Review

Genus *Prangos* (Apiaceae): A systematic review on essential oils composition and biological activities

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Essential oils are recognised for their exceptional medicinal value and are considered among the most attractive and potent plant-derived products. Accordingly, growing evidence of the health benefits of these natural essences has prompted researchers to further investigate essential oils and their components, which have been showing promising prospects so far. The objective of this study was to review the essential oils of the genus *Prangos* and their biological activities. The data were collected from scientific electronic databases including SciFinder, Scopus, Elsevier, Pubmed, Google Scholar, and Web of Science. A revision of the genus *Prangos* in Western Asia and in the East of the Mediterranean Sea claimed that there are about 45 species available. The genus *Prangos* distributed from Portugal to Tibet mainly consists of 45 species. *Prangos* species possess great importance as spices, and they are largely used as medicinal plants in Asia, especially in Iran, Turkey, and Iraq. It has been shown to possess gastrointestinal symptoms, as well as aphrodisiac, coagulant, carminative and tonic properties. A total of twenty-one *Prangos* species have been reported for their essential oils and biological activities. Monoterpenes were identified as the major components for several *Prangos* species with an abundance of α-pinene, β-pinene, (Z)-β-ocimene, δ-3-carene, and sabinene. The essential oils also presented remarkable biological activities such as antimicrobial, antioxidant, allelopathic, insecticidal, larvicidal, antiproliferative, anticholinesterases, antityrosinase, antidiabetic, repellent, antiobesity, wound healing, and fumigant toxicity effects. This is the first attempt to compile essential oils composition and their biological activities as well as the medicinal uses of the genus *Prangos*. In the future, several scientific investigations are required to understand the mechanism of the action of essential oils and their bioactive components.

Keywords: Apiaceae, *Prangos*, essential oil, composition, α-pinene, antimicrobial

1. INTRODUCTION

The Apiaceae family (also known as Umbelliferae) consists of nearly 3800 species, classified into four subfamilies and 29 tribes. According to the Plants of the World Online (POWO) database, there are 446 genera assigned to this flowering-plant type family [1]. The name originally derived from a celery-like plant of the genus Apium which has a wide distribution in Europe and Asia especially Turkey, as well as Africa, South America, and Australia. In Turkey, there are approximately 47 genera reported and 9 are endemic taxa plants [2].

Several plants of this family are well-known harvested crops including leaf and root vegetables such as carrots and celery, as well as herbs and spices such as parsley, anise, and caraway. Meanwhile, some members of the family have been used as an indigenous medicine over generations mainly in tropical and subtropical regions [3].

Prangos (Figure 1) is one of the genera in the Apiaceae family that is mainly

Figure 1 – *Some species of the genus Prangos*

found in western Asia and east of the Mediterranean Sea. It is reported that the majority of these perennial hemicryptophytes are clustered around Turkey, Iran, and Iraq [4]. About 45 species of *Prangos* were recorded and have an economic and medicinal impact. Generally, several *Prangos* species have been consumed in folk medicine such as *P. meliocarpoides* as a wound healing agent and treatment of gastrointestinal abnormalities [5-7]. Meanwhile, *P. ferulacea* and *P. heyniae* were used as a natural aphrodisiac. The most highlighted species of this genus are *P. ferulacea* and *P. pabularia* due to their extensive use by natives [8-10].
Phytochemical studies on the non-volatile metabolites of the genus *Prangos* reported the presence of coumarins, which includes prenylated coumarin (osthole) [11], aglycone coumarin (oxypeucedanin and isoarnottinin 4'-glucoside) [12], furanocoumarin (psoralen) [13] and other coumarin derivatives [10]. Due to this coumarins content, the genus *Prangos* shows various pharmacological properties such as natural anti-HIV agent [14], antifungal [15], antibacterial, antioxidant, and cytotoxic effects [16].
Essential oils have been used for thousands of years in countless cultures for their incredible health-promoting and medicinal properties. This secondary metabolite consists of versatile organic structures and complex mixtures of natural compounds including unsaturated hydrocarbons like terpenic compounds, aldehydes, ketones, esters, and phenols. The oils are mainly utilised for aromatherapy, insect repellents, and medical purposes and some are food-grade oils that are being used to flavour. Nowadays, many studies have revealed that the oils retain remarkably antimicrobial, antioxidant, and anti-inflammatory properties [17-19].
Hence, the review concerning the genus *Prangos* essential oils focusing on their medicinal uses, chemical compositions, and biological activities is necessary to clearly observe the potential of this genus, especially in the food and pharmaceutical industries. The facts pertaining to the *Prangos* essential oils and the biological activities of numerous species were searched thoroughly via online comprehensive discovery databases (SciFinder, Scopus, Elsevier, Pubmed, Google Scholar, and Web of Science) and the articles published in peer-reviewed journals were collected via a library search.

