Volatile components and biological activities of *Pulicaria* essential oils. A review

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The genus *Pulicaria* belongs to the Asteraceae family, consists of ca. 100 species with a distribution from Europe to North Africa and Asia, particularly around the Mediterranean. The *Pulicaria* essential oils were recognised to possess considerable biological activities with a varied chemical composition. This article aims to overview the medicinal uses, chemical compositions, and biological activities of *Pulicaria* essential oils considered as a medicinal plant, widely used as traditional herbal medicines in the treatment of various diseases. The data were collected from the scientific electronic databases including SciFinder, Scopus, Elsevier, PubMed, and Google Scholar. A total of sixteen *Pulicaria* species have been reported for their essential oils and biological activities. It can be observed that the major components were carvotanacetone, α-pinene, 4-terpineol, β-caryophyllene, and cis-chyrsanthenol. Pharmacological studies indicated that the essential oils exhibited antioxidant, antimicrobial, cytotoxicity, antibacterial, antifungal, anticholinesterase, leishmanicidal, allelopathic, anti-corrosive, antityrosinase, antitumor and insecticidal activities. The outcome of these studies will further support the therapeutic potential of the genus *Pulicaria* and provide convincing evidence to its future clinical applications in modern medicine.

Keywords: Asteraceae, *Pulicaria*, essential oil, carvotanacetone, antioxidant, antimicrobial

1. INTRODUCTION

The Asteraceae (Compositae) family is a widely distributed family throughout the world and contains about 200 genera and 2000 species [1]. The genus *Pulicaria* is an herbaceous plant of the Asteraceae family and consists of approximately 100 species [2]. It is widely distributed in Africa, Europe, and Asia, and concentrated mainly in the Mediterranean region. In North America, *Pulicaria* is known by the common name of false fleabane [3]. The leaves alternate and the capitulum is heterogamous and radiate, solitary or in terminal corymbs; receptacle epaleate, with scale-like ridges. The florets are radiate, small, disc florets 5-dentate, anthers sagittate and caudate, style branches linear, flat, and obtuse. The fruits are achenes cylindric, 4-ribbed and -angled, setulose-pubescent on the angles; pappus 2-seriate, the inner of smooth or barbellate bristles, and the outer of short connate scales [4].
Pulicaria species are used in the treatment of several diseases such as cancers, fever, hypoglycemia, microbial, inflammation, and spasmodic diseases [5]. Meanwhile, several different biological properties such as cytotoxic [6], antibacterial [7], anti-inflammatory [8], antihistaminic [9], antifungal [10], insecticide [11], and leishmanicidal [12] have been reported for the species of this genus. In addition, members of this genus have been traditionally used to repel insects, to reduce influenza and common cold symptoms, and to treat back pain, intestinal disorders, and inflammation [13]. The chemical investigation of the ge-

Table I - Traditional uses of several *Pulicaria* species

Plant	Local name	Traditional uses	References
P. arabica	Inula arabica	traditionally used to treat swelling and painful boils	[24]
P. crispa	Gethgath	used to treat inflammation and also as an insect repellent and herbal tea	[13]
P. dysenterica	Fleabane	treatment of dysentery	[25]
		the decoction from this plant is used as an antidiarrhoeal agent	[7]
P. gnaphalodes	Shabang	Traditionally used as anti-inflammatory and to treat severe heatstroke and diarrhea	[26]
P. incisa	Par'oshit gallonit	used as a traditional medicine for treating heart diseases by Bedouins	[27]
P. inuloides		the leaves are used to flavor foods and to make an herbal tea	[28]
P. jaubertii	Khooa	used as an aromatic cosmetic agent for women	[29]
P. stephanocarpa	Derbeb or Soqotra	used as a folkloric drug for treating headache, abscesses, boils and sores	[30]
P. odora	Ouden El hallouf	used to treat inflammation, back-pain, intestinal disorders, and menstrual cramps	[25]
	Mssakhen	given to women after childbirth	[25]
P. mauritanica	Ifanzi oudaden	used for treatment various inflammations and also used as herbal tea and to make various foods	[31]
P. salviifolia		administered traditionally for decreasing the blood sugar content, as a treatment of diabetes	[32]

