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VOLATILE COMPOUNDS IN DISTILLATES AND HEXANE EXTRACTS FROM THE FLOWERS OF P*HILADELPHUS CORONARIUS* AND *JASMINUM OFFICINALE*

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Jasminum L. of the Oleaceae family is a genus of plants cultivated for its aromatic flowers, which are a source of essential oil (EO). In temperate countries, jasmine, or pseudo jasmine, is often called Philadelphus coronarius L. of the Hydrangeácеae or Philadelphaceae family due to its similar fragrance.
The aim. *The aim of the study was to compare the component composition of volatile compounds of hydrodistillates and hexane extracts from flowers of Philadelphus coronarius L. and Jasminum officinale L..*
Materials and Methods. Hydrodistillates obtained from dried flowers of J. officinale and from dried and fresh flowers of P. coronarius, as well as hexane extracts from similar raw materials, were analyzed by GC-MS.
Research results. *109 compounds were identified. It was found that in the EO of J. officinale, obtained by hydrodistillation, the terpenoid content is 90.31 %, while in the hexane extract of the same raw material, the terpenoid content is only 36.24 %. In the EO of P. coronarius, obtained by hydrodistillation of dry flowers, the terpenoid content is 50.04 %, and from fresh flowers – 45.13 %. In the hexane extract of dry flowers of P. coronarius, the terpenoid content is only 14.63 %, while in the extract of fresh flowers – 52.55 %. In the EO of J. officinale obtained by hydrodistillation, the dominant components are (E)-geranyl linalool (12.86 %), linalool (10.72 %), (Z)-3-hexen-1-ol benzoate (7.82 %), α-farnesene (7.72 %), D-limonene (6.43 %), methyl anthranilate (5.9 %), (Z)-9-tricosene (4.15 %). In the EO obtained by hydrodistillation from dried flowers of P. coronarius, the dominant components are (1R)-(-)-myrtenal (12.73 %), myrtanal (11.09 %), pentadecanal (9.42 %), tricosane (8.33 %), (Z)-jasmone (7.09 %). In the EO, it is obtained by hydrodistillation from fresh P. coronarius flowers, the dominant components are: nerolidol (19.42 %), ethyl palmitate (19.13 %), methyl 2-methylpalmitate (16.44 %), myrtanal (9.91 %), pentadecanal (5.28 %), (Z)-jasmone (2.72 %).*
Conclusions. *The conducted studies identified the main differences in volatile compounds in distillates and hexane extracts of P. coronarius and J. officinale. A total of 109 compounds were identified in the objects, and the dominant components were established. During the drying process of P. coronarius flowers, the composition of the EO significantly changes. Only hexane extracts from dried flowers of J. officinale and P. coronarius contain triterpene squalene in significant amounts (13.96 % and 6.72 %). Common to the hexane extracts of the studied objects are aromatic compounds: benzyl alcohol, 2,4-di-tert-butylphenol; aliphatic compounds: 2,4-dimethyl-heptane, octanal, decanal*
Keywords: *Philadelphus coronarius, Jasminum officinale, essential oil, component composition*

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1. Introduction

The shrub of sweet mock-orange (*Philadelphus coronarius* L., *Hydrangeaceae* or *Philadelphaceae*) is a popular ornamental plant, which is grown quite worldwidely in parks, green areas and home gardens since 16th Century [1]. Due to the pleasant smell resembling common jasmine (*Jasmine officinal*e L., *Oleaceae*), this plant is popularly called common pseudo-jasmine (*harilik ebajasmiin*). In Ukraine, plants of the genus *Philadelphus* are called Garden Jasmine [2]. Despite the great diversity of *Philadelphus* L., only 5-6 species of the genus are cultivated (*P. coronarius* L., *P. microphyllus*, *P. Shrenkii* Rupr. et Max, *h. caucasicus* Koehne et al.), characterized by ecological plasticity, sufficiently high adaptability and certain decorative features.

P. coronarius is native to the North Caucasus, Transcaucasus, Turkey. It has been introduced to North America, Asia, and Europe [3]. *J. officinal*e is native to the Afghanistan, Bangladesh, China South-Central, East and West Himalaya, Iran, Nepal, Pakistan, Tadzhikistan, Tibet, Transcaucasus, Turkey. It has been naturalized to Central America and Europe [4].

The chemical composition of sweet *P. coronarius* has not been well studied. The relevant scientific literature is very limited; only a few articles about its chemical elements and pharmacological characteristics are available. Previous studies have reported on individual compounds found in the leaves of the sweet mock-orange, such as uvaol, 3-β-,28-dihydroxyoleanane-11(12),13(18)-diene, coumarins such as umbelliferone, scopolin; stigmasteryl-3-β-D-glucoside [5]; chlorogenic and caffeic acids, 7-methoxycoumarin (herniarin), delphinidin-3-rutinoside chloride, luteolin-7-glucoside, hyperoside, rutin, T-resveratrol [6]. The identified components of the *P. coronarius* flowers are gallic, *trans-p*-coumaric, chlorogenic, caffeic, ferulic, and rosmarinic acids, coumarins such as 7-methoxycoumarin (herniarin), bergapten and isopimpinellin; flavonoids such as delphinidin-3-rutinoside chloride, luteolin-7-glucoside, quercetin, diosmin, hyperoside, myricetin and rutin; T-resveratrol [6].

The volatile constituents of dried and fresh leaves, twigs and flowers of *P. coronarius* were isolated by hydrodistillation. Major components were epi-13-manool, isolongifolol, 2-nonanol and 7-hydroxycoumarin in flowers EO; (*E,E*)-farnesol in the leaves and twig; (E,E)-2,4-decadienal in the twig [7].

Literature data indicate the antiradical/scavenger, antimicrobial and anti-inflammatory activities of substances from the *P. coronarius* [8–10].

Jasminum L. of the *Oleaceae* family is a major genus of plants commonly cultivated for their aromatic flowers and uses in medicine, aromatherapy, and perfumery. There are 197 taxonomically recognized species (spp.) of the genus *Jasminum* in the world [11, 12]. It is also known as Common Jasmine, Poet's Jasmine, and True Jasmine [13].

Among the species of the genus *Jasmine*, the most studied are *J. grandiflorum, J. sambac*, and *J. nudiflorum,* which are the varieties grown commercially for producing essential oil (EO) [14–16].

J. officinale has more than 20 synonyms, forms hybrids and forms with other species of the genus, for example, *J. officinale* f. *grandiflorum* (L.) Kobuski*, Jasminum officinale* var. *grandiflorum* (L.) Stokes*, Jasminum officinale* subsp. *grandiflorum (L.)* E. Laguna.

The chemical composition of *J. officinalis* is less well studied. It is known that *J. officinale* contains secoiridoid glycosides, such as jasmolactone B, jasnervoside A, molihauside A [17, 18], jaspolyoside, jaspolyanoside [19], jaspogeranoside B and jasnervoside D [20, 21]; sesquiterpenoids [22]. Leaves of *J. officinale* containing alkaloids, carbohydrates, phenyl ethanoids such as salidroside hexoside, hydroxytyrosol hexoside, salidroside, hydroxytyrosol and tyrosol; phenolic acids such as protocatechuic, chlorogenic, *p*-hydroxybenzoic, *p*-coumaroyl hexoside, caffeoyl quinic, caftaric acid hexoside, dihydrosinapic acid hexoside, syringic acid hexoside, syringic, *p*-coumaric and rosmarinic; coumarins; flavonoids such as derivatives of quercetin, kaempferol, and isorhamnetin; saponins, tannins and terpenoids [23–25].

