UDC 615.3:633.8
DOI: 10.15587/2519-4852.2025.323994

RESEARCH IN COMPONENT COMPOSITION OF THE VOLATILE FRACTIONS FROM THE GENUS ANEMONE PLANTS

Liliia Tuzin, Andriy Grytsyk, Thanh Tung Nguyen, Ain Raal, Oleh Koshovyi

Plants of the genus Anemone L. of the Ranunculaceae family are perennial herbaceous plants. The genus includes about 200 species, five of which are growing on the territory of Ukraine. Despite their relatively wide distribution and availability of raw materials, plants of this genus remain insufficiently studied.

The aim. *The aim of the work was to conduct comparative research on the volatile substances in A. nemorosa L. and A. ranunculoides L. raw materials harvested in Ukraine.*

Materials and methods. *Hydrodistillates obtained from dried herb and rhizomes of A. nemorosa L. and dried herb of A. ranunculoides L. were analyzed using gas chromatography-mass spectrometry (GC/MS).*

Research results. *The investigation identified 68 and 50 compounds in A. nemorosa and A. ranunculoides raw materials, respectively. The key classes of organic compounds in the compositions of volatile fractions of the studied samples are: aldehydes (30.9–42.4 %), monoterpenoids (6.1–15.5 %), organic acids (4.2–15.8 %), aliphatic and aromatic hydrocarbons (0–8.7 %), sesquiterpenoids (7.9–18.9 %), diterpenoids (1.9–6.1 %), esters (1.8–4.4 %), aromatic compounds (4.4–7.9 %), alcohols (4.4–9.1 %) and ketones (4.4–9.1 %). The main components of the volatile fractions of A. nemorosa were identified as hexahydrofarnesyl acetone, dibutyl phthalate, phytol, hexanal, 2-pentylfuran, and (E)-β-ionone. For A. ranunculoides, the basic compounds were hexahydrofarnesyl acetone, n-hexadecanoic acid, phytol, phthalic acid, and pelargonaldehyde.*

Conclusions*. The component composition of volatile fractions in 11 samples of Anemone L. species from the flora of Ukraine was analyzed using the GC/MS method. It has been found that the A. nemorosa rhizomes contain the highest level of volatile fraction. The analysis of the component composition of volatile fractions in Anemone species indicates the prospects for further research in this plant species, their pharmacological activities, and their applications*

Keywords*: Anemone nemorosa L., Anemone ranunculoides L., Ranunculaceae, essential oil, herb, rhizomes, component composition, GC/MS*

How to cite:
Tuzin, L., Grytsyk, A., Nguyen, T. T., Raal, A., Koshovyi, O. (2025). Research in component composition of the volatile fractions from the genus anemone plants. ScienceRise: Pharmaceutical Science, 1 (53), 106–114. http://doi.org/10.15587/2519-4852.2025.323994

1. Introduction

The genus *Anemone* (*A.*) is one of the largest in the Ranunculaceae family (includes more than 200 species) [1]; the natural habitats of *Anemone* plants are North and South America, Mediterranean countries, Eastern Europe, North Africa and Asia [2].

There are 5 species growing on the territory of Ukraine, the most common being *A. nemorosa* L. and *A. ranunculoides* L. According to taxonomy, species growing on the territory of Ukraine belong to 3 sections: *Anemonanthea*: Wood anemone (*A. nemorosa L.*), Yellow wood anemone (*A. ranunculoides* L.); *Eriocephalus*: Snowdrop anemone (*A. sylvestris* L.); and *Omalocarpus*: Narcissus anemone (*A. narcissiflora* L.), Spreading anemone (*A. laxa* Juz.) [3, 4]. At the same time, research on the raw materials that grew in Ukraine has been minimal.

The *Anemone* L. genus species are perennial herbaceous plants with upright stems and whorled green leaves. Basal leaves characterize them. The flowers are solitary and symmetrical, with simple perianths consisting of 5–20 coloured petals. The stamens and pistils are numerous. The fruit is a nut-like achene [3].

The diverse chemical composition of *Anemone* species includes triterpene saponins (pentacyclic: oleanane, ursane, lupane types; tetracyclic triterpenoids of the cycloartane type), steroids, lactones, lipids, terpenoids, alkaloids and sugars [5]. *Anemone* L. species are rich in oleic acid and also contain coumarins, flavonoids, glycosides (ranunculin, anemonin, protoanemonin), organic acids (chelidonic acid), camphor, and ascorbic acid [5, 6]. It is very important to note that the *Anemone* L. species are alkaloid-containing and can cause poisoning and toxic effects. Thus, from the roots of *Anemone altaica*, such β-carboline alkaloids as anemonilins A and B, flazine and 4-(9H-β-carbolin-l-yl)-4-oxo-butyric acid were isolated [7]. In *Anemonia sulcata*, the methylpyridinium alkaloid homarine was found [8]. From the sea anemone *Heteractis aurora* indole alkaloids have been extracted [9]. In the chloroform fractions of A. *nemorosa* esters, fatty aldehydes, monocyclic terpene limonene and diterpene rimuen have been identified [10], but no studies of the distillates of these plants have been conducted.

Plants of the *Anemone* genus are non-officinal medicinal herbs. In traditional Chinese medicine, they

are used to treat dysentery, malaria, ringworm, ulcers and abscesses, arthritis, traumatic injuries, laryngopharingitis, parasitic diseases and hepatitis [5]. In homeopathy, A. *nemorosa* herbal medicines are used as sedatives, diaphoretics and diuretics in tinctures, pellets, homeopathic dilutions and granules [6, 11–14]. Folk medicine uses various parts of *Anemone* plants in infusions, decoctions, and tinctures. Wood anemone medicines are used to treat malignant tumours, respiratory and heart diseases, kidney and spleen disorders, eye diseases, fever, pain, and stomach ulcers. These drugs exhibit spasmolytic, sedative, diaphoretic, bactericidal, antifungal and expectorant properties [5, 6, 15].

Yellow wood anemone medicines have narcotic, pain-relieving, spasmolytic, hemostatic, expectorant, and antibacterial activity. In European folk medicine, infusions of yellow wood anemone leaves are used to treat gout, dropsy, chronic syphilis, paralysis, and cardiovascular, respiratory and kidney diseases [6].