nus showed the occurrence of secondary metabolites such as diterpenes [14-16], sesquiterpenes [17-19], caryophyllene derivatives [20-21], and flavonoids [22-23]. Several studies investigated earlier the chemistry and biodiversity of numerous species of the *Pulicaria* genus collected from different world localities. Some are related to their chemical composition and its variability, others described their biological activities such as antioxidant, antimicrobial, cytotoxicity, antibacterial, antifungal, anticholinesterase, leishmanicidal, allelopathic, anti-corrosive, antityrosinase, antitumor and insecticidal activities.
This article constitutes the overview of the chemical and biological activities of the genus *Pulicaria* essential oils considered as a medicinal plant, widely used in folk medicine overall the world. For this, databases such as Web of Science, PubMed, Science Direct, Scopus, and Google Scholar were interrogated. The "*Pulicaria*" and "Essential oil of *Pulicaria*" were the keywords used without restriction for the research.

2. MEDICINAL USES OF *PULICARIA*

Pulicaria species have been known for their medicinal benefits for centuries. Folks have been using the parts of the plants to extract essential oils for various reasons. The fruits, roots, leaves, and barks of these plant species are adopted in the therapy of diseases in the different approaches including pharmaceutics or traditional Chinese medicines.
Pulicaria species are used in the treatment of several diseases such as cancers, fever, hypoglycemia, microbial, inflammation, and spasmodic diseases [24-32]. Different *Pulicaria* species have been traditionally used in several countries; *P. jaubertii*, indigenous to Yemen, locally known as "Ansif" is used in folk medicine as diuretic, pyritic conditions in urogenital organs and to cure fever [41]. In Iran, *Pulicaria* species are known as "kak kosh" and "shebang" and are commonly used as herbal tea, flavouring agent, and medicinal plant [26]. In addition, *P. gnaphalodes* has been traditionally used as anti-inflammatory and to treat severe heatstroke and diarrhoea [26]. *P. odora* L. in Morocco is used in traditional medicine to treat back-pain, intestinal disorders, and menstrual cramps. The plant is also a constituent of the traditional remedy called "Mssakhen", which is given to women after childbirth [50]. *P. stephanocarpa* is known as "Derbeb" on Soqotra Island, is an aromatic herb and has been used as a folkloric drug for treating headaches, abscesses, boils, and sores [30]. In Sudan, *P. crispa* used in folk medicine for the treatment of colds, coughs, colic, excessive sweating, and as carminative [13]. *P. mauritanica* is considered a medicinal plant in Algerian folk medicine, used in the treatment of intestinal disorders, headaches, and is given to women after childbirth [46]. Table I shows the medicinal uses of several *Pulicaria* species.

3. CHEMICAL COMPOSITIONS OF *PULICARIA* ESSENTIAL OILS

Analysis of chemical components identified in *Pulicaria* essential oils shows that the oil consists of several groups of components, which are monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, oxygenated sesquiterpenes, aldehydes, and ketones. Table II shows the major components identified in *Pulicaria* essential oils from various origins.
In previous studies, sixteen *Pulicaria* species were described on the composition of the essential oils. These were *P. arabica* [24], *P. crispa* [33], *P. dysenterica* [34, 35], *P. glutinosa* [36], *P. incisa* [37], *P. inu-*