2. SEARCH STRATEGY

The protocol for performing this study was developed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) [20] (a) the first step was to exclude duplicate articles, (b) titles and abstracts were then read and the inclusion and exclusion criteria were applied and (c) all articles resulting from this stage were read in full, and the inclusion and exclusion criteria were applied again.
Figure 2 shows the flow diagram of the identification and selection of articles. Following this step, we reached the articles chosen for this study. This systematic review was conducted through searches using Scopus, PubMed, Science Direct, SciFinder, and Google Scholar. The keywords used were '*Prangos*', 'essential oil', and 'biological activity' articles over the period from the beginning of the database until December 2022.
The inclusion of articles considered the following criteria: (1) type of publication - original research articles, (2) only articles in English, (3) articles must present the chemical composition of *Prangos* essential oils, (4) articles must discuss the bioactivity of the essential oils.

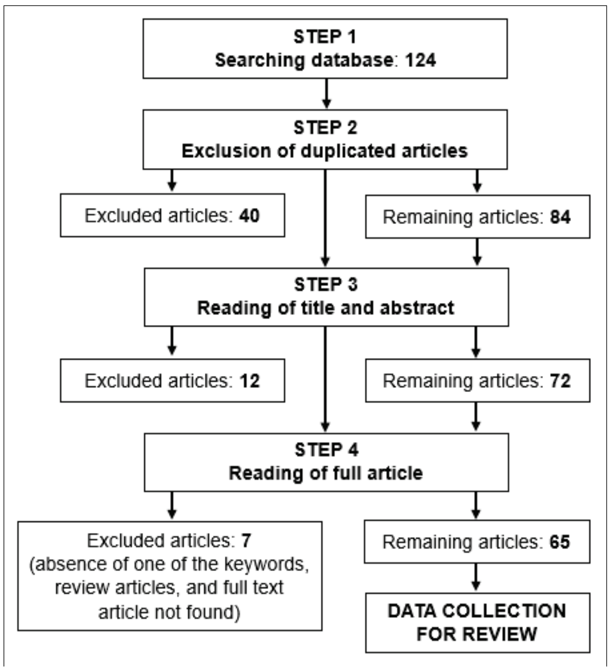

Figure 2 - PRISMA flow diagram of included studies

As the exclusion criteria, the following were used: (1) articles that did not present the search terms in the title and abstract; (2) review articles, (3) full-text articles not found, (4) articles without one of the keywords and (5) articles that did not present the composition of the essential oils.

3. MEDICINAL USES

Since a long time ago, traditional medicinal plants have been used for the treatment of different types of diseases around the world. It is proven that each part of the plants including roots, stems, flowers, seeds, and leaves is beneficial to humans. Recently, *Prangos* species have been used to treat multiple traditional therapies. Meanwhile, the aerial part of essential oils is the major contributor to the genus *Prangos* in terms of benefits of pharmacological effects. In Turkey, several *Prangos* species are used as sexual stimulants and to control external bleeding. Table I shows several *Prangos* species and their medicinal uses [21-33].

4. ESSENTIAL OILS COMPOSITION

The composition of essential oils contributes significantly to the determination of the pharmacological potential attributed to the plant species (indicated mainly by the major compounds) and is constantly being transformed, due to factors external to the biology of the plants (edaphic or environmental) and/or intrinsic to the biology of plants (physiological and genetic) [19].

The essential oils from *Prangos* species characterised by chemical diversity are shown in Table II [34-87]. The chemical composition for species of genus *Prangos* reported in the study consulted from 1996 to the present day. All the information collected was organised taking into account plant species, origin, part of the plant used, yield, identification of components, and main components. The essential oils from twenty-one species of *Prangos* were analysed according to the data reported in Table II. The important qualitative and quantitative differences in the chemical composition of the essential oils of genus *Prangos* can be estimated; the aerial parts are the most studied part of the plant, as well as fruits, inflorescences, leaves, roots, shoots, stems, and umbels. The most commonly used extraction processes were hydrodistillation. The components were characterised using mass spectrometry, retention indexes, and retention times. The amount of each component is given as a percentage of the total oil and, in general, 80-90% of the oil was identified.
Analysis of the essential oils demonstrated the highest yield given by the roots oil of *P. denticulata* which gave 3.20% [79]. In addition, the highest components identified were from the fruit oil of *P. denticulata* (121 components) [79], followed by the aerial parts' oil of *P. pabularia* (86 components) [63]. Monoterpenes (hydrocarbons and oxygenated) were found and classified as the major components. α-Pinene was reported as the major component in 23 studies. Besides, 5 studies were also reported; β-pinene, (Z)-β-ocimene, and δ-3-carene as the most abundant components. α-Pinene was found its richness in the fruit's oil of *P.*