Despite their widespread occurrence and accessibility, the chemical composition and pharmacological efficacy of *Anemone* L. species have not been sufficiently studied. Therefore, investigating their chemical composition, particularly that of volatile substances, is relevant. Since *A. nemorosa* L. and *A. ranunculoides* L. are among the most common species in Ukraine, they became the objects of our research, and the phytochemical study of their raw materials will allow us to expand scientific knowledge about the Ukrainian raw materials and develop methods for their standardization [16, 17], taking into account the national characteristics of the chemical composition of the plant.

Aim. The aim of the work was comparative research in the volatile substances of *A. nemorosa* L. and *A. ranunculoides* L. raw materials harvested in Ukraine.

2. Planning (methodology) of research

The stages describing the study of raw material samples in this research are shown in Fig. 1.

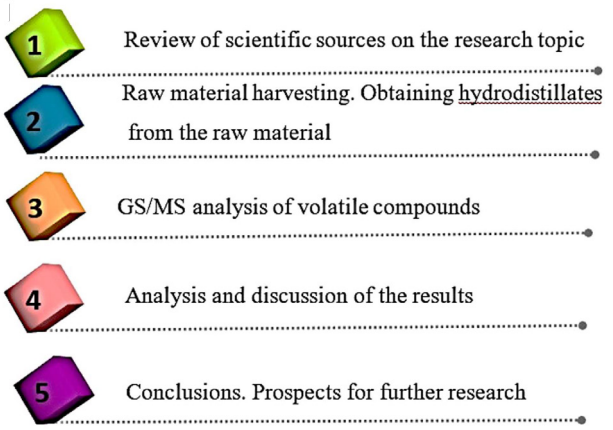

Fig. 1. Planning of research

3. Materials and methods

For analysis, the herbs of *A. nemorosa* L. and *A. ranunculoides* L. were harvested during the flowering, rhizomes were harvested in the spring at the beginning of vegetation.

Plant raw materials of *A. nemorosa* L. and *A. ranunculoides* L. were gathered in the Ivano-Frankivsk region (Ukraine) from five different potential growth sites (samples 1–7, 9–11) and the Ternopil region (Ukraine) (sample 8) (Table 1). The herb was harvested by cutting the stems a few centimetres above the ground level with scissors. Rhizomes were dug up, cleaned from soil, and washed with water. The raw materials were dried naturally in a well-ventilated attic at room temperature. Around 100–150 g of dried raw material was obtained for each sample.

The raw materials were identified according to the Plant identifier of Ukraine by candidate of Biological Sciences, Associate Professor Svitlana Danyliv at the Department of Pharmaceutical Management, Drug Technology and Pharmacognosy, Ivano-Frankivsk National Medical University, Ukraine. The samples of raw plant materials and the herbariums (#782–790) are stored in a dry, well-ventilated, light-protected place in the Department.

Table 1

The studied samples of *Anemone* plant raw materials from different habitats in Ukraine

Sample No.	Species	Raw material	Year of harvest	Administrative location	Geographical coordinates
1	*Anemone nemorosa* L.	herb	2023	Outskirts of the Klubivtsi village Tysmenytsia district Ivano-Frankivsk region	48°54'38.6"N 24°56'21.4"E
2			2024		
3			2023	Outskirts of the Pavlivka village Tysmenytsia district Ivano-Frankivsk region	48°59'17.4"N 24°36'47.8"E
4			2024		
5			2023	Outskirts of the tract Mochary Bohorodchany district Ivano-Frankivsk region	48°50'40.2"N 24°34'45.1"E
6			2024		
7			2024	Outskirts of the Slyvky village Kalush district Ivano-Frankivsk region	48°46'58.6"N 24°12'47.9"E
8			2024	Outskirts of the Ozeriany village Ternopil region	48°53'36.8"N 25°56'19.0"E
9		rhizomes	2023	Outskirts of the Pavlivka village Tysmenytsia district Ivano-Frankivsk region	48°59'17.4"N 24°36'47.8"E
10			2024	Outskirts of the Slyvky village Kalush district Ivano-Frankivsk region	48°46'58.6"N 24°12'47.9"E
11	*Anemone ranunculoides* L.	herb	2023	Outskirts of the Vovchynets village Ivano-Frankivsk district Ivano-Frankivsk region	48°57'45.4"N 24°44'55.6"E

According to the European Pharmacopoeia, volatile compounds were extracted by hydrodistillation method from 30.0 g of dried raw materials (herb and rhizomes) with 300 mL of purified water following the essential oil distillation procedure [13]. The analysis was performed using gas chromatography with mass spectrometry (GC/MS) on the Agilent 6890/5973 GCMS system equipped with a mass spectrometric detector (MSD) Chemstation.

Samples (1 µL each) diluted in *n*-hexane were injected at an injector temperature of 280 °C in split mode (ratio 20:1), with helium as the carrier gas on an Agilent HP-5MSI column (30 m length, 0.25 mm inner diameter, 0.25 µm film thickness). The carrier gas flow rate was maintained at 1 mL/min, and the column temperature program started at 50 °C (held for 2 min), then increased at 4 °C/min to 280 °C, which was maintained for 5 min [18, 19].

The mass spectrometer operated in electron ionization (EI) mode at 70 eV. Mass spectra were recorded in the range of 29–400 m/z with a solvent delay time of 4 minutes and a scanning speed of 3.8 scans/sec. Data processing was carried out using Agilent Masshunter software, applying deconvolution algorithms and different window size factors. Compounds were identified using the NIST23 library with a match factor ≥90 and retention indices (compared to *n*-alkanes C7–C30) [18, 20]. The percentage content of each compound was determined by peak area on chromatograms without correction factors.

4. Results

The investigation identified 68 and 50 compounds in *A. nemorosa* and *A. ranunculoides* raw materials, respectively. Identified components of volatile fractions included terpenoids and their derivatives, aliphatic and aromatic hydrocarbons, aldehydes, fatty acids, and others (Table 2).