Table II - Major components of *Pulicaria* essential oils

Species	Country	Part	Yield (%)	Total identified		Major components	References
				No	%		
P. arabica	Algeria	Aerial parts	0.20	24	99.90	Bicyclo(4,4,0)dec-1-ene, 2-isopropyl-5-methyl-9-methylene (17.23%), 1*H*-indene, 1-ethylideneoctahydro (13.24%), β-Bourbonene, (7.34%)	[24]
P. crispa	Egypt	Aerial parts	0.60	8	99.90	Carvotanacetone (81.99%)	[33]
P. dysenterica	Greece	Aerial parts	0.34	58	80.50	(*Z*)-Nerolidol (11.2%), caryophyllene oxide (9.1%), (*E*)-nerolidol (6.6%)	[34]
			0.24	56	72.60	β-Caryophyllene (12.8%), caryophyllene oxide (12.8%), (*E*)-nerolidol (6.9%)	
	Iran	Aerial parts	0.40	19	96.00	ar-Curcumene (28.3%), epi-α-cadinol (16.4%), (*E*)-coniferyl alcohol (11.0 %)	[35]
P. glutinosa	United Arab Emirates	Aerial parts	0.50	29	81.20	β-Elemene (15.4%), τ-cadinol (14.2%), α-cadinol (8.4%), germacrene D (5.9%)	[36]
			0.50	30	74.90	τ-cadinol (12.4%), β-Elemene (11.8%), α-cadinol (10.5%), δ-cadinene (7.4%)	
P. incisa	Egypt	Leaves	0.66	49	86.69	Carvotanacetone (66.01%), chrysanthenone (13.26%),	[37]
		Flowers	0.33	68	84.29	Carvotanacetone (50.87%), chrysanthenone (24.3%)	
P. inuloides	Yemen	Flowers	NM	10	87.46	2-cyclohexen-1-one, 2-methyl-5-(1-methyl) (55.1%), benzene, methyl-(20.6%)	[38]
P. jaubertii	Saudi Arabia	Leaves	0.50	16	99.92	Carvotanacetone (98.59%)	[39]
		Roots	0.43	23	94.74	Dimethoxydurene (38.48%), durenol (26.89%), 2',4'-dimethoxy-3'-methylacetophenone (20.52%)	
	Yemen	Flowers	0.84	17	99.10	Carvotanacetone (93.5%)	[40]
	Yemen	Aerial parts	0.15	26	98.36	Carvotanacetone (63.96%), 1-methyl-1,2-propanedione (5.89%)	[41]
P. gnaphalodes	Iran	Aerial parts	0.10	33	91.60	Calamenene-10-one (12.2%), longifolol (5.99%), curcumen-15-al-ar (5.64%), cadinene <14-hydroxy-delta-> (5.52%), calamene 10,-ol-trans (5.05%)	[42]
	Iran	Aerial parts	3.00	58	90.70	α-Pinene (30.2%), 1,8-cineole (12.1%), β-citronellol (9.6%), mertenol (6.6%), α-terpineol (6.1%), 4-terpineol (5.9%)	[43]
	Iran	Aerial parts	0.10	88	89.00	Myrtenol (13.2%), citronellol (9.0%), (*E*)-nuciferol (5.2%), shiromoll (5.1%), geraniol (5.1%), α-pinene (5.0%)	[44]
	Iran	Aerial parts	NM	10	92.04	Chrysanthenyl acetate (22.38%), 2L-4L-dihydroxy eicosane (18.5%), verbenol (16.59%), dehydroaromadendrene (12.54%), β-pinene (6.43%), 1,8-cineol (5.6%)	[11]
	Iran	Aerial parts	NM	NM	NM	α-Pinene (34.0%), 1,8-cineole (12.0%)	[45]
	Iran	Aerial parts	NM	80	92.30	(-)-γ-Curcumen-15-al (14.9%), (-)-*epi*-β-bisabolol (13.8%), *ar*-curcumene (9.7%), γ-curcumene (8.0%),	[46]
	Iran	Aerial parts	NM	146	96.00	α-Pinene (34.0%), 1,8-cineole (11.9%), cadina-1(10),4-dien-8α-ol (11.0%),	[47]
	Iran	Aerial parts	NM	27	48.03	1,8-Cineole (9.45%), α-pinene (3.81%), terpinen-4-ol (3.66%), α-terpineol (3.63%), chrysanthenone (3.41%)	[12]
P. mauritanica	Algeria	Aerial parts	0.35	21	97.00	Carvotanacetone (89.2%)	[48]
	Morocco	Aerial parts	0.65	25	94.30	Carvotanacetone (87.3%)	[31]
	Morocco	Aerial parts	0.45	42	92.10	Carvotanacetone (87.3%)	[49]