Published data on the component composition of the EO refer to the species *J. officinale var. grandiflorum*, which modern taxonomists consider a synonym of *J. grandiflorum* and *J. sambac* [11, 14].

Thirty compounds were identified in the EO of *J. officinale* var. *grandifloroum*. The major volatile components were phytol (25.77 %), 3,7,11-trimethyldodeca-1,6,10-trien-3-ol (12.54 %) and 3,7,11-trimethyldodeca-6,10-dien-3-ol (dehydronerolidol) (12.42 %). Other compounds identified in the *J. officinale* L. var. *grandifloroum* EO were: benzylacetate; nerolidol; methyl myristate;7-tetradecene; benzyl benzoate; neophytadiene; perhydrofarnesyl acetone; phytol acetate; nonadecane; geranyllinalool; methyl palmitate; 3,7,11,15-tetramethyl-1-hexadecen-3-ol; hexadecanoic acid; 3,7,11,15-tetramethylhexadecanoic acidmethyl ester; 9,12,15-octadecatrienoic acidmethyl ester; heneicosane; octadecanoic acid methyl ester; 9,12,15-octadecatrienoic acid; docosane; tricosane; tetracosane; pentacosane; hexacosane; heptacosane; octacosane; squalene and nonacosane [26].

Literature reports suggest that the *J. officinale* can be used in mental depression, impotence, nervous tension, menstrual disorders [27] and used as analgesic, antispasmodic, galactogogue, etc. [28–30]. Literature data indicate the antimicrobial [31, 32], antiradical/scavenger [23, 33], and anti-inflammatory [22] activities of substances from the *J. officinale* [34].

It is known that the composition of EO depends on the conditions of plant growth, harvesting time, drying conditions of raw materials, methods of obtaining EO, and other factors [35–37].

Both *J. officinale* and *P. coronarius* have a very pleasant fragrance. In Ukraine and most European countries, *P. coronarius* is widely cultivated, whereas *J. officinale* is predominantly imported from East Asian regions. As a result, ordinary consumers often confuse them and may use the flowers of *P. coronarius* to prepare teas. Considering this, it is reasonable to compare the chemical composition of the EOs of these two species and determine how the drying process and extraction of these substances from raw materials affect the composition of biologically active compounds in the volatile fraction of the final product.

The aim of this work was a comparative study of volatile compounds of hydrodistillate and hexane extract of dried and fresh flowers of *P. coronarius* and dried flowers of *J. officinale*.

2. Planning (methodology) of research

The study protocol describing the different stages of the present research work is presented in the following flow chart (Fig. 1).

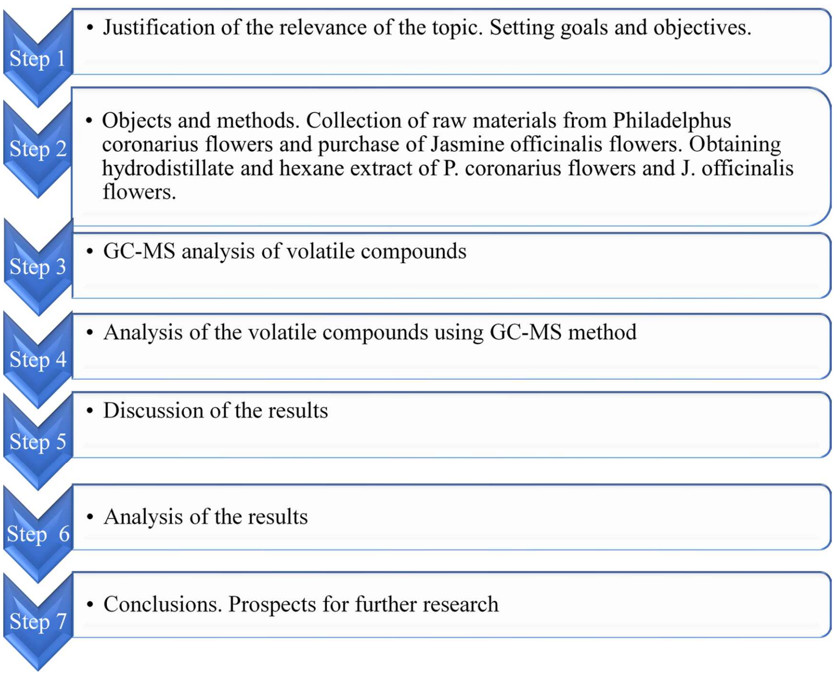

Fig. 1. Research design

3. Materials and methods

Plant material.

The fresh flowers (about a 100 g) of *P. coronarius*, (Fig. 2) were collected in June 2024 from the private garden in Tartu, Estonia (58.36827°N 26.73669°E). The plant has been identified by Prof. A. Raal using a special tree and shrub specifier [38]. The collected fresh flowers were divided into two equal parts. One part was dried at room temperature for 7 days and stored in a paper bag until analysis. The second part was stored fresh in a freezer at –18 °C.

The dried *J. officinale* flowers were purchased from Kubja farm (Kubja Ürditalu), a company engaged in cultivating and packaging medicinal plants [39]. Packaged commercial jasmine flowers (*Jasminium flos*, Fig. 3) were imported from Pakistan in 2024.

Fig. 2. *P. coronarius*

Fig. 3. Herbal tea of *J. officinale*

GC-MS analysis of volatile compounds.

The volatile compounds (VC) samples were hydrodistilled from the dried or fresh flowers *P. coronarius* using the EO distillation method described in the European Pharmacopoeia [40]. The distilled VC samples were analyzed by gas chromatography with mass detections (GC/MS), using an Agilent 6890/5973 GCMS system controlled by mass spectrometry detectors (MSD) Chemstation. 1 µL of the sample was injected at an injector temperature of 280 °C in split mode (20:1), using He as the carrier gas onto Agilent HP-5MSI column (30 m length, 0.25 mm inner diameter, 0.25 µm film thickness). The carrier gas was held at the constant flow rate of 1 mL/min. The oven was held at 50 °C for 2 min, followed by a ramp of 4 °C/min to a final temperature of 280 °C and held at 280 °C for 5 minutes. The analysis of the essential oil was performed using the European Pharmacopoeia method, which requires only one sample to be analyzed. Therefore, one GC analysis was also performed on all distillates. The error of the GC apparatus itself is less than 1 %. Therefore, it makes no sense to chromatograph the same essential oil 3-4 times and find the standard deviation between the results.

The MSD was operated in EI mode at 70 eV. Mass spectra were recorded in the range of 29–400 m/z with a delay time of 4 min and a scan speed of 3.8 scans per second. The data were analyzed by the deconvolution algorithm of Agilent Masshunter Software package using different window size factors. Obtained compounds were identified by using NIST23 library with Match Factor ≥90 and by retention indexes (relative to *n*-alkanes C7–C30) [41]. The area percentages of each peak were calculated from the total areas in the chromatograms without using correction factors. Thus, the normalization method was used, which shows the percentage of a substance in the fraction based on the percentage of the peak area relative to the total peak areas.