Table 2

Content (>0.1 %) of volatiles in distillates from *Anemone nemorosa* herb and rhizomes, and *Anemone ranunculoides* herb

Compound	Retention index		Formula	Content (%) in EO samples											Range	Average value
	MS	Library		1	2	3	4	5	6	7	8	9	10	11		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Monoterpenoid																
Safranal	1198	1201	$C_{10}H_{14}O$	0.24	<0.1	0.33	nd	0.22	0.10	0.28	0.24	nd	nd	0.15	nd–0.33	0.22
α-Fellandrene	972	972	$C_{10}H_{16}$	0.10	<0.1	1.16	nd	nd	nd	0.10	nd	nd	nd	nd	nd–1.16	0.45
α-Pinene	975	976	$C_{10}H_{16}$	0.92	0.62	0.31	nd	nd	nd	0.56	nd	nd	nd	nd	nd–0.92	0.60
β-Cyclocitral	1220	1220	$C_{10}H_{16}O$	0.18	0.20	nd	0.85	0.22	nd	nd	0.54	2.64	nd	0.15	nd–2.64	0.68
Fenchyl acetate	1219	1224	$C_{12}H_{20}O_2$	nd	nd	1.79	nd	nd	nd	nd	nd	nd	nd	nd	nd–1.79	1.79
Isobornyl acetate	1285	1288	$C_{12}H_{20}O_2$	<0.1	nd	0.77	0.65	0.11	nd	0.21	0.32	nd	<0.1	0.37	nd–0.77	0.41
Linalool	1098	1099	$C_{10}H_{18}O$	0.36	1.35	0.28	2.43	0.62	1.13	1.70	1.90	1.25	0.66	0.16	0.16–2.43	1.08
(*E*)-β-Damascenone	1385	1386	$C_{13}H_{18}O$	0.50	0.49	0.42	0.74	0.88	0.52	0.29	0.47	0.13	nd	0.11	nd–0.88	0.46
(*E*)-Geranyllinalol	**2032**	**2034**	**$C_{20}H_{34}O$**	0.57	3.40	nd	0.14	2.94	6.61	nd	1.42	nd	nd	nd	**nd–6.61**	**2.51**
Total				2.87	6.06	5.06	4.81	4.99	8.36	3.14	4.89	4.02	0.66	0.94	–	
Diterpenoid																
Phytol	2115	2114	$C_{20}H_{40}O$	7.51	49.77	12.86	27.88	26.97	39.40	24.01	36.33	0.94	0.15	8.26	**0.15–49.77**	**21.28**
(*E*)-Geranyl-acetone	1453	1453	$C_{13}H_{22}O$	0.38	nd	nd	1.11	0.89	0.34	0.93	0.54	2.72	0.89	0.22	nd–2.72	0.89
Total				7.89	49.77	12.86	28.99	27.86	39.74	24.94	36.87	3.66	1.04	8.48	–	
Sesquiterpenoid																
Elemene	1393	1395	$C_{15}H_{24}$	nd	nd	1.03	nd	0.54	0.52	nd	1.17	nd	0.61	nd	nd–1.17	0.77
Caryo-phyllene	1421	1422	$C_{15}H_{24}$	0.24	0.73	nd	1.55	0.26	0.34	0.68	0.49	nd	0.40	0.90	nd–1.55	0.62
(*E*)-β-Farnesene	1458	1457	$C_{15}H_{24}$	0.18	nd	1.14	nd	nd	nd	nd	nd	nd	nd	nd	nd–1.14	0.66
α-Farnesene	1510	1508	$C_{15}H_{24}$	0.18	0.60	1.02	1.07	0.32	1.05	1.16	nd	nd	nd	nd	nd–1.16	0.77
β-Copaene	**1484**	**1486**	**$C_{15}H_{24}O$**	0.80	2.37	5.46	3.80	0.93	nd	1.77	1.03	nd	nd	1.78	**nd–5.46**	**2.24**
Caryo-phyllene oxide	1587	1581	$C_{15}H_{24}O$	nd	0.44	0.17	1.43	nd	nd	0.52	0.49	nd	nd	0.86	nd–1.43	0.65
Acorenone	1695	1685	$C_{15}H_{24}O$	nd	nd	20.71	nd	nd	nd	nd	nd	nd	nd	nd	nd–20.71	20.71
(*E*)-β-Ionone	**1488**	**1486**	**$C_{13}H_{20}O$**	1.65	2.90	3.92	11.63	3.61	2.85	8.57	6.10	0.65	0.24	1.18	**0.24–11.63**	**3.94**
Galaxolide	1862	1851	$C_{18}H_{26}O$	1.01	nd	0.99	0.37	nd	0.45	0.81	0.79	1.10	0.38	1.54	nd–1.54	0.83
Hexahydro-farnesyl acetone	**1851**	**1844**	**$C_{18}H_{36}O$**	26.71	6.10	16.40	8.89	16.69	12.92	8.66	8.98	4.43	0.89	35.68	**0.89–35.68**	**13.30**
Isophytol	1954	1948	$C_{20}H_{40}O$	nd	1.84	0.81	1.66	1.78	4.48	0.48	1.03	nd	nd	0.54	nd–4.48	1.58
Total				30.77	14.98	51.65	30.4	24.13	22.61	22.65	20.08	6.18	2.52	42.48	–	