Continua Tabella II

Species	Country	Part	Yield (%)	Total identified		Major components	References
				No	%		
P. odora	Morocco	Roots	0.80	27	86.41	Thymol (47.83%), thymol isobutyrate (30.05%)	[50]
P. salviifolia	Uzbekistan	Aerial parts	0.38	98	89.60	4-Terpineol (13.4%), α-cadinol (5.7%), 6-*epi*-shyobunol (5.2%), γ-terpinene (5.0%)	[51]
	Kazakhstan	Aerial parts	0.025	35	90.89	4-terpineol (11.2%), δ-cadinene (9.2%), α-cadinol (11.3%), caryophyllene (8.2%)	[52]
P. sicula	Italy	Aerial parts	0.05	66	91.8	Borneol (23.7%), caryophyllene oxide (10.2%), bornyl acetate (6.5%), isothymol isobutyrate (6.2%)	[53]
P. somalensis	Saudi Arabia	Aerial parts	0.50	71	91.80	Juniper camphor (24.7%), α-sinensal (7.7%), 6-*epi*-shyobunol (6.6%), α-zingiberene (5.8%), α-bisabolol (5.3%)	[54]
P. tephanocarpa	Yemen	Leaves	1.20	83	97.20	(*E*)-Caryophyllene (13.4%), (*E*)-nerolidol (8.5%), caryophyllene oxide (8.5%), α-cadinol (8.2%), spathulenol (6.8%)	[55]
P. undulata	Yemen	Leaves	2.10	22	99.70	Carvotanacetone (91.4%)	[56]
	Algeria	Aerial parts	1.20	31	68.40	Carvotanacetone (14.8%), δ-cadinene (8.2%), α-cadinol (4.7%), thujanol (4.7%).	[57]
	Egypt	Aerial parts	0.17	64	93.90	Carvacrol (46.5%), xanthoxylin (18.1%), carvotanacetone (8.7%)	[58]
	Iran	Aerial parts	0.32	28	91.60	α-Pinene (45.7%), 1,8-cineole (27.1%)	[59]
	Iran	Aerial parts	0.50	40	99.90	4-Terpineole (20.12%), 1*S*-*cis*-calamenene (13.37%), junipene (8.66%), *cis*-sabinene hydrate (8.29%), γ-terpinene (7.00%), linalool (5.60%)	[60]
	Iran	Aerial parts	1.34	34	93.17	*cis*-Chrysanthenol (15.36%), 1,8-cineole (11.73%), carvacrol acetate (10.77%), chrysanthenone (8.85%), eudesma-4(15)-7-dien-1-β-ol (8.48%)	[61]
			1.50	36	95.08	*cis*-Chrysanthenol (15.59%), 1,8-cineole (14.68%), carvacrol acetate (11.82%), chrysanthenone (10.25%), 2-ethyl phenol (7.40%)	
	Sudan	Aerial parts	2.50	43	80.97	Carvotanacetone (55.87%), β-linalool (4.55%)	[62]
P. vulgaris	Tunisia	Aerial parts	0.05	19	93.20	*cis*-β-Guaiene (59.7%), τ-cadinol (5.2%), 5-*epi*-7-epi-α-eudesmol (4.7%), β-eudesmol (4.4%)	[63]
		Roots	0.02	21	97.20	γ-Irone (39.2%), 7-*epi*-silphiperfol-5-ene (19.3%), 2,5-dimethoxy-*p*-cymene (8.5%), γ-himachalene (8.0%)	
	Iran	Aerial parts	NM	23	98.08	Thymol (50.22%), carvotanacetone (20.2%), thymol isobutyrate (16.8%)	[64]
	Italy	Aerial parts	0.22	52	93.60	Hexadecanoic acid (21.7%), β-caryophyllene (14.3%), geranyl propionate (8.2%)	[65]

NM – not mentioned

loides [38], *P. jaubertii* [39-41], *P. gnaphalodes* [11, 12, 42-47], *P. mauritanica* [10, 31, 48, 49], *P. odora* [50], *P. salviifolia* [51, 52], *P. sicula* [53], *P. somalensis* [54], *P. stephanocarpa* [55], *P. undulata* [56-62] and *P. vulgaris* [63-65]. Most of the species were reported from Algeria, Egypt, Greece, Iran, Italy, Kazakhstan, Morocco, Saudi Arabia, Sudan, Tunisia, United Arab Emirates, Uzbekistan, and Yemen.