Hexane extracts.

Hexane extracts of the studied flowers were prepared using the maceration method within 24 hours with a proportion of plant material and solvent of 1:40 (dried flowers) or 1:10 (fresh flowers). After maceration, the extracts were filtered through a paper filter and concentrated in 50 times at 22±2 °C for GC-analyses.

4. Results

A total of 109 compounds were identified in the studied objects (Table 1).

In the EO of *J. officinale*, obtained by hydrodistillation, 46 compounds were identified. The dominant components are: (*E*)-geranyl linalool (12.86 %), linalool (10.72 %), (*Z*)-3-hexen-1-ol benzoate (7.82 %), α-farnesene (7.72 %), D-limonene (6.43 %), methyl anthranilate (5.9 %), (*Z*)-9-tricosene (4.15 %).

In the hexane extract of *J. officinale* flowers, 29 compounds were identified. The dominant components are: (*Z*)-9-tricosene (23.31 %), pentacosane (20.83 %), squalene (13.96 %), (*E*)-geranyl linalool (11.44 %), 3-methyl-nonacosane (9.96 %).

In the EO obtained by hydrodistillation from dried flowers of *P. coronarius*, 43 compounds were identified. The dominant components are: (1*R*)-(-)-myrtenal (12.73 %), myrtanal (11.09 %), pentadecanal (9.42 %), tricosane (8.33 %), (*Z*)-jasmone (7.09 %).

In the EO obtained by hydrodistillation from fresh flowers of *P. coronarius*, 37 compounds were identified. The dominant components are nerolidol (19.42 %), ethyl palmitate (19.13 %), methyl 2-methylpalmitate (16.44 %), myrtanal (9.91 %), pentadecanal (5.28 %), (*Z*)-jasmone (2.72 %).

In the hexane extract obtained from the dried flowers of *P. coronarius*, 20 compounds were identified. The dominant components are: pentadecanal (18.06 %), decanal (13.92 %), octanal (13.52 %), octacosanal (12.15 %), squalene (6.72 %), 2-pentacosanone (6.47 %).

In the hexane extract obtained from fresh flowers of *P. coronarius*, 30 compounds were identified. The dominant components are: nerolidol (23.52 %), ethyl palmitate (23.17 %), myrtanal (12.01 % + 4.92 %), pentadecanal (6.39 %).

Table 1

Component composition of hydrodistillate and hexane extract of *J. officinale* and *P. coronarius* flowers

Compound	Retention index		Formula	Content of volatiles in the distillates, %			Content of volatiles in hexane extracts, %		
	Experimental	NIST23 Library		*J. officinale* dry flowers	*P. coronarius* dry flowers	*P. coronarius* fresh flowers	*J. officinale* dry flowers	*P. coronarius* dry flowers	*P. coronarius* fresh flowers
1	2	3	4	5	6	7	8	9	10
Hexanal	799	801	$C_6H_{12}O$	0.52	0.5	0.08	nd	1.12	0.09
Heptane, 2,4-dimethyl-	818	821	C_9H_{20}	nd	nd	nd	0.06	0.45	nd
Furfural	828	833	$C_5H_4O_2$	0.03	nd	nd	nd	nd	nd
(*E*)-2-Hexenal	848	854	$C_6H_{10}O$	0.14	0.5	nd	nd	nd	nd
p-Xylene	866	865	C_8H_{10}	nd	nd	0.41	nd	nd	0.49
m-Xylene	868	866	C_8H_{10}	nd	nd	nd	nd	1.08	nd
2-Heptanone	891	891	$C_7H_{14}O$	nd	nd	nd	nd	0.42	nd
Heptanal	901	901	$C_7H_{14}O$	nd	0.36	0.13	nd	0.33	0.16
α-Phellandrene	932	927	$C_{10}H_{16}$	nd	nd	nd	0.03	nd	nd
Benzaldehyde	958	962	C_7H_6O	0.5	0.15	0.07	nd	nd	nd
Prenylacetone	986	986	$C_8H_{14}O$	0.2	nd	nd	nd	nd	nd
2-Pentylfuran	991	993	$C_9H_{14}O$	nd	0.38	nd	nd	nd	nd
Octanal	1003	1003	$C_8H_{16}O$	nd	nd	nd	0.2	13.52	nd
D-Limonene	1028	1029	$C_{10}H_{16}$	6.43	nd	nd	0.55	nd	nd
Benzyl alcohol	1032	1036	C_7H_8O	nd	nd	nd	0.79	2.97	nd
Benzeneacetaldehyde	1042	1045	C_8H_8O	0.35	0.24	nd	nd	nd	nd
Formic acid phenylmethyl ester	1076	1079	$C_8H_8O_2$	0.07	nd	nd	nd	nd	nd
Linalool	1100	1099	$C_{10}H_{18}O$	10.72	1.56	0.42	nd	nd	0.51
Nonanal	1103	1104	$C_{10}H_{18}O$	0.38	0.43	0.14	nd	1.08	0.17
Norinone	1135	1135	$C_9H_{14}O$	nd	4.93	1.17	nd	nd	1.42
(+)-Camphor	1143	1144	$C_{10}H_{16}O$	0.73	nd	nd	nd	nd	nd
(*E,Z*)-2,6-Nonadienal	1152	1155	$C_9H_{14}O$	nd	0.72	nd	nd	nd	nd
p-Menthone	1152	1154	$C_{10}H_{18}O$	nd	nd	nd	0.26	nd	nd
2-Nonenal, (*E*)-	1158	1162	$C_9H_{16}O$	nd	0.95	nd	nd	nd	nd
Ethyl benzoate	1170	1171	$C_9H_{10}O_2$	nd	0.37	0.13	nd	nd	0.16
DL-Menthol	1171	1173	$C_{10}H_{20}O$	2.2	nd	nd	0.57	nd	nd
Terpinen-4-ol	1176	1182	$C_{10}H_{18}O$	0.26	nd	nd	nd	nd	nd
Myrtanal	1182	1188	$C_{10}H_{16}O$	nd	11.09	9.91	nd	nd	16.93
α-Terpineol	1189	1189	$C_{10}H_{18}O$	1.51	nd	nd	nd	nd	nd
(1R)-(-)-Myrtenal	1195	1196	$C_{10}H_{14}O$	nd	12.73	0.77	nd	nd	0.93
Methyl chavicol	1197	1196	$C_{10}H_{12}O$	1.72	nd	nd	nd	nd	nd
Decanal	1204	1206	$C_{10}H_{20}O$	nd	0.36	0.09	0.21	13.92	0.11
2-Aminobenzaldehyde	1213	1219	C_7H_7NO	nd	1.6	1.03	nd	nd	nd
Nerol	1227	1228	$C_{10}H_{18}O$	0.5	nd	nd	nd	nd	nd
(-)-Carvone	1243	1244	$C_{10}H_{14}O$	3.02	nd	nd	0.5	nd	nd
Geraniol	1253	1255	$C_{10}H_{18}O$	1.64	nd	nd	nd	nd	nd
(Z)-(-)-Myrtanol	1258	1261	$C_{10}H_{18}O$	nd	3.44	1.42	2.39	nd	nd
Phellandral	1274	1276	$C_{10}H_{16}O$	nd	nd	0.69	nd	nd	0.84
2-Hydroxy-iso-butyrophenone	1280	1279	$C_{10}H_{12}O_2$	nd	nd	nd	0.32	nd	nd
Anethole	1285	1287	$C_{10}H_{12}O$	3.43	nd	nd	nd	nd	nd
Indole	1291	1294	C_8H_7N	nd	0.94	1.97	nd	nd	2.39
Methyl anthranilate	1341	1343	$C_8H_9NO_2$	5.9	nd	nd	0.5	nd	nd
α-Terpinyl acetate	1349	1350	$C_{12}H_{20}O_2$	0.52	nd	nd	nd	nd	nd
Eugenol	1357	1357	$C_{10}H_{12}O_2$	0.21	0.34	0.28	nd	nd	0.34
8-Hydroxylinalool	1361	1361	$C_{10}H_{18}O_2$	nd	nd	nd	0.59	nd	nd
Copaene	1377	1376	$C_{15}H_{24}$	0.84	nd	nd	nd	nd	nd
Elemene-isomer	1393	1395	$C_{15}H_{24}$	0.67	nd	nd	nd	nd	nd

