonyl group. This electronic effect cause the appearance of this absorption band at ~1700 cm^{-1} instead of 1720 cm^{-1} (normal position of C=O of ketone). The presence of components with C=C bonds in the volatile oil was indicated by a band (weak & sharp) at ~1600 cm^{-1}, whereas the two equivalent bands (weak & sharp) at 1380 cm^{-1} and 1360 cm^{-1} were attributed to isopropyl group of monoterpenes.

On the other hand, the presence of a band at 3020 cm^{-1} and some bands at 2965-2850 cm^{-1} indicated that the oil contain a component that is hydrogen bonded to *sp2* carbons, and hydrogen bonded to *sp3*, respectively, but none with hydrogen bonded to *sp* carbons were observed. Finally, the appearance of some broad and sharp bands in the range from ~750 to ~ 670 cm^{-1} indicated that the stereo configuration of C=C is *cis* configuration.

RSA can be considered as a measure of the ability of investigated sample or one of its components to act as "radicals scavengers". The relationship between therapeutic action(s) of *plant* volatile oil extract and the existence of chemical components (in this extract) with structural feature containing characterize functional group(s), were previously documented. RSC was found to be correlated to the presence of mainly monoterpene ketones, epoxides and aldehydes (Nikšić *et al.,* 2012). In addition, Ezoubeiri *et al*., (2005), reported that the structural feature required for a strong RSA and antimicrobial activity are those containing phenolic groups.

However, the presence of the oxygenated monoterpene carvotanacetone (α,β-unsaturated ketone), as the main component of the volatile oils of PjSO (98.34%) and PjHP (64%), encourage us to evaluate RSA (experimentally in vitro) of the investigated volatile oils.

This is in order to confirm this relationship and to support that the consumption of food produced with natural volatile oils or aromatic plant extracts is expected to be cure, retard the hazard of diseases caused by free radical (Alezandro *et al*., 2011). In addition, to find out the actual reasons for traditional uses of fresh or dried leaves of *P. jaubertii* with milk and certain kind of bread to make delicious traditional daily meal called Shafoot and to verify whether the traditional uses of this plant is actually useful for fortified human body from diseases caused by free radical.

Recorded results in Table 2 revealed that the investigated volatile oil of *P. jaubertii* (PjOS), showed high RSA as revealed by its ability to reduce violet DPPH radicals form into the yellow neutral form.

Based on the recorded results in Table 2 and according to the information from the literature syrvey, it is logic to conceive that the RSA of the investigated volatile oils of the medicinal aromatic plant PjSO and PjHP, could be mostly correlated to the presence of the monoterpene ketone (carvotanacetone). So, it's reasonable to hypothesize that this oxygenated monoterpene is a potent antioxidant "radical scavengers" (Niksic *et al.,* 2012).

The activities of the volatile oils are well comparable to that of ascorbic acid, which is known for its uses as a natural antioxidant. The results of RSA of the volatile oil of *P. jaubertii* (PjSO) showed that this extract has a higher radical scavenging activity in comparison with that of the volatile oil of *P. jaubertii* (PjHP), which has a significant activity. On the other hand, the obtained results reveal that the RSA of the volatile oil of PjSO (particularly at the higher concentration), is slightly higher than that of ascorbic acid (vitamin C). These results are directly connected to the quantitative difference of both volatile oils compositions, especially their diversity in the relative amount of their main constituent (carvotanacetone).

These results also indicate that the volatile oil of PjSO should act as "radicals scavengers", therefore, could serve as safe natural alternative for synthetic antioxidants in food and pharmaceutical industries.

Natural antioxidants, especially those found in antioxidant-rich plant extracts, are of key importance in health and protection against diseases. They delay lipids oxidation and for this reason, they are used in food industry to improve the quality of food (Kamkar *et al*., 2013).

A significant influence of growth location was observed on composition and volatile oils content of *P. jaubertii* (PjSO and PjHP). Qualitative and quantitative aspects of the two profiles are different (Table 3), except for the occurrence of components 7 (main constituent), 8, 9, 14 and 17. Significant differences were also seen in the numbers of detected and identified components. Volatile oils of PjSO and PjHP were differed particularly with regard to the composition percentage of the oxygenated monoterpene carvotanacetone (98.34% and 63.96%), respectively. This variation in the relative amounts of the main constituent of both volatile oils (Table 3) could be the reason for the variation in their RSA (Table 2) and this indicates that the oxygenated monoterpene carvotanacetone is the component responsible for RSA of both volatile oils.

Literature review reveals that the diversity of the volatile oils composition of *Pulicaria* species and the variation among their main constituent percentage are linked to their growth locations. For example, composition analysis of volatile oil of Iranian *P. undulate* (Nematollahi *et al*., 2006), showed the dominance of the oxygenated monoterpenes α-pinene (45.7%) and 1,8-cineol (27.1%), whereas, the main constituent of the volatile oils of *P. undulate* growing in either Sudan or Yemen is carvotanacetone, but with different yield percentages (55.8% and 91.4%), respectively (Ali *et al*., 2012).

CONCLUSION

This study showed that the volatile oil composition of PjSO is characterized by the presence of carvotanacetone as the main constituent, whose concentration is higher than that found in several other *Pulicaria* species and thus, the investigated volatile oil of PjSO has commercial potential for production of oxygenated monoterpene carvotanacetone. Furthermore, RSA results indicate that PjSO volatile oil has a higher RSA in comparison with that of PjHP volatile oil and slightly higher than that of ascorbic acid at higher concentrations. The present work found that PjSO volatile oil could serve as safe natural alternative for synthetic antioxidants in food and pharmaceutical industries.

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CONFLICT OF INTEREST

The authors declare that this article content has no conflict of interest.

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