Carvotanacetone has been reported as a major component in most of *Pulicaria* essential oils. Its richness was identified in *P. crispa* [33], *P. incisa* [37], *P. jaubertii* [39-41], *P. mauritanica* [10, 31, 48, 49], and *P. undulata* [56, 57, 62] essential oils. The essential oil containing carvotanacetone has been reported to possess strongest bactericidal activity, moderate cytotoxic activity and acetylcholinesterase inhibitory effect [71]. It is also well documented that isolated carvotanacetone compound has no antimicrobial activity against *Candida albicans* and *Cryptococcus neoformans* as well as no cytotoxic toxicity against

K562 cells, human chronic myelogenous leukaemia and KB cells, human oral epidermoid carcinoma and antiviral activity [72]. The higher amount of carvotanacetone may provide help to the researchers to study and understand the evolutionary trends. Alternatively, geography, climate and edaphic factors also play a vital role in the composition and content of secondary metabolites in the plant [70].

Oxygenated monoterpenes were found in several *Pulicaria* essential oils. α-Pinene was identified dominantly in Iranian *Pulicaria* oils that are from *P. gnaphalodes* [43, 45, 47] and *P. undulata* [59]. In addition, 4-terpineol was also found in a high percentage in the oils of *P. salviifolia* [51, 52] and *P. undulata* [60]. Meanwhile, the other monoterpenoids recognised were myrtenol [44], 1,8-cineole [12], thymol [50, 64], carvacrol [58] and borneol [53]. Another group of components that was found in *Pulicaria* essential oils was sesquiterpene hydrocarbons. Caryophyllene has been identified in the oils of *P. dysenterica* [34] and *P. stephanocarpa* [55]. Meanwhile, oxygenated sesquiterpenes; (*Z*)-nerolidol [34] and τ-cadinol [36] were also present in extraordinary amounts in the oils of *P. dysenterica* and *P. glutinosa*, respectively.

4. BIOLOGICAL ACTIVITIES

The literature study reveals that *Pulicaria* essential oils have been reported in various biological activities. Most of the studies were reported on antioxidant [24, 33, 38, 40, 43, 44, 54, 55, 58, 63], antimicrobial [24, 37, 38-40, 44, 48-50, 55, 56, 65, 66], and cytotoxicity [33, 37, 56, 58, 63, 64, 66].

Antioxidants are substances that can prevent or slow the damage to cells caused by free radicals, unstable molecules that the body produces as a reaction to environmental and other pressures. The *P. inuloides* oil showed high phenolic content (144 mg GAE/g), β-carotene bleaching (I: 90.77%), and DPPH radical scavenging (IC_{50} value 4.95 μg/mL) [38]. In DPPH radical scavenging, the *P. somalensis* oil was found to be significant with IC_{50} value 81.2 μg/mL [54]. In addition, *P. crispa* and *P. gnaphalodes* oils were inhibited DPPH radical with the inhibition percentage of 66.19% [33] and 36.0% [44], respectively. However, the essential oils of *P. jaubertii* [40], *P. stephanocarpa* [55], *P. arabica* [24], *P. gnaphalodes* [43] and *P. vulgaris* [63] showed weak activity in DPPH radical scavenging.