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10
(*Z*)-Jasmone	1399	1394	$C_{11}H_{16}O$	nd	7.09	2.72	nd	nd	3.29
Methyleugenol	1404	1402	$C_{11}H_{14}O_2$	0.57	nd	nd	nd	nd	nd
Dodecanal	1408	1409	$C_{12}H_{24}O$	nd	nd	nd	nd	1.48	nd
Benzoic acid 2-amino-ethyl ester	1414	1414	$C_9H_{11}NO_2$	0.07	3.32	1.11	nd	nd	1.35
Caryophyllene	1421	1419	$C_{15}H_{24}$	3.06	nd	nd	0.49	nd	nd
Cinnamic acid, ethyl ester	1466	1464	$C_{11}H_{12}O_2$	nd	0.58	0.2	nd	nd	0.25
1-Dodecanol	1474	1474	$C_{12}H_{26}O$	nd	0.67	nd	nd	nd	nd
γ-Muurolene	1479	1477	$C_{15}H_{24}$	0.63	nd	nd	nd	nd	nd
α-Curcumene	1484	1483	$C_{15}H_{22}$	1.24	nd	nd	nd	nd	nd
α-Muurolene	1503	1499	$C_{15}H_{24}$	0.73	nd	nd	nd	nd	nd
α-Farnesene	1511	1508	$C_{15}H_{24}$	7.72	nd	nd	nd	nd	nd
2,4-Di-tert-butylphenol	1513	1514	$C_{14}H_{22}O$	nd	nd	nd	0.84	3.86	nd
Cadinene	1517	1513	$C_{15}H_{24}$	2.06	nd	nd	nd	nd	nd
Amorphene	1527	1524	$C_{15}H_{24}$	3.49	nd	nd	nd	nd	nd
Nerolidol	1568	1564	$C_{15}H_{26}O$	1.29	nd	19.42	nd	nd	23.52
(*Z*)-3-Hexen-1-ol benzoate	1574	1570	$C_{13}H_{16}O_2$	7.82	1.21	2.61	0.96	nd	3.16
n-Hexyl benzoate	1580	1580	$C_{13}H_{18}O_2$	nd	0.52	0.21	nd	nd	0.26
Caryophyllene oxide	1587	1581	$C_{15}H_{24}O$	2.41	nd	nd	nd	nd	nd
Tetradecanal	1613	1613	$C_{14}H_{28}O$	nd	0.72	nd	nd	nd	nd
Benzophenone	1629	1635	$C_{13}H_{10}O$	nd	0.37	nd	nd	nd	nd
α-Cadinol	1659	1653	$C_{15}H_{26}O$	3.67	nd	nd	0.64	nd	nd
Octyl ether	1665	1665	$C_{16}H_{34}O$	nd	0.19	nd	nd	nd	nd
Heptadecane	1700	1700	$C_{17}H_{36}$	nd	0.52	nd	nd	nd	nd
Pentadecanal	1715	1715	$C_{15}H_{30}O$	0.1	9.42	5.28	nd	18.06	6.39
Methyl tetradecanoate	1726	1725	$C_{15}H_{30}O_2$	nd	nd	1.04	nd	nd	1.26
Benzyl benzoate	1767	1763	$C_{14}H_{12}O_2$	1.47	nd	nd	0.48	nd	nd
Cyclotetradecane	1778	1673	$C_{14}H_{28}$	nd	nd	0.14	nd	nd	nd
Ethyl myristate	1795	1794	$C_{16}H_{32}O_2$	nd	nd	nd	nd	nd	2.2
Myristic acid	1795	1794	$C_{16}H_{32}O_2$	nd	nd	1.88	nd	nd	nd
Octadecane	1800	1800	$C_{18}H_{38}$	nd	0.92	nd	nd	nd	nd
Hexahydrofarnesyl acetone	1852	1844	$C_{18}H_{36}O$	nd	nd	2.62	nd	nd	nd
Methyl palmitate	1933	1926	$C_{17}H_{34}O_2$	0.53	0.3	16.44	nd	nd	nd
Dibutyl phthalate	1968	1965	$C_{16}H_{22}O_4$	nd	3.67	0.5	0.93	nd	nd
Ethyl palmitate	1998	1993	$C_{18}H_{36}O_2$	nd	1.04	19.13	nd	1.84	23.17
Eicosane	2000	2000	$C_{20}H_{42}$	nd	0.95	nd	nd	nd	nd
(*E*)-Geranyl linalool	2033	2034	$C_{20}H_{34}O$	12.86	1.68	0.19	11.44	nd	nd
Heneicosane	2101	2100	$C_{21}H_{44}$	1.43	6.09	nd	nd	nd	nd
Linolenic acid	2101	2099	$C_{19}H_{32}O_2$	0.81	nd	nd	nd	nd	nd
2-Nonadecanone	2105	2106	$C_{19}H_{38}O$	nd	nd	nd	nd	4.81	nd
Phytol	2114	2114	$C_{20}H_{40}O$	nd	1.3	nd	nd	nd	nd
Methyl stearate	2128	2128	$C_{19}H_{38}O_2$	nd	nd	1.13	nd	nd	1.37
Linoleic acid ethyl ester	2163	2161	$C_{20}H_{36}O_2$	nd	nd	0.43	nd	nd	0.53
Hexadecanamide	2178	2184	$C_{16}H_{33}NO$	nd	nd	nd	nd	1.19	nd
Stearic acid, ethyl ester	2196	2195	$C_{20}H_{40}O_2$	nd	nd	1.65	nd	nd	1.99
Eicosanal-	2225	2224	$C_{20}H_{40}O$	nd	nd	nd	nd	2.91	nd
(*Z*)-9-Tricosene	2277	2275	$C_{23}H_{46}$	4.15	nd	nd	23.31	nd	nd
Docosanal	2430	2430	$C_{22}H_{44}O$	nd	1.26	nd	nd	nd	nd
Tricosane	2300	2300	$C_{23}H_{48}$	nd	8.33	2.31	nd	nd	2.79
Eicosanoic acid, methyl ester	2329	2329	$C_{21}H_{42}O_2$	nd	nd	0.47	nd	nd	0.57
Tetracosane	2400	2400	$C_{24}H_{50}$	0.33	nd	nd	3.46	nd	nd
Behenic alcohol	2492	2496	$C_{22}H_{46}O$	nd	3.07	nd	nd	nd	nd
Pentacosane	2500	2500	$C_{25}H_{52}$	1.01	3.22	1.81	20.83	nd	2.19
Hexacosane	2600	2600	$C_{26}H_{54}$	nd	nd	nd	1.48	nd	nd
Tetracosanal	2634	2632	$C_{24}H_{48}O$	nd	1.98	nd	nd	2.08	nd