Table I - Medicinal uses of several *Prangos* species

Species	Plant Part	Plant Origin	Traditional uses	References
P. pabularia	Roots, Fruits, Leaves	Turkey, India	Traditionally used as laxative, antihypertensive, and carminative agents and are also recommended for the treatment of digestive disorders	[21]
P. ferulacea	Roots, Shoots, Leaves	Iran, Turkey	Treat gastrointestinal abnormalities, act as natural aphrodisiac, and increase body strength, anti-diabetic agent	[22]
P. platychlaena	Roots	Turkey	Treat wounds of cattle, stop external bleeding, prevent gum ailment and cavity formation	[23]
P. uechtritzii	Whole plant	Turkey	Treat haemorrhoids	[24]
	Roots	Turkey	Act as natural aphrodisiac	[25]
P. haussknechtii	Aerial parts	Iraq	Has carminative, diuretic, and act as natural sedative	[26]
P. asperula	Aerial parts	Lebanon	Reduce blood pressure, treat skin disease, digestive disorder and haemorrhoids	[27]
P. heyniae	Roots	Turkey	Natural aphrodisiac	[28]
P. meliocarpoides	Fruits	Turkey	Treat external bleeding, digestive disorder, wounds, scars and mucosal disease	[5]
	Roots	Turkey	Natural aphrodisiac	
P. uloptera	Aerial parts	Iran	Treat leukoplakia, digestive disorders and wounds	[29]
P. tschimganica	Aerial parts	Uzbekistan	Treat leukoplakia	[30]
P. gaubae	Fruits	Iran	Natural nutritional agent	[31]
P. acaulis	Aerial parts	Iran	Used as sedative and anti-infective agent, as well as pain relief and tooth whitener	[32]
P. peucedanifolia	Aerial parts	Iran	Treating kidney disorders, bladder inflammation, and hemorrhoids	[33]

Table II - Major chemical components identified from *Prangos* essential oils

Species	Locality	Part	Yield (%)	Identification (No. %)	Major components	References
P. ferulacea	Italy	Flowers	0.62	15, 96.58	(Z)-β-Ocimene (44.44%), sabinene (20.1%), γ-terpinene (8.09%), 3-thujene (5.79%), and α-pinene (4.28%)	[34]
		Leaves	0.28	19, 96.22	(Z)-β-Ocimene (61.91%), sabinene (10.11%), caryophyllene (7.65%), and (*E*)-β-ocimene (4.62%)	
		Aerial parts	0.62	31, 89.10	(E)-β-ocimene (43.1%), (*Z*)-β-ocimene (15.8%), and α-pinene (5.6%)	[35]
	Iran	Aerial parts	1.80	22, 99.87	β-Pinene (27.01%), δ-3-carene (24.78%), α-pinene (18.34%), and β-caryophyllene (17.69%)	[36]
			0.17-0.29	34, 99.90	(*E*)-Caryophyllene (48.21%), α-humulene (10.28%), spathulenol (9.36%), linalool (3.46%), and δ-3-carene (3.37%)	[37]
			0.20	27, 99.25	β-Pinene (43.1%), α-pinene (22.1%), and δ-3-carene (16.9%)	[38]
			1.90-2.10	38-47, 92.30-95.76	Terpinolene (56.3-38.1%), α-terpinene (2.25-1.6%), (*E*)-caryophyllene (4.7-3.6%), and bornyl acetate (2.9-1.8%)	[39]
			0.20	31, 98.00	α-Pinene (57.0%), 3-ethylidene-2-methyl-1-hexen-4-yne (5.3%), and β-pinene (4.5%)	[40]
			0.60	21, 96.23	β-Phellandrene (20.39%), α-terpinolene (15.26%), α-pinene (11.59%), δ-3-carene (11.06%), α-phellandrene (9.09%), and *trans*-β-ocimene (9.67%)	[41]
			1.60	10, NM	α-Pinene (36.6%) and β-pinene (31.1%)	[42]
		Leaves	1.17-1.23	32, 93.25-95.14	(*E*)-β-Ocimene (22-0.6-28.25%), limonene (12.19-15.18%), 2,3,6-trimethylbenzaldehyde (7.03-8.57%), and terpinolene (6.63-8.73%)	[43]
			0.54-1.55	22, 76.70-90.30	α-Pinene (4.8-16.4%), β-pinene (9.4-27.9%), and δ-3-carene (8.1-20.6%)	[44]
			0.43	39, 99.77	α-Pinene (36.82%), camphene (15.83%), limonene (10.52%), β-pinene (8.73%), and myrcene (5.88%)	[45]
			0.25	65, 96.20	β-Pinene (29.6%), α-pinene (19.8%), δ-3-carene (11.4%), and β-phellandrene (11.1%)	[46]
			0.90	10, 81.70	Linalool (36.7%), caryophyllene oxide (16.3%), and α-pinene (12.1%)	[47]
		Flowers	0.78	56, 99.42	α-Pinene (20.91%), bornyl acetate (13.80%), camphene (11.94%), limonene (8.57%), β-pinene (7.47%), and myrcene (6.03%)	[45]
			0.40	52, 91.50	β-Pinene (20.6%), α-pinene (8.8%), δ-3-carene (10.4%), and β-phellandrene (8.1%)	[46]
			1.10	17, 98.20	Linalool (19.0%), lavandulyl acetate (16.0%), 1,8-cineole (14.5%), α-pinene (12.4%), and geranyl isobutyrate (12.2%)	[47]
		Roots	1.20	14, 95.10	β-Phellandrene (32.1%), *m*-tolualdehyde (26.2%), and δ-3-carene (25.8%	[48]
			0.20	53, 96.30	δ-3-Carene (22.5%), β-phellandrene (11.8%), α-pinene (8.6%), terpinolene (7.2%), *p*-cymene (6.3%), α-phellandrene (6.2%), and myrcene (4.5%)	[49]
		Stems	0.80	11, 43.30	1,8-Cineole (19.0%) and α-pinene (10.3%)	[47]
		Fruits	0.80	14, 93.70	α-Pinene (63.1%), *cis*-ocimene (9.7%), and β-pinene (8.3%)	[50]
		Umbels	0.50	12, 94.70	α-Pinene (42.2%), *cis*-ocimene (36.3%), and myrecene (5.0%)	
	Turkey	Aerial parts	NM	21, 98.86	2,3,6-Trimethyl benzaldehyde (66.59%), chrysanthemyl acetate (15.06%), β-ocimene (3.76%), and p-mentha-1,5-dien-8-ol (3.57%)	[51]
		Fruits	0.36-0.98	23, 85.32-93.83	γ-Terpinene (30.22-33.27%) and α-pinene (16.71-12.83%)	[52]
P. asperula	Lebanon	Fruits	0.52	22, 95.10	Sabinene (29.8%), β-phellandrene (19.2%), α-pinene (9.8%), trans-nerolidol (9.2%), and α-phellandrene (8.0%)	[53]
		Leaves	NM	42, 92.10	Sabinene (20.6%), β-phellandrene (19.0%), γ-terpinene (9.0%), and α-pinene (8.4%)	[54]
	Iran	Leaves	0.20	47, 98.80	2,3,6-Trimethyl benzaldehyde (18.4%), δ-3-carene (18.0%), and α-pinene (17.4%)	[55]