An antimicrobial is any substance of natural, semisynthetic, or synthetic origin that kills or inhibits the growth of microorganisms but causes little or no damage to the host. In the case of Gram-positive bacteria, the leaf oils of *P. stephanocarpa* [55] and *P. undulata* [56] exhibited strong activity against *Staphylococcus aureus* with MIC value 3.12 μL/mL, each. Meanwhile, *P. vulgaris* oil exhibited significant activity against *Bacillus cereus* and *Bacillus subtilis* with MIC value 25 μg/mL [65]. In the case of Gram-negative bacteria, *P. inuloides* oil showed the best activity against *Escherichia coli* with diameter zone of inhibition, 14.7 mm [38], whereas *P. mauritanica* oil showed the best activity with MIC value 0.3 mg/mL [49]. In another study, *P. incisa* leaf oil displayed strong activity against *Geotricum candidum* and *Streptococcus pneumoniae* with MIC value 3.9 μg/mL, each. Furthermore, *P. wightiana* leaf oil displayed significant activity against *Listeria monocytogenes*, *L. innocua*, and *L. ivanovii* with MIC value 5.49 μg/mL, each [66].

Cytotoxicity studies are a useful initial step in determining the potential toxicity of a test substance, including plant extracts or biologically active compounds. In the case of *Pulicaria* essential oils, Hep G2 and MCF-7 cell lines have been widely investigated. The *P. crispa* oil was found to possess IC_{50} values of 20.11 μL/mL against HepG-2 cell lines [33], whereas *P. incisa* oil showed higher activity against HepG-2 cell line with IC_{50} value 11.4 μg/mL compared with 37.4 μg/mL for flower oil [37]. Meanwhile, *P. wightiana* oil possessed significant activity against MCF-7 cell line with IC_{50} values of 3.0 (48 h) and 12.9 (72 h) μg/mL [66]. The *P. vulgaris* oil exhibited significant activity against MCF-7 cell line with IC_{50} values of 5.36 μg/mL [64], however, *P. undulata* oil showed moderate cytotoxic activity with IC_{50} value 64.6 μg/mL [56]

Other bioactivity studies were also reported that are antibacterial [63, 64], antifungal [10, 64], anticholinesterase [48, 55], leishmanicidal [12, 67], allelopathic [54], anti-corrosive [31], antityrosinase [63], antitumor [39], and insecticidal [11] activities. Table III describes the details of the biological activities reported by the *Pulicaria* essential oils. According to Pengelly [68], it is often the unique chemical combination rather than a single component that is responsible for any therapeutic activity. Lahlou [69] stipulates that essential oil, in its totality, acted less than the major constituents and suggest. in some cases, that biological activity of the essences from the aromatic plants studied may be attributable both to their major components and to the minor ones in these oils. Hence, the synergistic effects of active chemicals with other constituents of the essential oil should be taken into consideration [70].

5. CONCLUSIONS

This article aims to give the relevant literature of the medicinal uses, chemical compositions, and bioactivity information on the *Pulicaria* essential oils. What emerged is that chemical components from *Pulicaria* essential oils exhibit a variety of biological activities. Besides, due to the variability of the composition of