Continuation of Table 1

2-Pentacosanone	2717	2715	$C_{25}H_{50}O$	nd	nd	nd	nd	6.47	nd
3-Methylheptacosane	2774	2773	$C_{28}H_{58}$	nd	nd	nd	1.76	nd	nd
Squalene	2832	2827	$C_{30}H_{50}$	nd	nd	nd	13.96	6.72	nd
Octacosane, 2-methyl-	2864	2863	$C_{29}H_{60}$	nd	nd	nd	2.33	nd	nd
Nonacosane, 3-methyl-	2974	2973	$C_{30}H_{62}$	nd	nd	nd	9.96	nd	nd
Octacosanal	3042	3036	$C_{28}H_{56}O$	nd	nd	nd	nd	12.15	nd

Note: nd – not detected.

5. Discussion

In the EO of *J. officinale*, obtained by hydrodistillation, the content of terpenoids is 68.20 %, of which monoterpenoids account for 27.53 %, sesquiterpenoids – 27.81 %, diterpenoids – 12.86 % and aromatic compounds – 22.11 % (Table 2, Fig. 4). The remaining compounds are represented by saturated and unsaturated hydrocarbons and aldehydes.

It should be noted that our results of studying the composition of the EO of *J. officinale* differ from the generally accepted opinion that the main component of jasmine EO is jasmone [42, 43]. This compound was not detected in either the EO or the hexane extract of *J. officinale*.

Our data for the hydrodistillate of *J. officinale* differ from the literature data for *J. officinale* var. *grandifloroum*, in which the major volatile components were phytol (25.77 %), 3,7,11-trimethyldodeca-1,6,10-trien-3-ol (12.54 %) and 3,7,11-trimethyldodeca-6,10-dien-3-ol (dehydronerolidol) (12.42 %) [26]. This publication also confirmed the presence of nerolidol, benzyl benzoate, geranyllinalool, and several aliphatic hydrocarbons in the EO of *J. officinale* var. *grandifloroum* obtained by hydrodistillation, which coincides with our results for *J. officinale*.

In the hexane extract of *J. officinale* flowers, the content of terpenoids is only 31.42 %, of which 4.89 % are monoterpenoids, 1.13 % are sesquiterpenoids, 11.44 % are diterpenoid geranilinalool, 13.96 % are triterpenoid squalene (Fig. 5). It is obvious that hexane, as a lipophilic solvent, is able to extract a significant part of hydrocarbons and their derivatives contained in plant raw materials, which explains the low relative content of terpenoids in the extract.

Terpenoids identified in both the hydrodistillate and the hexane extrac *J. officinale* are D-limonene, DL-menthol, (-)-carvone, caryophyllene, α-cadinol, (E)-geranyl linalool.

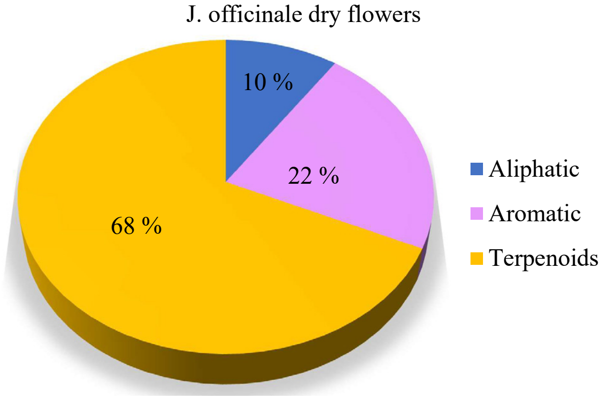

Fig. 4. Group composition of hydrodistillate from dried *J. officinale* flowers

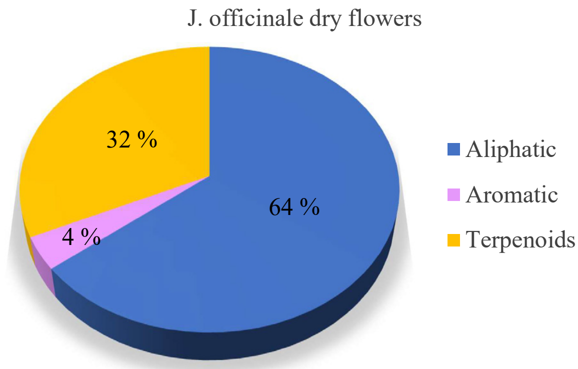

Fig. 5. Group composition of hexane extract from dried *J. officinale* flowers

In the EO of *P. coronarius*, obtained by hydrodistillation of dry flowers, the content of terpenoids is 33.75 %, of which monoterpenoids account for 33.75 %, sesquiterpenoids are absent, diterpenoids – 2.98 %; aromatic compounds – 13.31 % (Fig. 6). In the EO of *P. coronarius*, obtained by hydrodistillation of fresh flowers, the content of terpenoids is 36.61 %, of which monoter-penoids account for 14.38 %, sesquiterpenoids – 22.04 %, diterpenoids – 0.19 %; aromatic compounds – 8.52 % (Fig. 7).

In the hexane extract of dried flowers of *P. coronarius*, the content of terpenoids is 6.72 %, of which monoterpenoids, sesquiterpenoids and di-

Table 2

Content of groups of substances in hydrodistillate and hexane extracts of flowers *J. officinale* and *P. coronarius*

Group of compounds	Content of volatiles in the distillates, %			Content of volatiles in hexane extracts, %		
	J. officinale dry flowers	*P. coronarius* dry flowers	*P. coronarius* fresh flowers	*J. officinale* dry flowers	*P. coronarius* dry flowers	*P. coronarius* fresh flowers
Aliphatic	9.63	49.97	54.87	63.6	81.83	46.28
Aromatic	22.11	13.31	8.52	4.82	7.91	8.4
Monoterpenoids	27.53	33.75	14.38	4.89	0	20.63
Sesquiterpenoids	27.81	0	22.04	1.13	0	23.52
Diterpenoids	12.86	2.98	0.19	11.44	0	0
Triterpenoids	0	0	0	13.96	6.72	0

terpenoids are absent, the triterpenoid squalene is 6.72 %, and aromatic compounds are 7.91 % (Fig. 8). In the hexane extract of fresh *P. coronarius* flowers, the content of terpenoids is 44.15 %, of which monoterpenoids account for 20.63 %, sesquiterpenoids – 23.52 %; aromatic compounds – 8.40 % (Fig. 9).