Continuation of Table 2

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Aldehyde																
Capric aldehyde	1204	1206	$C_{10}H_{20}O$	0.50	0.23	0.45	0.70	0.72	0.50	0.74	0.52	0.92	0.56	0.48	0.23–0.92	0.57
(*E,Z*)-2,4-Decadienal	1315	1317	$C_{10}H_{16}O$	0.55	nd	0.53	0.93	0.46	0.48	0.92	0.80	nd	7.57	nd	nd–7.57	1.53
Tridecanal	1511	1512	$C_{13}H_{26}O$	0.35	nd	nd	nd	0.43	nd	0.23	nd	nd	nd	0.46	nd–0.46	0.37
Undecanal	1306	1307	$C_{11}H_{22}O$	0.30	0.15	0.32	0.39	0.43	0.38	0.47	0.34	0.53	nd	0.17	nd–0.53	0.35
Tetradecanal	1613	1613	$C_{14}H_{28}O$	1.26	0.84	1.48	1.63	1.73	1.37	1.29	1.04	0.52	0.12	0.63	0.12–1.73	1.08
(*Z*)-2-Hexyl-cinnamaldehyde	1750	1755	$C_{15}H_{20}O$	0.64	0.27	0.61	0.13	1.26	0.20	0.41	0.31	0.68	0.34	1.46	0.13–1.46	0.57
2-Butyl-2-octenal	1374	1378	$C_{12}H_{22}O$	nd	nd	nd	nd	nd	nd	nd	nd	6.00	nd	nd	nd–6	6.00
Lauric aldehyde	1408	1409	$C_{12}H_{24}O$	0.62	0.39	0.64	0.64	0.79	0.63	0.71	0.52	0.25	nd	0.32	nd–0.79	0.55
n-Pentadecanal	1715	1715	$C_{15}H_{30}O$	nd	0.24	0.26	0.25	0.81	0.46	0.40	0.35	nd	nd	0.38	nd–0.81	0.39
(*E*)-2-Nonenal	1158	1162	$C_9H_{16}O$	0.53	0.10	0.45	0.29	0.37	0.15	0.32	0.26	1.71	0.69	0.35	0.10–1.71	0.47
Pelargonaldehyde	1103	1104	$C_9H_{18}O$	3.07	1.73	2.59	3.89	3.38	3.15	4.60	3.46	2.03	0.85	2.87	0.85–4.6	2.87
Benzeneacetaldehyde	1042	1045	C_8H_8O	0.43	1.62	0.79	2.34	0.76	2.49	1.49	0.92	1.19	1.28	0.27	0.27–2.49	1.23
(*E*)-2-Octenal	1056	1060	$C_8H_{14}O$	0.32	nd	0.33	0.36	0.25	nd	0.35	0.30	3.62	1.89	0.20	nd–3.62	0.85
Benzaldehyde	958	962	C_7H_6O	<0.01	<0.1	0.13	0.20	<0.1	<0.1	nd	0.07	0.48	0.53	0.10	nd–0.53	0.25
(*E*)-2-Hexenal	848	854	$C_6H_{10}O$	0.75	1.20	1.14	3.16	1.07	1.61	3.54	2.29	0.37	0.33	0.35	0.33–3.54	1.44
Hexanal	**798**	**801**	**$C_6H_{12}O$**	1.60	0.58	1.80	3.98	1.12	0.99	2.06	1.32	5.26	0.65	0.94	**0.58–5.26**	**1.85**
(*E,Z*)-2,4-Heptadienal	1009	1012	$C_7H_{10}O$	0.24	nd	0.25	0.49	0.15	0.11	0.43	0.31	nd	1.37	nd	nd–1.37	0.42
(*E*)-2-Heptenal	954	958	$C_7H_{12}O$	0.30	nd	0.11	0.13	nd	nd	0.13	nd	0.76	0.50	0.14	nd–0.76	0.30
Heptanal	901	901	$C_7H_{14}O$	0.25	<0.1	0.21	0.32	0.19	nd	0.42	0.29	1.28	0.16	0.19	nd–1.28	0.37
3-Furaldehyde	829	831	$C_5H_4O_2$	nd	<0.1	<0.1	<0.1	0.15	<0.1	nd	nd	nd	nd	0.11	nd–0.15	0.13
Total				11.71	7.35	12.09	19.83	14.07	12.52	18.51	13.1	25.6	16.84	9.42	–	
Alcohol																
Lauryl alcohol	1474	1474	$C_{12}H_{26}O$	0.65	0.19	nd	0.28	1.01	nd	nd	nd	1.93	nd	0.62	nd–1.93	0.78
1-Octen-3-ol	978	980	$C_8H_{16}O$	0.19	0.55	nd	nd	nd	0.79	1.75	1.54	3.13	1.40	0.24	nd–3.13	1.20
Total				0.84	0.74	0	0.28	1.01	0.79	1.75	1.54	5.06	1.4	0.86	–	
Acid																
Benzoic acid	1767	1763	$C_{14}H_{12}O_2$	0.74	1.25	0.85	0.98	1.15	0.84	1.39	1.17	1.49	0.53	1.43	0.53–1.49	1.07
Dodecanoic acid	1566	1567	$C_{12}H_{24}O_2$	0.64	nd	nd	nd	0.14	nd	0.23	nd	1.37	nd	1.23	nd–1.37	0.72
Phthalic acid	**1878**	**1869**	**$C_{16}H_{22}O_4$**	4.82	5.88	1.62	nd	5.58	1.52	1.92	1.59	5.96	67.16	2.93	nd–67.16	**9.90**
Capric acid	1369	1373	$C_{10}H_{20}O_2$	0.80	nd	0.10	0.64	0.28	nd	0.35	0.43	nd	nd	1.46	nd–1.46	0.58
***n*-Hexa-decanoic acid**	1972	1968	$C_{16}H_{32}O_2$	25.11	4.36	4.73	nd	6.57	nd	9.40	6.82	16.24	nd	18.3	**nd–25.11**	**11.44**
Palmitic acid	1934	1926	$C_{17}H_{34}O_2$	0.39	0.77	0.25	nd	0.36	0.44	0.35	0.42	0.77	nd	1.24	nd–1.24	0.55
Pelargonic acid	1273	1273	$C_9H_{18}O_2$	1.13	nd	0.27	nd	0.30	nd	nd	0.30	nd	nd	2.55	nd–2.55	0.91
Caprylic acid	1179	1180	$C_8H_{16}O_2$	0.29	nd	nd	nd	nd	nd	nd	0.39	2.02	nd	nd	nd–2.02	0.90
Total				33,92	12,26	7,82	1.62	14.38	2.8	13.64	11.12	27.85	67.69	29.14	–	
Ester																
Dibutyl phthalate	1968	1965	$C_{16}H_{22}O_4$	2.31	1.06	0.78	0.96	2.28	0.87	1.24	1.23	14.17	4.65	2.02	**0.78–14.17**	**2.87**
(*Z*)-9,12,15-Octadeca-trienoic acid, methyl ester	2102	2099	$C_{19}H_{32}O_2$	nd	1.55	nd	nd	0.53	0.78	0.87	nd	nd	nd	1.88	nd–1.88	1.12
Total				2.31	2.61	0.78	0.96	2.81	1.65	2.11	1.23	14.17	4.65	3.9	–	
Hydrocarbon																
Phenanthrene	2085	2080	$C_{20}H_{32}$	nd	0.83	nd	nd	1.47	nd	nd	nd	0.74	nd	nd	nd–1.47	1.01
Pentadecane	1500	1500	$C_{15}H_{32}$	2.17	1.11	2.16	nd	0.32	0.63	nd	nd	nd	nd	nd	nd–2.17	1.28
Tricosane	**2300**	**2300**	$C_{23}H_{48}$	2.35	nd	2.50	3.02	2.74	3.10	5.16	4.70	nd	nd	nd	**nd–5.16**	**3.37**
Pentacosane	2500	2500	$C_{25}H_{52}$	0.84	2.07	nd	1.51	1.29	1.20	1.81	1.58	nd	nd	1.13	nd–2.07	1.43
Heptacosane	2700	2700	$C_{27}H_{56}$	nd	nd	0.29	1.78	nd	0.89	1.42	0.55	nd	nd	nd	nd–1.78	0.99
1,3,7,11-Tride-ca-tetraene	1581	1577	$C_{16}H_{26}$	nd	0.56	nd	0.48	0.75	2.51	nd	nd	nd	nd	0.86	nd–2.51	1.03
Total				5.36	4.57	4.95	6.79	6.57	8.33	8.39	6.83	0.74	0	1.99	–	