Continue Tabella II

Species	Locality	Part	Yield (%)	Identification (No. %)	Major components	References
		Aerial parts	0.95	42, 99.62	δ-3-Carene (25.54%), α-terpinolene (14.76%)α-pinene (13.6%), limonene (12.94%), myrcene (8.1%), and β-pinene (5.4%)	[56]
P. uloptera	Iran	Aerial parts	0.85	12, 94.94	α-Pinene (25.20%), decanal (18.03%), β-caryophyllene (16.98%), limonene (7.15%), and caryophyllene oxide (6.25%)	[36]
			0.80	60, NM	δ-3-carene (26.3-32.1%), α-pinene (15.4-16.8%), and camphene (2.7-4.1%)	[57]
			0.41	60, NM	α-Pinene (14.26-15.37%), δ-3-carene (26.12-26.42%), β-myrcene (9.8-10.16%), p-cymene 88.21-8.60%), and β-phellandrene (7.62-8.16%)	[58]
			0.45	11, 90.96	Safrole (21.67%), α-pinene (20.09%), and spathulenol (13.66%)	[59]
			0.70	28, 89.10	β-Caryophyllene (27.1%), caryophyllene oxide (15.9%), and α-pinene (12.4%)	[60]
		Umbels	0.40	10, 93.20	α-Pinene (31.7%), β-bourbonene (15.9%), α-curcumene (10.6%), spathulenol (9.0%), and m-cymene (5.5%)	[61]
		Fruits	0.40	18, 83.00	α-Pinene (14.98%), β-bourbonene (7.81%), α-humulene (7.74%), germacrene B (7.23%), and n-tetracosane (6.65%)	
P. pabularia	Tajikistan	Roots	0.10	42, 97.30	5-Pentylcyclohexa-1,3-diene (44.6%), menthone (12.6%), 1-tridecyne (10.9%), and osthole (6.0%)	[62]
	Uzbekistan	Aerial parts	0.42	86, 93.40	cis-allo-Ocimene (17.6%), δ-3-carene (14.2%), limonene (7.6%), 2,4,6-trimethylbenzaldehyde (6.8%), and α-terpinolene (6.1%)	[63]
	Turkey	Aerial parts	NM	34, 91.30	α-Pinene (32.4%), δ-3-carene (12.4%), germacrene D (8.1%), limonene (6.4%), and bicyclogermacrene (6.2%)	[64]
	Iran	Leaves	0.20	23, 90.31	Spathulenol (16.0%), α-bisabolol (14.3%), and (Z)-4-methoxycinnamaldehyde (9.47%)	[65]
		Fruits	0.40	15, 70.01	α-Pinene (33.87%), spathulenol (9.32%), and α-santalene (7.05%)	
		Umbels	0.30	23, 71.31	α-Pinene (21.46%), α-santalene (6.36%), and p-methoxyacetophenone (5.39%)	
	India	Shoots	0.30	31, 97.34	Durylaldehyde (62.16%), bicyclo[3.1.1]hept-2-en-4-ol (8.84%), and chrysanthenyl acetate (5.12%)	[81]
P. heyniae	Turkey	Aerial parts	0.10–12.2	41, 95.90	β-Bisabolenal (12.2%), caryophyllene oxide (7.9%), germacrene D (7.8%), elemol (7.4%) and α-humulene (6.7%)	[66]
			0.30-0.90	20-66, 96.30-97.40%	Germacrene D (10.3-12.1%), β-bisabolene (14.4%), kessane (26.9%), germacrene B (8.2%), elemol (3.4-46.9%), β-bisabolenal (1.4-70.7%), and β-bisabolenol (8.4%)	[67]
		Fruits	1.40-2.70	34, 97.0-98.70	α-Pinene (6.8-12.8%), α-phellandrene (0.1-17.1%), and β-phellandrene (4.2-22.4%)	[68]
			0.30-0.90	61-79, 89.80-92.20	β-Bisabolenal (53.3-18.0%), β-bisabolenol (14.6-2.3%), and β-bisabolene (12.1-10.1%)	[69]
P. platychlaena	Iran	Aerial parts	0.04-2.85	35, 90.14-92.55	δ-3-Carene (9.25-43.17%), α-pinene (4.58-27.41%), β-pinene (3.72-25.55%), and β-phellandrene (4.02-17.88%)	[70]
		Leaves	0.27	36, 90.44	(E)-β-Ocimene (25.93%), bornyl acetate (24.58%), α-pinene (5.84%), sylvestrene (4.62%), and γ-terpinene (3.75%)	[71]
		Stems	0.04	38, 92.72	Bornyl acetate (25.49%), (E)-β-ocimene (22.94%), α-pinene (9.5%), p-cymene (6.48), γ-terpinene (4.13%), and sylvestrene (4.01%)	
		Flowers	1.02	43, 96.49	(E)-β-Ocimene (28.5%), bornyl acetate (24.18%), γ-terpinene (14.15%), p-cymene (6.48%), and α-pinene (4.16%)	
	Turkey	Fruits	0.40	15, 98.82	α-Pinene (69.75%), β-phellandrene (10.58%), δ-3-carene (3.39%), and p-cymene (3.38%)	[72]
P. acaulis	Iran	Aerial parts	NM	21-26, 89.10-98.74	α-Pinene (13.7-22.87%) and 3-ethylidene-2-methyl-1-hexen-4-yne (14.3-21.36%)	[73]
		Stems	0.18	11, 100	3-Ethylidene-2-methyl-1-hexen-4-yne (56.8%) and α-pinene (34.2%)	[74]
		Leaves	0.25	18, 99.74	α-Pinene (39.54%), 3-ethylidene-2-methyl-1-hexen-4-yne(37.94%), and α-terpinene (10.9%)	