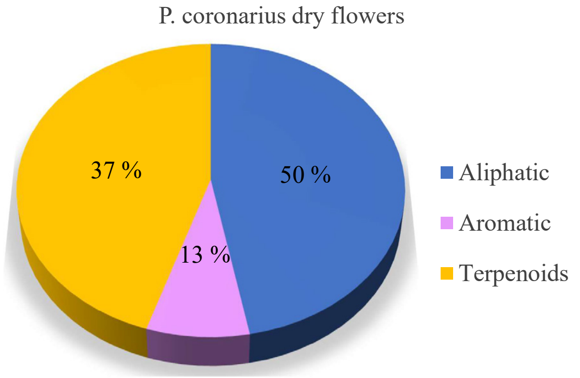

Fig. 6. Group composition of hydrodistillate from dried *P. coronarius* flowers

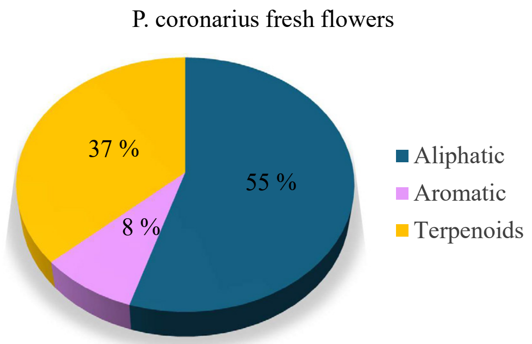

Fig. 7. Group composition of hydrodistillate from fresh *P. coronarius* flowers

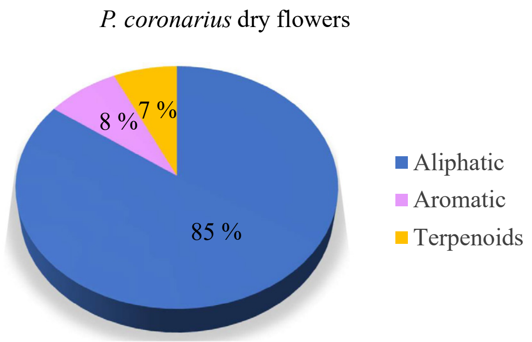

Fig. 8. Group composition of hexane extract from dried *P. coronarius* flowers

As can be seen from the study results, the component composition of EO obtained from dried plant raw materials differs from the composition of EO obtained from fresh raw materials *P. coronarius*, both in quantitative and qualitative terms (Fig. 6, 7).

Only the EO obtained from fresh flowers of *P. coronarius* contains terpenoids phellandral, nerolidol in significant amounts, hexahydrofarnesylacetone, esters of higher fatty acids.

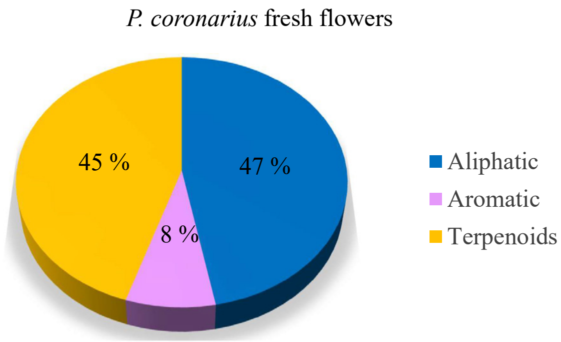

Fig. 9. Group composition of hexane extract from fresh *P. coronarius* flowers

In the EO obtained from dried flowers, aromatic compounds such as benzolacetaldehyde, benzophenone, diterpenoid phytol and several aliphatic compounds were found, which are not present in the EO obtained from fresh raw materials.

The hexane extract of dried flowers of *P. coronarius* differs from other hexane extracts in the complete absence of mono-, sesqui- and diterpenoids. The hexane extract of fresh flowers of *P. coronarius* contains a significant amount of terpenoids, such as linalool, norinone, myrtanal and nerolidol in significant amounts (19.42 %), (1R)-(-)-myrtenal, phellandral, eugenol, and (*Z*)-jasmone.

This is due to the fact that during the drying of raw materials, compounds can undergo various chemical transformations: ester cleavage, cyclization, oxidation, saturation of double bonds, isomerization to form stable molecules.

As an example, we can cite nerolidol, which from fresh raw materials *P. coronarius* in hydrodistillate is 19.4 %, in hexane extract 23.52 % and which is absent in those obtained under similar conditions from dry raw materials. Considering the chemical structure of nerolidol, we can assume its transformation, namely oxidation and cyclization (to bisabolol and further to its oxides), isomerization (to farnesol), biosynthesis of other sesqui- and diterpenes, sterols, which continues during drying, dehydration and, as a result, transformation to aliphatic compounds. These assumptions have a scientific basis, which takes into account the chemical properties of the substance and its participation in the biosynthesis of substances in plants. As can be seen from the table, simultaneously with the "disappearance" of nerolidol in dry raw materials, the content of such compounds as pentadecanal increases from 5.28 % to 9.42 % in hydrodistillates, from 6.39 % to 18.06 % in hexane extracts; pentadecanal from 5.28 % to 9.42 % and from 6.39 % to 18.06 %, respectively. The increase in the content of linalool, nonanal, norinone from dry raw materials can be explained by their release from complex compounds by enzymatic action.

When comparing the component composition of the hydrodistillate of *P. coronarius* (dry and fresh raw materials) and *J. officinale*, it was found that the common components are terpenoids and aromatic compounds, such as linalool, eugenol, eugenol, (*E*)-geranyl linalool, benzaldehyde, benzoic acid 2-amino-ethyl ester, (*Z*)-3-hexen-1-ol benzoate.

The EO of *J. officinale* differs significantly from the EO of *P. coronarius* primarily in the presence of terpenes and aromatic compounds, such as D-limonene, (+)-camphor, DL-menthol, terpinen-4-ol, α-terpineol, methyl chavicol, nerol, (-)-carvone, geraniol, anethole, methyl anthranilate, α-terpinyl acetate, copaene, elemene-isomer, methyleugenol, caryophyllene, α-muurolene, γ-muurolene, α-curcumene, α-farnesene, cadinene, amorphene, caryophyllene oxide, α-cadinol, benzyl benzoate, phenylmethyl formiat.

The EO of *P. coronarius* contains terpenoids and aromatic compounds, that are not present in the EO of *J. officinale*: norinone, (E,Z)-2,6-nonadienal, myrtanal, (1R)-(-)-myrtenal, *(Z)*-(-)-myrtanol, (Z)-jasmone, phytol, ethyl benzoate, 2-aminobenzaldehyde, ethyl cinnamat, n-hexyl benzoate, benzophenone, dibutyl phthalate.

Only hexane extracts from dried flowers of *J. officinale* and *P. coronarius* contain triterpene squalene in significant amounts (13.96 % and 6.72 %). Common to the hexane extracts of the studied objects are aromatic compounds: benzyl alcohol, 2,4-di-tert-butylphenol; aliphatic compounds: 2,4-dimethyl-heptane, octanal, decanal.