Continuation of Table 2

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ketone																
4-Cyclopentene-1,3-dione	882	883	$C_5H_4O_2$	<0.1	0.16	0.14	0.61	0.10	0.22	<0.1	0.21	nd	0.53	<0.1	nd–0.61	0.28
Benzo-phenone	1629	1635	$C_{13}H_{10}O$	0.21	nd	0.18	0.23	0.27	0.24	0.11	0.12	0.34	0.25	0.25	nd–0.34	0.22
3,5-Octadien-2-one	1069	1091	$C_8H_{12}O$	0.08	nd	0.19	0.35	<0.1	nd	0.10	<0.1	2.55	2.21	nd	nd–2.55	0.91
1-Octen-3-one	977	979	$C_8H_{14}O$	0.52	0.55	0.31	1.40	0.26	0.31	1.75	1.54	nd	nd	0.62	nd–1.75	0.81
Total				0.81	0.71	0.82	2.59	0.63	0.77	1.96	1.87	2.89	2.99	0.87	–	
Aromatic compound, geterocycle																
Benzo-thiazole	1221	1228	C_7H_5NS	nd	nd	nd	nd	nd	nd	nd	nd	0.09	2.09	nd	nd–2.09	1.09
Total				0	0	0	0	0	0	0	0	0.09	2.09	0	–	
Aromaric compound, phenol																
Vinylguajacol	1312	1316	$C_9H_{10}O_2$	0.99	nd	1.61	0.59	1.80	0.96	1.22	0.67	nd	nd	0.81	nd–1.8	1.08
Total				0.99	0	1.61	0.59	1.8	0.96	1.22	0.67	0	0	0.81	–	
Aromatic compound, furans																
(*Z*)-2-(2-Pentenyl)-furan	1001	1002	$C_9H_{12}O$	0.39	0.13	0.55	0.83	0.58	0.42	0.41	0.46	0.16	nd	0.17	nd–0.83	0.41
2-Pentylfuran	**991**	**993**	$\mathbf{C_9H_{14}O}$	1.87	0.47	1.76	2.20	1.03	0.89	1.19	1.24	9.58	<0.1	0.87	<0.1–9.58	**2.11**
Total				2.26	0.6	2.31	3.03	1.61	1.31	1.6	1.7	9.74	0	1.04	–	
Content of EO, **mL**/kg				0.65	1.32	0.21	1.64	0.18	0.21	0.33	0.18	1.33	2.31	1.33	–	

Notes: bold – >5 %; nd – not detected.

5. Discussion

According to the Table 2, the key classes of organic compounds in the compositions of essential oils of the studied samples are: aldehydes (30.9–42.4 %), monoterpenoids (6.1–15.5 %), organic acids (4.2–15.8 %), aliphatic and aromatic hydrocarbons (0–8.7 %), sesquiterpenoids (7.9–18.9 %), diterpenoids (1.9–6.1 %), esters (1.8–4.4 %), aromatic compounds (4.4–7.9 %), alcohols (4.4–9.1 %) and ketones (4.4–9.1 %).

The chemical composition and quantitative content of volatile fractions in the plants varies depending on the place of growth; the content of volatile fractions in samples ranges from 0.18 to 2.31 mL/kg.

For *A. nemorosa* L. the main components of volatile fractions of both herb and rhizomes are hexahydrofarnesyl acetone (0.89–26.71 %), dibutyl phthalate (0.87–14.17 %), phytol (0.15–49.77 %), hexanal (0.58–5.26 %), 2-pentylfuran (<0.1–9.58 %), and (*E*)-β-ionone (0.24–11.63 %) (Fig. 2). Additionally, the volatile fractions contain more than 5 % of compounds such as β-copaene, *n*-hexadecanoic acid, (*E*)-geranyl linalool, and tricosane. However, these compounds were not identified in all samples. It should be noted that the composition of volatile fractions of the herb and the rhizomes are quite similar, but there are some differences: (*E*)-geranyllinalol and β-copaene were absent in the rhizomes' distillates; the content of (*E*)-2-octenal and β-cyclocitral was significantly higher in the rhizomes, while the content of phytol and (*E*)-β-ionone was significantly lower compared to the herb.

For a sample of *A. ranunculoides L. herb*, the predominant components are hexahydrofarnesyl acetone (35.68 %), *n*-hexadecanoic acid (18.30 %), phytol (8.26 %), phthalic acid (2,93 %), and pelargonaldehyde (2,87 %).

Fifteen compounds were common across all samples, including aldehydes (hexanal, benzeneacetaldehyde, pelargonaldehyde, (*E*)-2-nonenal, capric aldehyde, tetradecanal, (*Z*)-2-hexylcinnamaldehyde), furans (2-pentylfuran), monoterpenoids (linalool, (*E*)-β-ionone), organic acids (benzoic acid), sesquiterpenoids (hexahydrofarnesyl acetone), diterpenoids (phytol), and esters (dibutyl phthalate).

For most dominant components, low coefficients of variation were determined among the samples (Table 3).

High coefficients of variation (>1) for 2-pentylfuran, phthalic acid, and dibutyl phthalate indicate significant variability in the content of these compounds across the samples [21].

Table 3

Differences in the composition of the main components of volatile fractions in the studied samples

Compound	Retention index		Range, %	Average value	Variation coefficient
	MS	Library			
Hexanal	798	801	0.58–5.26	1.85	0.798
2-Pentylfuran	991	993	<0.1–9.58	2.11	1.268
β-Copaene	1484	1486	nd–5.46	2.24	0.725
(*E*)-β-Ionone	1488	1486	0.24–11.63	3.94	0.898
Hexahydrofarnesyl acetone	1851	1844	0.89–35.68	13.30	0.769
Phthalic acid	1878	1869	nd–67.16	9.90	2.042
Dibutyl phthalate	1968	1965	0.78–14.17	2.87	1.362
n-Hexadecanoic acid	1972	1968	nd–25.11	10.46	0.728
(*E*)-Geranyllinalol	2032	2034	nd–6.61	2.51	0.948
Phytol	2115	2114	0.15–49.77	21.28	0.778
Tricosane	2300	2300	nd–5.16	3.37	0.329

Note: nd – not detected.