Continue Tabella II

Species	Locality	Part	Yield (%)	Identification (No. %)	Major components	References
		Flowers	0.38	22, 98.18	α-Pinene (25.04%), 3-ethylidene-2-methyl-1-hexen-4-yne (23.51%), α-terpinene (17.26%), and limonene (13.64%)	
P. uechtritzii	Turkey	Aerial parts	0.10-24.60	30, 97.40	p-Cymene (24.6%), caryophyllene oxide (19.6%), 7-epi-1,2-dehydrosesquicineole (12.6%), limonene (3.2%), α-bisabolol (3.2%)	[66]
		Fruits	2.10	18, 97.42	α-Pinene (40.82%), nonene (17.03%), β-phellandrene (11.14%), δ-3-carene (7.39%), and p-cymene (4.90%)	[72]
			0.76	32-109, 86.70-90.00	α-Pinene (11.23%), α-phellandrene (8.42%), β-phellandrene (8.26%), α-bisabolol (7.04%)	[75]
			0.70	38, 84.50	p-Cymene (10.9%), γ-terpinene (7.0%), β-phellandrene (7.8%), α-phellandrene (6.3%), and (Z)-β-ocimene (4.6%)	[76]
P. latiloba	Iran	Flowers	NM	28, 86.80	Limonene (18.3%), myrcene (10.4%), (E)-β-ocimene (7.8%), α-phellandrene (6.4%), and α-pinene (5.7%)	[77]
		Leaves	NM	23, 84.60	Limonene (17.4%), myrcene (9.4%), α-pinene (6.1%), α-phellandrene (5.4%), and (E)-β-ocimene (5.3%)	
		Stems	NM	29, 83.70	Limonene (13.5%), myrcene (8.6%), α-phellandrene (4.9%), germacrene D (4.5%), and γ-curcumene (4.3%)	
		Aerial parts	0.66	27, 87.00	α-Pinene (25.1%), limonene (16.1%), and myrcene (9.5%), elemol (5.7%)	[78]
P. denticulata	Turkey	Fruits	trace	121, 95.20	Sabinene (26.1%) and p-cymene (19.7%)	[79]
		Roots	3.20	70, 88.10	δ-3-Carene (49.3%) and (Z)-3,5-nonadiyne-7-ene (20.4%)	
P. turcica	Turkey	Fruits	0.37	72, 87.20	α-Humulene (11.0%), germacrene D (10.6%), naphthalene (8.5%), terpinolene (7.9%), and bornyl acetate (6.9%)	[80]
P. meliocarpoides	Turkey	Aerial parts	0.10-16.70	40, 99.50	Sabinene (16.7%), p-cymene (13.2%), bornyl acetate (11.8%), α-pinene (6.2%), and p-cymen-8-ol (6.1%)	[66]
P. trifida	Italy	Aerial parts	0.52	25, 91.30	cis-β-Ocimene (18.12%), α-phellandrene (12.14%), sylvestrene (11.32%), p-mentha-1,3,8-triene (9.56%), and α-pinene (8.85%)	[82]
P. odontalgica	Russia	Aerial parts	0.07	38, 88.40	γ-Elemene (9.84%), bisabolol(9.41%), trans-nerolidol (3.90%), and linalyl isobutyrate (3.41%)	[83]
P. gaubae	Iran	Aerial parts	0.40	41, 92.80	Germacrene D (26.7%), caryophyllene oxide (14.3%), (E)-caryophyllene (13.8%), and spathulenol (11.3%)	[84]
P. uechritzii	Turkey	Aerial parts	NM	NM	β-Pinene (28.79%), methyle linolenate (7.27%), α-terpineol (7.20%), spathulenol (5.60%), and humulene-1,2-epoxyde (4.20%)	[85]
P. peucedanifolia	Turkey	Aerial parts	NM	37, 89.50	α-Pinene (38.1%), bicyclogermacrene (11.3%), and δ-3-carene (9.2%)	[64]
P. coryombosa	Iran	Aerial parts	0.40	21, 97.40	β-Elemene (40.7%), kessane (10.7%), and caryophyllene oxide (10.5%)	[59]
P. scabra	Iran	Fruits	1.60	20, 92.30	β-Elemene (19.9%), β-farnesene (16.2%), epi-globulol (1.5%), γ-cadinene (10.0%), and β-caryophyllene (9.2%)	[61]
		Inflo-rescens	0.30	14, 80.10	epi-Globulol (21.1%), β-elemene (19.7%), caryophyllene oxide (9.0%), and α-cadinol (6.2%)	
P. serpentinica	Iran	Aerial parts	0.64	43, 92.20	β−Carryophyllene (26.4%), δ-3-carene (6.1%), linalool (5.7%), α-phellandrene (5.3%), p-cymene (5.2%), and camphene (5.1%)	[86]
P. cheilanthifolia	Iran	Aerial parts	1.10	17, 98.00	β-Myrcene (16.8%), camphor (16.6%), and trans-caryophyllene (16.1%)	[87]