Table III - Biological activities of *Pulicaria* essential oils

Bioactivities	**Essential oils**	**Description**	**References**
Antioxidant	*P. jaubertii*	The flower oil showed weak activity in DPPH radical scavenging with IC_{50} value 280 µg/mL	[40]
	P. inuloides	The oil showed high phenolic content (144 mg GAE/g), β-carotene bleaching (I: 90.77%), and DPPH radical scavenging (IC_{50} value 4.95 µg/mL)	[38]
	P. stephanocarpa	The leaf oil showed weak activity in DPPH radical scavenging with IC_{50} value 330 µg/mL	[55]
	P. somalensis	The oil was found to be significant in DPPH radical scavenging (IC_{50} value 81.2 µg/mL) and ABTS (IC_{50} value 64.4 µg/mL) assays	[54]
	P. crispa	The oil was inhibited DPPH radical with the inhibition percentage of 66.19% and trolox equivalent antioxidant capacity (TEAC) of 9.22 µg/mL	[33]
	P. arabica	The oil was found inactive in DPPH radical scavenging	[24]
	P. gnaphalodes	The oil strongly reduced the concentration of DPPH radical (36.0%), and showed high inhibition in β-carotene bleaching test (73.1%)	[44]
	P. gnaphalodes	The oil was found lower scavenging ability on DPPH (IC_{50} value 147 µg/mL), whereas β-carotene bleaching gave inhibition of 50.11%	[43]
	P. vulgaris	The oil (aerial part) was found weak activity in DPPH radical scavenging (IC_{50} 83.5 µg/mL), ABTS (IC_{50} 174.0 µg/mL), reducing power (IC_{50} 505.0 µg/mL) assays. In addition, the root oil displayed significant in DPPH radical scavenging (IC_{50} 34.5 µg/mL), ABTS (IC_{50} 78.0 µg/mL), reducing power (IC_{50} 228.0 µg/mL) assays	[63]
	P. undulata	The oil showed a moderate ability to reduce DPPH radicals (IC_{50} value 422.5 µg/mL), high reactivity towards ABTS radical (IC_{50} value 7.9 µg/mL), and good reducing power ability (FRAP assay, TEAC 236.5 µmol TE/g)	[58]
Antimicrobial	*P. jaubertii*	The flower oil showed the strong activity against *Staphylococcus aureus* with MIC value 250 µg/mL	[40]
	P. jaubertii	The leaf and root oils was found inactive against *Staphylococcus aureus* and *Bacillus subtilis* with MIC values 500-2000 µg/mL	[39]
	P. inuloides	The oil showed the best activity against *Escherichia coli* with diameter zone of inhibition, 14.7 mm	[38]
	P. stephanocarpa	The leaf oil exhibited strong activity against *Staphylococcus aureus* with MIC value 3.12 µL/mL	[55]
	P. vulgaris	The oil exhibited significant activity against *Bacillus cereus* and *Bacillus subtilis* with MIC value 25 µg/mL	[65]
	P. mauritanica	The oil displayed moderate effect against *Citrobacter freundii*, *Candida albicans*, *Alternaria alternate*, and *Cladosporium herbarum* with MIC value 2.0 µg/mL, each	[48]
	P. mauritanica	The oil showed the best activity against *Escherichia coli* with MIC value 0.3 mg/mL	[49]
	P. gnaphalodes	The oil has shown maximum zone of inhibition against *Candida albicans* (23 mm)	[44]
	P. odora	The root oil showed the best activity against *Streptococcus C (IPT 2-035)* with diameter zone of inhibition, 75 mm	[50]
	P. arabica	The oil showed the best activity against *Candida albicans* with diameter zone of inhibition, 16.33 mm	[24]
	P. incisa	The leaf oil displayed strong activity against *Geotricum candidum* and *Streptococcus pneumoniae* with MIC value 3.9 µg/mL, each. Besides, the flower oil gave the best activity against *Bacillis subtilis* with MIC value 32.3 µg/mL	[37]
	P. wightiana	The leaf oil displayed significant activity against *Listeria monocytogenes*, *L. innocua*, and *L. ivanovii* with MIC value 5.49 µg/mL, each	[66]
	P. undulata	The leaf oil showed the strongest bactericidal activity against *Staphylococcus aureus*, *methicillin-resistant S. aureus*, and *Candida albicans* with MIC value 3.12 µg/mL, each	[56]
Cytotoxicity	*P. crispa*	The oil was found to possess EC_{100} value of 12.8 µL/mL in the assay against peripheral blood mononuclear cells ($PBMC_S$). in addition, the oil showed IC_{50} values of 4.73 and 20.11 µL/mL against colorectal Caco-2 and HepG-2 carcinoma cell lines, respectively	[33]
	P. incisa	The leaf oil showed higher activity against HepG-2 carcinoma cell lines with IC_{50} value 11.4 µg/mL compared with 37.4 µg/mL for flower oil	[37]
	P. wightiana	The oil possessed significant activity against MCF-7 cell line with IC_{50} values of 3.0 (48 h) and 12.9 (72 h) µg/mL	[66]
	P. vulgaris	The oil exhibited a significant activity against MCF-7 and Hep-G2 cell lines with IC_{50} values of 5.36 and 7.16 µg/mL, respectively	[64]
	P. vulgaris	The root (IC_{50} values 96.87 and 121.30 µg/mL) and aerial part (IC_{50} values 217.2 and 181.0 µg/mL) oils showed moderately active against HeLa and A549 cell lines	[63]