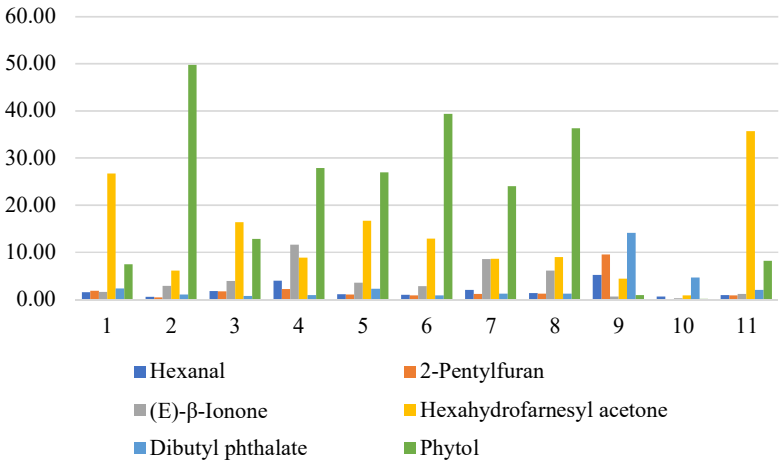

Fig. 2. Content of the main components of the volatile fractions in the studied samples

The percentage content of the main components of volatile fractions in *A. nemorosa* herb, depending on the growth location, is shown in Fig. 3.

It can also be assumed that the storage period of raw materials affects the content of biologically active substances. The total volatile fraction content in samples of herbal raw materials harvested in 2023 (0.18–0.65 %) was lower than in those harvested in 2024 (0.21–1.64 %).

In the study [10], the dominant components in the chloroform fractions of *A. nemorosa* were acetyltributyl citrate, dibutyl sebacinate, and nonadecyl ester of 2,4-difluorobenzoic acid, which were not detected in our raw material samples. Hydrocarbon pentacosane was the component common to our raw material samples and the lipophilic chloroform fractions. To our knowledge, no other results on the study of volatile compounds from these two *Anemone* species have been published as internationally available articles. Thus, the distillates of *A. nemorosa* L. herb, rhizomes, and *A. ranunculoides* L. herb were studied for the first time.

The biological activity of essential oils is not the sum of the activities of their individual components but manifests as the interaction of one component with another [22]. Hexahydrofarnesyl acetone, which belongs to sesquiterpens, is one of the main compounds in all studied samples, exhibits potent antimicrobial properties against gram-positive and gram-negative bacteria [23, 24], has anti-inflammatory and analgetic effects [25], and demonstrates antitumor activity *in vitro* [26]. Diterpene phytol and its derivatives possess antimicrobial, antitumor, antidiabetic, hypolipidemic, spasmolytic, anticonvulsant, antioxidant, anti-inflammatory, anxiolytic activities, stimulate hair growth, and act as an anti-dandruff agent [27]. Phytol is also a component of chlorophyll, vitamin E, and K [22, 28]. (*E*)-β-Ionone capable of slowing tumour growth and inducing apoptosis in gastric adenocarcinoma cells [29]. Dibutyl phthalate is used as a coating component for tablets (e.g., mesalamine) in treating inflammatory bowel diseases [30]. β-Copaene has antioxidant properties and influences cell proliferation [31]. *n*-Hexadecanoic acid exhibits anti-inflammatory, antioxidant and antimicrobial activities [32, 33]. Geranyl linalool is a natural compound found in essential oils and is known for its anti-inflammatory and antioxidant properties. It has shown potential in treating skin diseases and promoting wound healing. Additionally, geranyl linalool demonstrates antimicrobial activity against various pathogens, making it promising in pharmacy and medicine [34, 35]. The hydrocarbon tricosane exhibits antimicrobial properties [36].

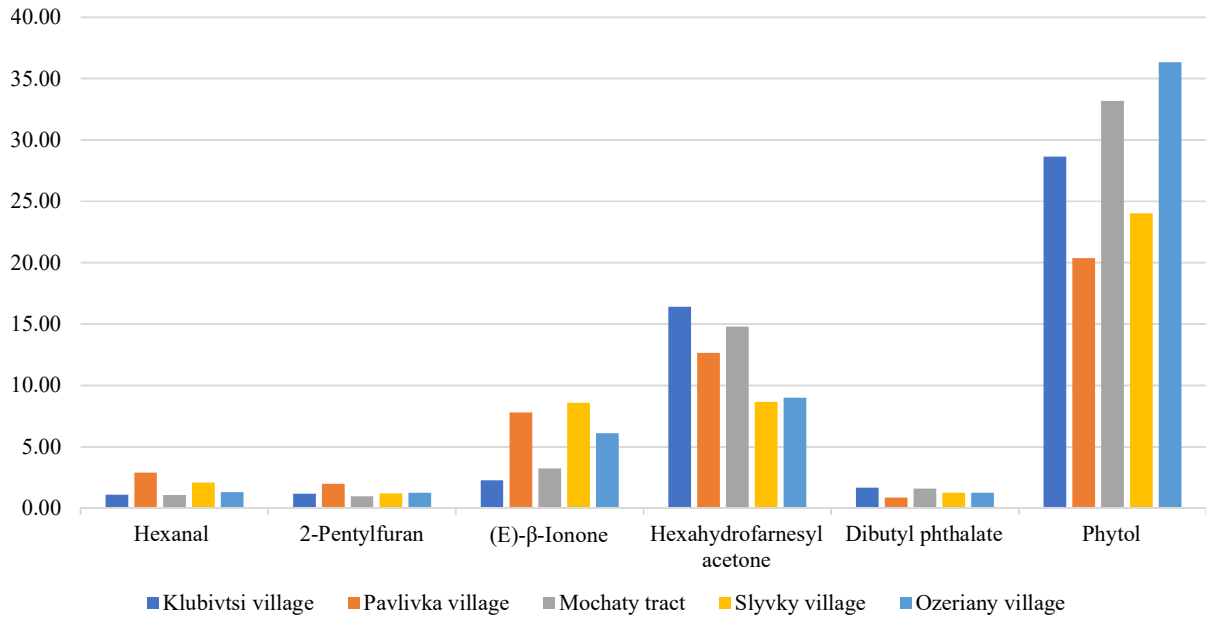

Fig. 3. Percentage content of the main components of essential oils in *Anemone nemorosa* herb depending on the growth location

Practical relevance. New data have been obtained on the chemical composition of volatile fractions in the raw materials of *A. nemorosa* and *A. ranunculoides*. Most of these compounds were identified in these species for the first time. This provides a basis for further study of these raw materials for the development of new plant-based medicinal products.