platychlaena (69.75%) [72], and *P. ferulacea* (63.1%) [50], whereas β-pinene gave the highest percentage from the aerial parts oil of *P. ferulacea* (43.1%) [38]. Other monoterpenes identified in principal amounts were sabinene [53, 54, 66, 79], terpinolene [39], β-phellandrene [41], linalool [47], 1,8-cineole [47], γ-terpinene [52], bornyl acetate [71], p-cymene [66], limonene [77], and β-myrcene [87].

In another study, sesquiterpenes (hydrocarbons and oxygenated) were also described as the major group components. Among them, (*E*)-caryophyllene was reported from the aerial parts' oil of *P. ferulacea* [37] and *P. uloptera* [60]. In addition, spathulenol [65], germacrene D [67], α-humulene [80], γ-elemene [83], β-elemene [59], and *epi*-globulol [61] were also found as the highest percentage in several *Prangos* essential oils. Safrole was the only phenylpropanoid identified in aerial parts' oil of *P. uloptera* [59].

5. BIOLOGICAL ACTIVITIES

The genus *Prangos* is well-known for its diverse biological activities. The essential oils are reported to have antimicrobial [34, 36, 41, 47, 48, 50, 53, 71, 72, 82, 88], antioxidant [34, 45, 66, 82, 84, 89], allelopathic [40, 65], insecticidal [51], larvicidal [67, 90], antiproliferative [54, 81, 89], anticholinesterase [66, 84, 89], antityrosinase [66, 84], antidiabetic [62, 66, 84], repellent [91], antiobesity [84], wound healing [48], and fumigant toxicity [92] properties. All reported biological activities from *Prangos* essential oils are summarised in Table III.

Out of twelve tested profiles, *Prangos* species showed the highest antimicrobial, antioxidant and insecticidal capabilities. Some *Prangos* species were investigated for their antimicrobial and antioxidant activities. Preparations of essential oils of *Prangos* species have been widely researched for their activities against gram-positive and gram-negative bacteria, as well as some species of yeast-like fungi, and compared to the activity of standard drugs. Different antimicrobial activity assays with different antibiotic and antifungal controls were used, including disc diffusion and microdilution. According to this established profile, the *P. trifida* [82] and *P. platychlaena* [72] oils demonstrated good inhibitory potential against gram-positive (*B. subtilis*, *S. aureus*); *P. ferulacea* [88] and *P. uechtritzii* [72] oils against gram-negative bacteria (*E. coli*, *P. aeruginosa*), as well as *P. uloptera* [36] oil against fungi (*C. krusei*). The antimicrobial activity observed has been attributed to the presence of different bioactive components with an impact on the growth and metabolism of microorganisms.