Continua Tabella III

Bioactivities	Essential oils	Description	References
	P. undulata	The leaf oil showed moderate cytotoxic activity against MCF-7 breast tumor cells with IC_{50} value 64.6 µg/mL	[56]
	P. undulata	The oil showed moderate results with IC_{50} values 18.53, 40.64 and 22.23 µg/mL against three cell lines A375, T98G, and HCT116, respectively	[58]
Antibacterial	*P. vulgaris*	The oil showed significantly inhibited the growth of *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* with MIC values of 17.5, 25.2, 19.4 and 33.2 µg/mL, respectively	[64]
	P. vulgaris	The root (14.0 and 13.5 mm) and aerial part (20 and 19 mm) oils were more resistant towards *Pseudomonas syringaepv. syringae* and *Agrobacterium tumefaciens*	[63]
Antifungal	*P. mauritanica*	The oil demonstrated significant inhibition of the mycelial growth of all strains with the complete inhibition of *Alternaria* sp., and *Penicillium expansum* at MIC value 2 mL/mL	[10]
	P. vulgaris	The oil showed significantly inhibited the growth of *Aspergillus niger* and *Candida albicans* with MIC values of 15.5 and 9.9 µg/mL, respectively	[64]
Anticholinesterase	*P. stephanocarpa*	The leaf oil revealed an AChE inhibitory activity of 47% at a concentration of 200 µg/mL	[55]
	P. undulata	The oil showed a good activity against AChE enzyme with IC_{50} value of 139.2 µg/mL	[58]
Leishmanicidal	*P. gnaphalodes*	The oil inhibited *Leishmania major* growth in concentrations ranging from 0.125 to 50 µL/mL (parasite culture) in 24 h	[12]
	P. vulgaris	The oil was found active against the promastigote forms of *Leishmania major* and *Leishmania infantum*, with IC_{50} values of 244.70 and 233.65 µg/mL, respectively	[67]
Allelopathic	*P. somalensis*	The oil showed significant activity against the weeds of *Dactyloctenium aegyptium* (crowfoot grass) (IC_{50} value 0.7 µg/mL) and *Bidens pilosa* (hairy beggarticks) (IC_{50} value 1.0 µg/mL)	[54]
Anti-corrosive	*P. mauritanica*	The inhibition efficiency of the oil was found to increase with oil concentration to attain 91.5% at 2g/L	[31]
Antityrosinase	*P. vulgaris*	The root and aerial part oils inhibited effect on mushroom tyrosinase with IC_{50} values of 76 and 39 µg/mL, respectively	[63]
Antitumor	*P. jaubertii*	The leaf and root oils exerted an activity against MCF-7 cell lines with IC_{50} values 3.8 and 9.3 µg/mL, respectively. Besides, the leaf and root oils also showed an activity against HepG-2 cell lines with IC_{50} values 3.8 and 9.3 µg/mL, respectively	[39]
Insecticide	*P. gnaphalodes*	The oil showed significant activity against *Callosobruchus maculatus* with LC_{50} value of 1.54 µL/L	[11]

essential oils, further studies are necessary, particularly regarding their chemicals and factors of variation mainly those related to the geographical area, which may cause an important change in the biological activities of oils. This variability can define different chemotypes according to the existing bioactive compound, even at low concentrations. In this respect, *Pulicaria* species might be of interest. The essential oil isolated from *Pulicaria* species may bear the potential for drug development due to its high concentration of carvotanacetone. However, numerous investigations should be carried out on their mode of action and their probable toxicological effects, as well as clinical trials in order to optimise their potential uses for therapeutic applications and drug development.

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