Research limitations. In the GC/MS method, the obtained mass spectra of the compounds were compared with the spectra from the database library; therefore, it is likely that not all compounds were identified. More detailed results would be obtained if the volatile compound content of both *Anemone* species were presented as separate study results in two tables rather than compared in a common table. On the other hand, such a comparison is essential for assessing the pharmaceutical potential of both plant species.

Prospects for further research. Considering the obtained research results and the presence of compounds such as hexahydrofarnesyl acetone, phytol, geranyl linalool, (*E*)-β-ionone, β-copaene, *n*-hexadecanoic acid, and linalool, it is advisable to study plants of this genus further, their pharmacological activity and the possibilities of further application in medicine.

6. Conclusions

The component composition of volatile fractions in 11 samples of *Anemone L.* species from the flora of Ukraine was analyzed using the GC/MS method. The study identified 68 and 50 compounds in the raw materials of *A. nemorosa* and *A. ranunculoides*, respectively. These compounds include terpenoids and their derivatives, aliphatic and aromatic hydrocarbons, aldehydes, fatty acids, ketones, and others. The main components of the essential oil of *A. nemorosa* were identified as hexahydrofarnesyl acetone, dibutyl phthalate, phytol, hexanal, 2-pentylfuran, and (*E*)-β-ionone. For *A. ranunculoides*, the basic compounds were hexahydrofarnesyl acetone, *n*-hexadecanoic acid, phytol, phthalic acid, and pelargonaldehyde. It was found that the highest concentration of volatile fraction is present in the rhizomes of *A. nemorosa*. The analysis of the component composition of volatile fractions in *Anemone* species indicates the prospects for further research in this plant species, their pharmacological activities, and their applications.

Conflicts of interest

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

Funding

This work was supported by the European Union in the MSCA4Ukraine project “Design and development of 3D-printed medicines for bioactive materials of Ukrainian and Estonian medicinal plants origin” [ID number 1232466]. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the MSCA4Ukraine Consortium as a whole nor any individual member institutions of the MSCA4Ukraine Consortium can be held responsible for them.

Data availability

Data will be made available at a reasonable request.

Use of artificial intelligence

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

Acknowledgement

We are grateful to the associate professor of the Department of Pharmaceutical Management, Drug Technology and Pharmacognosy, Ivano-Frankivsk National Medical University Svitlana Danyliv for botanical assessment and identification of the studied raw materials. The authors sincerely thank all of the defenders of Ukraine whose efforts made this study possible.

References

1. The WFO Plant List. Available at: https://wfoplantlist.org/

2. POWO. Plants of the World Online. Kew Science. Available at: https://powo.science.kew.org/

3. Klokov, M. V., Visylina, O. D., (Eds.) (1953). Flora URSR. Tom V. Kyiv: Vydavnytstvo Akademii nauk Ukrainskoi RSR, 527.

4. Ziman, S. M., Kadota, Y., Bulakh, O. V. (2013). Comparative-morphological approaches to the taxonomy of the genus Anemone L. (Ranunculaceae). Ukrainian Botanical Journal, 70 (2), 152–157. https://doi.org/10.15407/ukrbotj70.02.152

5. Hao, D.-C., Gu, X., Xiao, P. (2017). Anemone medicinal plants: ethnopharmacology, phytochemistry and biology. Acta Pharmaceutica Sinica B, 7 (2), 146–158. https://doi.org/10.1016/j.apsb.2016.12.001

6. Hrodzinskyi, A. M. (Ed.) (1991). Likarski roslyny: Entsyklopedychnyi dovidnyk. Kyiv: Holov. red. URE, 544.

7. Du, K., Zeng, M.-N., Wang, Y.-Z., Liu, Y.-F., Feng, W.-S. (2023). Two new β-carboline alkaloids from the roots of Anemone altaica. Journal of Natural Medicines, 77 (2), 397–402. https://doi.org/10.1007/s11418-023-01679-w

8. Silva, T., De Andrade, P., Paiva-Martins, F., Valentão, P., Pereira, D. (2017). In Vitro Anti-Inflammatory and Cytotoxic Effects of Aqueous Extracts from the Edible Sea Anemones Anemonia sulcata and Actinia equina. International Journal of Molecular Sciences, 18 (3), 653. https://doi.org/10.3390/ijms18030653

9. Shaker, K. H., Göhl, M., Müller, T., Seifert, K. (2015). Indole Alkaloids from the Sea Anemone Heteractis aurora and Homarine from Octopus cyanea. Chemistry & Biodiversity, 12 (11), 1746–1755. https://doi.org/10.1002/cbdv.201400406

10. Khropot, O., Konechnyi, Y., Polish, N., Konechna, R., Bazavluk, Y., Korniychuk, O., Novikov, V. (2019). The Study of the Composition of Chloroform Fraction of Anemone nemorosa L. French-Ukrainian Journal of Chemistry, 7 (2), 153–159. https://doi.org/10.17721/fujcv7i2p153-159

11. Anemone nemorosa CH. Schwabe India. Available at: https://www.schwabeindia.com/product/anemone-nemorosa/

12. Tinctures Anemone. Pine`s Herbals. Available at: https://pinesherbals.com/tinctures/anemone-1

13. Medicaments Homeopathie. Anemone nemorosa Tubes granules. Mon coin Sante. Available at: https://moncoinsante.com/mcs/fr/a-b/9840-anemone-nemorosa-tubes-granules.html

14. Anemone Nemorosa Homeopathy 2 Dram Pellets 6C, 30C, 200C, 1M, 10M. Homeomart Blog. Available at: https://homeomart.net/?s=anemone&orderby=relevance&order=DESC