In antioxidant activity, various assays have been performed on the *Prangos* essential oils such as DPPH, CUPRAC, ABTS, FRAP, MCA, PBD, and metal chelating. The flowers and leaves' oils of *P. ferulacea* [45] showed a strong activity in DPPH with IC_{50} values 23.9 and 22.9 µl/mL, respectively. Besides, *P. heyniae* oil showed a significant activity in ABTS (92.9 mg TE/g) and FRAP (61.2 mg TE/g) assays [66]. Meanwhile, *P. meliocarpoides* oil have a potential activity in CUPRAC (113.4 mg TE/g) and PBD (24.3 mmol TE/g) assays [66].

Interestingly, it was also verified that the *Prangos* essential oils have significant mosquitocidal and insecticidal properties. The *P. ferulacea* oils exhibited a strong protection against two mosquito species Culex *quinquefasciatus* and *Anopheles stephensi* [90], as well as egg stages of *Ephestia kuehniella* and *Trichogramma embryophagum* [51]. While *P. heyniae* showed positive inhibitory properties against the first instar *Aedes aegypti* lice cycle [67]. Not limited to mosquito, *Prangos* species are also able to serve as a beetle repellent. For example, the *P. acaulis* has demonstrated resistance to three beetle species including the red flour beetle (*Tribolium castaneum*), rice weevil (*Sitophilus oryzae*) and cowpea seed beetle (*Callosobruchus maculatus*) [91]. The profiles of these plant-derived insect repellents could be utilised for developing eco-friendly and safer alternatives to current synthetic repellents.

6. CONCLUSION AND FUTURE PERSPECTIVES

In this review, we summarise the information on the chemical composition and biological activities of the genus *Prangos* as well as its medicinal uses. The principal chemical components of *Prangos* essential oils were α-pinene, β-pinene, (Z)-β-ocimene, δ-3-carene, and sabinene. These predominant chemical components of *Prangos* essential oils can serve as a novel potential natural source, which can be used in the pharmaceutical and food industries. Previous studies revealed that *Prangos* essential oils can protect people from several diseases due to their potent biological activities including antimicrobial, antioxidant, allelopathic, insecticidal, larvicidal, antiproliferative, anticholinesterases, antityrosinase, antidiabetic, repellent, antiobesity, wound healing, and fumigant toxicity effects. Hence, future studies need to conduct systematic revisions using cell and animal models, as well as clinical and experimental investigations of *Prangos* essential oils. Besides, future research should look at the toxicity, bioavailability, and pharmacokinetics of *Prangos* essential oils to find the chemical components responsible for their activities and expand the existing medical application of the genus *Prangos.*

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Table III - Biological activities from *Prangos* essential oils.