The hexane extract of *J. officinale* is characterized by the presence of such terpenoids as *α*-phellandrene, D-limonene, *p*-menthone, DL-menthol, (-)-carvone, (-)-cis-myrtanol, 8-hydroxylinalool, caryophyllene, *α*-cadinol, benzyl benzoate, (*E*)-geranyl linalool and aromatic compounds, such as benzyl alcohol, 2-hydroxy-iso-butyrophenone, methyl anthranilate, 2,4-di-tert-butylphenol, (*Z*)-3-hexen-1-ol benzoate, dibutyl phthalate, benzyl benzoate.

Practical significance. To obtain the required amount of terpenoids, it is recommended to use either the method of hydrodistillation or the method of extraction of fresh *P. coronarius* raw materials with hexane. It is impractical to use the extraction of dry raw materials with hexane as a method for obtaining such a small amount of terpenoids.

Research limitations. A full-fledged study is limited by the lack of fresh *J. officinale* raw materials. Only one sample of each raw material was analyzed, which does not allow us to verify the same tendencies in plant material originating from different growing locations.

Prospects for further research. It is advisable to continue relevant studies of species of the genus *Jasminum* L. and genus *Philadelphus* L. as sources of valuable biological substances for medicine and pharmaceuticals.

6. Conclusions

The studies that were conducted identified the main differences in volatile compounds in distillates and hexane extracts of *P. coronarius* and *J. officinale*. A total of 109 compounds were identified in the objects, and the dominant components were established. In the *J. officinale* EO the dominant components are (E)-geranyl linalool, linalool, (Z)-3-hexen-1-ol benzoate, α-farnesene, D-limonene, methyl anthranilate and (Z)-9-tricosene. In the EO from the dried *P. coronarius* flowers, the dominant components are (1R)-(-)-myrtenal, myrtanal, pentadecanal, tricosane and (Z)-jasmone, while benzolacetaldehyde, benzophenone; diterpenoid phytol and several aliphatic compounds were found only here. In the EO from the fresh *P. coronarius* flowers, the dominant components are nerolidol, ethyl palmitate, methyl 2-methylpalmitate, myrtanal, pentadecanal and (Z)-jasmone, while phellandral, nerolidol in significant amounts, hexahydrofarnesylacetone were found opposite to the dried raw material. Thus, during the drying process of *P. coronarius* flowers, the composition of the EO significantly changes. Only hexane extracts from dried flowers of *J. officinale* and *P. coronarius* contain triterpene squalene in significant amounts (13.96 % and 6.72 %). Common to the hexane extracts of the studied objects are aromatic compounds: benzyl alcohol, 2,4-di-tert-butylphenol; aliphatic compounds: 2,4-dimethyl-heptane, octanal, decanal.

Conflicts of interest

The authors declare that they have no conflict of interest concerning this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The datasets used and/or analyzed during the current study are available from the author and/or corresponding author upon reasonable request.

Use of artificial intelligence

The authors confirm they did not use artificial intelligence technologies when creating the current work.

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References

1. Harilik ebajasmiin. Wikipedia. Available at: https://et.wikipedia.org/wiki/Harilik_ebajasmiin Last accessed: 10.25.2024

2. Ebajasmiin (perekond). Wikipedia. Available at: https://et.wikipedia.org/wiki/Ebajasmiin_(perekond)

3. Philadelphus coronarius L. Plants of the World Online. Kew Science. Available at: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:792194-1

4. Philadelphus coronarius L. World flora online. Available at: https://www.worldfloraonline.org/taxon/wfo-0000465348

5. Mucaji, P., Grancai, D., Nagy, M., Czigleová, S., Buděsínský, M., Ubik, K. (2001). Nonpolar components of the leaves of Philadelphus coronarius L. Ceska a Slovenska farmacie, 50 (6), 274–276.

6. Pető, Á., Kósa, D., Haimhoffer, Á., Nemes, D., Fehér, P., Ujhelyi, Z. et al. (2022). Topical Dosage Formulation of Lyophilized Philadelphus coronarius L. Leaf and Flower: Antimicrobial, Antioxidant and Anti-Inflammatory Assessment of the Plant. Molecules, 27 (9), 2652. https://doi.org/10.3390/molecules27092652

7. Czigle, S., Mu[cbreve]aji, P., Gran[cbreve]ai, D., Veres, K., Háznagy-Radnai, E., Dobos, Á., Máthé, I., Tóth, L. (2006). Identification of the Components ofPhiladelphus coronariusL. Essential Oil. Journal of Essential Oil Research, 18 (4), 423–426. https://doi.org/10.1080/10412905.2006.9699130

8. Klecáková, J., Chobot, V., Jahodár, L., Laakso, I., Víchová, P. (2004). Antiradical activity of petals of Philadelphus coronarius L. Central European Journal of Public Health, 12, 39–40.

9. Nagy, M., Grancai, D., Jantova, S., Ruzekova, L. (2000). Antibacterial activity of plant extracts from the families Fabaceae, Oleaceae, Philadelphaceae, Rosaceae and Staphyleaceae. Phytotherapy Research, 14 (8), 601–603. https://doi.org/10.1002/1099-1573(200012)14:8<601::aid-ptr771>3.0.co;2-b

10. Dilshara, M. G., Jayasooriya, R. G. P. T., Lee, S., Jeong, J. B., Seo, Y. T., Choi, Y. H. et al. (2013). Water extract of processed Hydrangea macrophylla (Thunb.) Ser. leaf attenuates the expression of pro-inflammatory mediators by suppressing Akt-mediated NF-κB activation. Environmental Toxicology and Pharmacology, 35 (2), 311–319. https://doi.org/10.1016/j.etap.2012.12.012

11. Jasminum L. Plants of the World Online. Kew Science. Available at: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:328128-2

12. Jasminum officinale L. Plants of the World Online. Kew Science. Available at: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:609672-1

13. BSBI List 2007 (xls). Botanical Society of Britain and Ireland. Archived from the original (xls) on 2015-06-26.; "Jasminum officinale". Germplasm Resources Information Network. Agricultural Research Service, United States Department of Agriculture.

14. Makeri, M., Salihu, A.; Nayik, G. A., Ansari, M. J. (Eds.) (2023). Jasmine essential oil: Production, extraction, characterization, and applications. Essential Oils. Academic Press, 147–177. https://doi.org/10.1016/b978-0-323-91740-7.00013-x

15. Dinh Phuc, N., Phuong Thy, L. H., Duc Lam, T., Yen, V. H., Thi Ngoc Lan, N. (2019). Extraction of Jasmine Essential Oil By Hydrodistillation method and Applications On Formulation of Natural Facial Cleansers. IOP Conference Series: Materials Science and Engineering, 542 (1), 012057. https://doi.org/10.1088/1757-899x/542/1/012057

16. Jasmine Essential Oil Market Research Report (2021). Report ID: Global Forecast To 2028, 249. Available at: https://industrygrowthinsights.com/report/jasmine-essential-oil-market/

17. Singh, B., Sharma, R. A. (2020). Secondary Metabolites of Medicinal Plants, 4 Volume Set: Ethnopharmacological Properties, Biological Activity and Production Strategies. Hoboken: John Wiley & Sons, 574–584. https://doi.org/10.1002/9783527825578

18. Rattan, R. (2023). Genus Jasminum: Phytochemicals and Pharmacological effects-a Review. International Journal of Research and Analytical Reviews, 10 (2), 787–795.