Bioactivities	Species	Description	References
Antimicrobial	*P. ferulacea*	The flower oil showed activity against *S. tiphymurium*, *B. cereus*, and *B. subtilis* while the leaves oil against *B. cereus*, and *B. subtilis*, with same MIC value 100 µg/mL	[34]
		The essential oil gave activity against *E. faecalis* with MIC value 2.27 µg/mL	[88]
		The roots oil inhibited the growth of *S. aureus* and *P. aeruginusa* each with MIC value of 20 µg/mL	[48]
		The essential oil shows activity against *E. coli* and *S. saprophytacus* with MIC values 3.27 and 8.19 µg/mL, respectively	[41]
		The leaves and flower oils showed activity against *S. aureus* with MIC value 0.5 µg/mL	[47]
		The essential oil exhibited modest activities against *E. coli*, *S. epidermidis*, *P. aeruginosa* and *C. kefyr* with inhibition zones of 9-12 mm	[50]
	P. platychlaena	The leaves, stems and flowers oil gave MIC value 1.16 (*P. aeruginosa*), 3.08 (*S. aureus*), and 0.86 (*S. aureus*) mg/mL, respectively	[71]
		The essential oil showed activity against *B. subtilis* with MIC value 36 mg/mL	[72]
	P. asperula	The essential oil showed activity against *Trichophyton rubrum* and *T. tonsurans* with MIC value 64 µg/mL	[53]
	P. uechtritzii	The essential oil showed activity against *E. coli* with MIC value 9 mg/mL	[72]
	P. trifida	The essential oil showed activity against *B. subtilis* with MIC value 0.12 mg/mL	[82]
	P. uloptera	The essential oil was able to inhibit *C. krusei* with MIC value 0.039 µL/mL	[36]
Antioxidant	*P. ferulacea*	The essential oil gave IC_{50} values 100 (flower oil) and 500 µg/mL (leaves oil) in ABTS assay	[34]
		The essential oil gave IC_{50} values 726.5 µg/mL (DPPH), 89.5 µg/mL (ABTS), and 52.5 µg/mL (FRAP)	[89]
		The flowers and leaves oil gave IC_{50} values 23.9 and 22.9 µl/mL, respectively in DPPH	[45]
	P. heyniae	The essential oil gave 0.43 mg TE/g (DPPH), 92.9 mg TE/g (ABTS), 103.1 mg TE/g (CUPRAC), 61.2 mg TE/g (FRAP), 30.0 mg TE/g (MCA), and 20.3 mmol TE/g (PBD)	[66]
	P. meliocarpoides	The essential oil gave 1.0 mg TE/g (DPPH), 24.1 mg TE/g (ABTS), 113.4 mg TE/g (CUPRAC), 47.9 mg TE/g (FRAP), 28.6 mg TE/g (MCA), and 24.3 mmol TE/g (PBD)	
	P. uechtritzii	The essential oil gave 1.7 mg TE/g (DPPH), 58.1 mg TE/g (ABTS), 109.1 mg TE/g (CUPRAC), 56.4 mg TE/g (FRAP), 30.9 mg TE/g (MCA), and 15.6 mmol TE/g (PBD)	
	P. trifida	The essential oil gave IC_{50} values 0.8 mg/mL (ABTS) and 0.11 mg/mL (H_2O_2)	[82]
	P. gaubae	The essential oil gave 2.02 mmol TEs/g (ABTS), 0.47 mmol TEs/g (CUPRAC), 0.37 mmol TEs/g (FRAP), and 37.8 mg EDTAEs/g (Metal chelating)	[84]
Allelopathic	*P. pabularia*	The essential oil exhibited high activity with IC_{50} values 0.11, 0.14 and 0.12 mg/mL for inhibition of the seed germination, shoot and root elongation, respectively	[65]
	P. ferulacea	The essential oil stunted the root growth of lettuce with an IC_{50} value 244.19 mg/mL	[40]
Insecticidal	*P. ferulacea*	The LC_{50} and LC_{99} values of the essential oil against the egg stages of *E. kuehniella* and *T. embryophagum* were 320.3-486.8 µL/L air and 2.1-5.6 µL/L air, respectively	[51]
Larvicidal	*P. ferulacea*	The LC_{50} of essential oil against *Cx. quinquefasciatus* and *An. stephensi* were respectively 1.95 and 24.20 ppm for the fruits, 2.75 and 19.60 ppm for leaves, and 2.60 and 21.07 ppm for stems	[90]
	P. heyniae	The essential oil showed good activity at 125 and 62.5 ppm against 1st instar *A. aegypti*	[67]
Antiproliferative	*P. pabularia*	The essential oil by MTT assay against human lung adenocarcinoma epithelial (A549) cells revealed that the activity of 56.12%	[81]
	P. ferulacea	The essential oil exhibited a moderate activity on MDAMB 231 cell line (IC_{50} value 22.41 mg/mL), HCT116 (IC_{50} value 30.35 mg/mL) and A375 (IC_{50} value 25.08 mg/mL)	[89]
	P. asperula	The essential oil exerted activity with IC_{50} value 139.17 µg/mL on the renal adenocarcinoma cell line	[54]
Anticholinesterases	*P. heyniae*	The essential oil gave 9.85 mg GALAE/g aginst BChE	[66]
	P. ferulacea	The essential oil gave IC_{50} value 86.1 µg/mL against AChE	[89]
	P. gaubae	The essential oil gave 2.97 mg GEs/g (AChE) and 3.30 mg GEs/g (BChE)	[84]
Tyrosinase	*P. heyniae*	The essential oil gave 53.9 mg KAE/g	[66]
	P. meliocarpoides	The essential oil gave 69.5 mg KAE/g	
	P. uechtritzii	The essential oil gave mg 46.3 KAE/g	

Continue Table III

Bioactivities	Species	Description	References
	P. gaubae	The essential oil gave 29.2 mg KAEs/g	[84]
Antidiabetic	*P. gaubae*	The essential oil gave 1.35 mmol AEs/g (α-amylase) and 38.8 mmol AEs/g (α-glucosidase)	[84]
	P. heyniae	The essential oil gave 0.09 mmol ACAE/g (α-amylase)	[66]
	P. meliocarpoides	The essential oil gave 0.41 mmol ACAE/g (α-amylase)	
	P. uechtritzii	The essential oil gave 0.61 mmol ACAE/g (α-amylase)	
	P. pabularia	The essential oil showed PTP-1B enzymatic inhibition with IC_{50} value 0.06 µg/mL	[62]
Repellent	*P. acaulis*	The repellency at 2.0 µl/mL was 63.6, 83.6 and 71.6% against *T. castaneum*, *S. oryzae* and *C. maculatus*, respectively	[91]
Antiobesity	*P. gaubae*	The essential oil gave 1.59 mmol OEs/g (Lipase)	[84]
Wound healing	*P. ferulacea*	The essential oil significantly enhanced the migration rate of L929 cells by 87.05% at conc. 4.0 µg/mL	[48]
Toxicity	*P. ferulacea*	The essential oil showed the fumigant toxicity against *Sitophilus oryzae* (34.4% mortality, 72 h)	[92]

TE: Trolox equivalent; MCA: Metal chelating ability; PBD: Phosphomolybdenum assay; KAE: Kojic acid equivalent; ACAE: Acarbose equivalent; GALAE: Galantamine equivalent; GEs: galanthamine equivalents; AEs: acarbose equivalents; KAEs: kojic acid equivalents; OEs: orlistat equivalents; AChE: acetylcholinesterase; BChE: butyrylcholinesterase

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