19. Rattan, R. (2023). Secoiridoids from Jasminum Species- A Report. of Emerging Technologies and Innovative Research. Journal of Emerging Technologies and Innovative Research, 10 (6), 104–109. Available at: https://www.researchgate.net/publication/373709272

20. Frezza, C., Nicolosi, R. M., Brasili, E., Mura, F., De Vita, D. (2024). Occurrence and Biological Activities of Seco-Iridoids from Jasminum L. Chemistry & Biodiversity, 21 (4). https://doi.org/10.1002/cbdv.202400254

21. Elhawary, S., El-Hefnawy, H., Mokhtar, F. A., Sobeh, M., Mostafa, E., Osman, S., El-Raey, M. (2020). Green Synthesis of Silver Nanoparticles Using Extract of Jasminum officinal L. Leaves and Evaluation of Cytotoxic Activity Towards Bladder (5637) and Breast Cancer (MCF-7) Cell Lines. International journal of nanomedicine, 15, 9771–9781. https://doi.org/10.2147/ijn.s269880

22. Lu, Y., Han, Z.-Z., Zhang, C.-G., Ye, Z., Wu, L.-L., Xu, H. (2019). Four new sesquiterpenoids with anti-inflammatory activity from the stems of Jasminum officinale. Fitoterapia, 135, 22–26. https://doi.org/10.1016/j.fitote.2019.03.029

23. Dubey, P., Tiwari, A., Gupta, S. K., Watal, G. (2016). Phytochemical and biochemical studies of Jasminum officinale leaves. International Journal of Pharmaceutical Sciences and Research, 7 (6), 2632–2640. https://doi.org/10.13040/ijpsr.0975-8232.7(6).2632-40

24. El-Hawary, S. S., EL-Hefnawy, H. M., Osman, S. M., EL-Raey, M. A., Mokhtar Ali, F. A. (2019). Phenolic profiling of differentJasminumspecies cultivated in Egypt and their antioxidant activity. Natural Product Research, 35 (22), 4663–4668. https://doi.org/10.1080/14786419.2019.1700508

25. Al-Snafi, A. E. (2018). Pharmacology and Medical Properties of Jasminum officinale – A Review. Indo American Journal of Pharmaceutical Sciences, 5 (4), 2191–2197. http://doi.org/10.5281/zenodo.1214994

26. Wei, F., Chen, F., Tan, X. (2015). Gas Chromatographic-Mass Spectrometric Analysis of Essential Oil of Jasminum officinale L var Grandiflorum Flower. Tropical Journal of Pharmaceutical Research, 14 (1), 149–152. https://doi.org/10.4314/tjpr.v14i1.21

27. Garg, P., Garg, V. (2023). Bibliometric Analysis of the Genus Jasminum: Global Status, Research and Trends. Journal of Herbal Medicine, 41, 100711. https://doi.org/10.1016/j.hermed.2023.100711

28. Kaviani, M., Maghbool, S., Azima, S., Tabaei, M. H. (2014). Comparison of the effect of aromatherapy with Jasminum officinale and Salvia officinale on pain severity and labor outcome in nulliparous women. Iranian journal of nursing and midwifery research, 19 (6), 666–672.

29. Mukhlis, H., Nurhayati, N., Wandini, R. (2018). Effectiveness of Jasmine oil (Jasminum officinale) massage on reduction of labor pain among primigravida mothers. Malahayati International Journal of Nursing and Health Science, 1 (2), 47–52. https://doi.org/10.33024/minh.v1i2.1590

30. Saxena, S., Uniyal, V., Bhatt, R. P. (2012). Inhibitory effect of essential oils against Trichosporon ovoides causing Piedra Hair Infection. Brazilian Journal of Microbiology, 43 (4), 1347–1354. https://doi.org/10.1590/s1517-83822012000400016

31. Al-Khazraji, S. M. (2015). Evaluation of antibacterial activity of Jasminum officinale. IOSR Journal of Pharmacy and Biological Sciences, 10 (1), 121–124.

32. Rama, G., Ampati S. (2013). Evaluation of flowers of Jasminum officinale for antibacterial activity. Journal of Advanced Pharmaceutical Sciences, 3 (1), 428–431.

33. Balkrishna, A., Rohela, A., Kumar, A., Kumar, A., Arya, V., Thakur, P. et al. (2021). Mechanistic Insight into Antimicrobial and Antioxidant Potential of Jasminum Species: A Herbal Approach for Disease Management. Plants, 10 (6), 1089. https://doi.org/10.3390/plants10061089

34. Khan, U. A., Rahman, H., Niaz, Z., Qasim, M., Khan, J., Tayyaba, Rehman, B. (2013). Antibacterial activity of some medicinal plants against selected human pathogenic bacteria. European Journal of Microbiology and Immunology, 3 (4), 272–274. https://doi.org/10.1556/eujmi.3.2013.4.6

35. Bera, P., Kotamreddy, J. N. R., Samanta, T., Maiti, S., Mitra, A. (2015). Inter-specific variation in headspace scent volatiles composition of four commercially cultivated jasmine flowers. Natural Product Research, 29 (14), 1328–1335. https://doi.org/10.1080/14786419.2014.1000319

36. Issa, M. Y., Mohsen, E., Younis, I. Y., Nofal, E. S., Farag, M. A. (2020). Volatiles distribution in jasmine flowers taxa grown in Egypt and its commercial products as analyzed via solid-phase microextraction (SPME) coupled to chemometrics. Industrial Crops and Products, 144, 112002. https://doi.org/10.1016/j.indcrop.2019.112002

37. Lasekan, O., Lasekan, A. (2012). Flavour chemistry of mate and some common herbal teas. Trends in Food Science & Technology, 27 (1), 37–46. https://doi.org/10.1016/j.tifs.2012.05.004

38. Henno, O. (1995). Puude ja põõsaste välimääraja. Tallinn, 580.

39. Kubja ürditalu. Aastast 1988. Available at: https://kubja.ee/ Last accessed: 10.25.2024

40. European Pharmacopoeia. 11th ed. (2022). Strasbourg: Council of Europe.

41. Hrytsyk, Y., Koshovyi, O., Lepiku, M., Jakštas, V., Žvikas, V., Matus, T. et al. (2024). Phytochemical and Pharmacological Research in Galenic Remedies of Solidago canadensis L. Herb. Phyton, 93 (9), 2303–2315. https://doi.org/10.32604/phyton.2024.055117

42. (Z)-Jasmone. Available at: https://www.thegoodscentscompany.com/data/rw1016891.html

43. Wasternack, C., Song, S. (2017). Jasmonates: biosynthesis, metabolism, and signaling by proteins activating and repressing transcription. Journal of Experimental Botany, 68 (6), 1303–1321. https://doi.org/10.1093/jxb/erw443

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