15. Lukianchuk, A., Khropot, O., Konechnyi, Y., Konechna, R., Novikov, V. (2017). Wood anemone. Anemone Nemorosa L. Analytical review. ScienceRise: Pharmaceutical Science, 3 (7), 34–38. https://doi.org/10.15587/2519-4852.2017.104438

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

17. Vlasova, I., Gontova, T., Grytsyk, L., Zhumashova, G., Sayakova, G., Boshkayeva, A. et al. (2022). Determination of standardization parameters of Oxycoccus macrocarpus (Ait.) Pursh and Oxycoccus palustris Pers. Leaves. ScienceRise: Pharmaceutical Science, 3 (37), 48–57. https://doi.org/10.15587/2519-4852.2022.260352

18. Raal, A., Ilina, T., Kovalyova, A., Koshovyi, O. (2024). Volatile compounds in distillates and hexane extracts from the flowers of Philadelphus coronarius and Jasminum officinale. ScienceRise: Pharmaceutical Science, 6 (52), 37–46. https://doi.org/10.15587/2519-4852.2024.318497

19. 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

20. Raal, A., Komarov, R., Orav, A., Kapp, K., Grytsyk, A., Koshovyi, O. (2022). Chemical composition of essential oil of common juniper (Juniperus communis L.) branches from Estonia. ScienceRise: Pharmaceutical Science, 6 (40), 66–73. https://doi.org/10.15587/2519-4852.2022.271048

21. Raal, A., Ilina, T., Kovaleva, A., Orav, A., Karileet, M., Džaniašvili, M. et al. (2024). Variation in the composition of the essential oil of commercial Artemisia absinthium L. herb samples from different countries. ScienceRise: Pharmaceutical Science, 2 (48), 19–28. https://doi.org/10.15587/2519-4852.2024.302232

22. Dubel, N., Grytsyk, A., Grytsyk, L., Koshovyi, O., Kovaleva, A. (2022). Research in components of essential oils from flowers and leaves of the genus Alchemilla L. species. ScienceRise: Pharmaceutical Science, 3 (37), 34–39. https://doi.org/10.15587/2519-4852.2022.259059

23. Filipowicz, N., Kamiński, M., Kurlenda, J., Asztemborska, M., Ochocka, J. R. (2003). Antibacterial and antifungal activity of juniper berry oil and its selected components. Phytotherapy Research, 17 (3), 227–231. https://doi.org/10.1002/ptr.1110

24. Balogun, O. S., Ajayi, O. S., Adeleke, A. J. (2017). Hexahydrofarnesyl Acetone-Rich Extractives from Hildegardia barteri. Journal of Herbs, Spices & Medicinal Plants, 23 (4), 393–400. https://doi.org/10.1080/10496475.2017.1350614

25. Avoseh, O. N., Mtunzi, F. M., Ogunwande, I. A., Ascrizzi, R., Guido, F. (2021). Albizia lebbeck and Albizia zygia volatile oils exhibit anti-nociceptive and anti-inflammatory properties in pain models. Journal of Ethnopharmacology, 268, 113676. https://doi.org/10.1016/j.jep.2020.113676

26. Jiangseubchatveera, N., Liawruangrath, B., Liawruangrath, S., Teerawutgulrag, A., Santiarworn, D., Korth, J., Pyne, S. G. (2015). The Chemical Constituents and the Cytotoxicity, Antioxidant and Antibacterial Activities of the Essential Oil ofGraptophyllum pictum(L.) Griff. Journal of Essential Oil Bearing Plants, 18 (1), 11–17. https://doi.org/10.1080/097206 0x.2014.935036

27. Islam, Md. T., de Alencar, M. V. O. B., da Conceição Machado, K., da Conceição Machado, K., de Carvalho Melo-Cavalcante, A. A., de Sousa, D. P., de Freitas, R. M. (2015). Phytol in a pharma-medico-stance. Chemico-Biological Interactions, 240, 60–73. https://doi.org/10.1016/j.cbi.2015.07.010

28. Giordani, R., Hadef, Y., Kaloustian, J. (2008). Compositions and antifungal activities of essential oils of some Algerian aromatic plants. Fitoterapia, 79 (3), 199–203. https://doi.org/10.1016/j.fitote.2007.11.004

29. Ansari, M., Emami, S. (2016). β-Ionone and its analogs as promising anticancer agents. European Journal of Medicinal Chemistry, 123, 141–154. https://doi.org/10.1016/j.ejmech.2016.07.037

30. Nassan, F. L., Korevaar, T. I. M., Coull, B. A., Skakkebæk, N. E., Krawetz, S. A., Estill, M. et al. (2019). Dibutyl-phthalate exposure from mesalamine medications and serum thyroid hormones in men. International Journal of Hygiene and Environmental Health, 222 (1), 101–110. https://doi.org/10.1016/j.ijheh.2018.08.008

31. Türkez, H., Çelik, K., Toğar, B. (2013). Effects of copaene, a tricyclic sesquiterpene, on human lymphocytes cells in vitro. Cytotechnology, 66 (4), 597–603. https://doi.org/10.1007/s10616-013-9611-1

32. Aparna, V., Dileep, K. V., Mandal, P. K., Karthe, P., Sadasivan, C., Haridas, M. (2012). Anti-Inflammatory Property of n-Hexadecanoic Acid: Structural Evidence and Kinetic Assessment. Chemical Biology & Drug Design, 80 (3), 434–439. https://doi.org/10.1111/j.1747-0285.2012.01418.x

33. Siswadi, S., Saragih, G. S. (2021). Phytochemical analysis of bioactive compounds in ethanolic extract of Sterculia quadrifida R.Br. International conference on life sciences and technology (ICoLiST 2020), 2353, 030098. https://doi.org/10.1063/5.0053057

34. Kiazolu, J. B., Intisar, A., Zhang, L., Wang, Y., Zhang, R., Wu, Z., Zhang, W. (2016). Phytochemical screening and chemical variability in volatile oils of aerial parts of Morinda morindoides. Natural Product Research, 30 (19), 2249–2252. https://doi.org/10.1080/14786419.2016.1154058

35. Radulović, N. S., Miljković, V. M., Mladenović, M. Z., Nikolić, G. S. (2017). Essential Oils of Morus alba and M. nigra Leaves: Effect of Drying on the Chemical Composition. Natural Product Communications, 12 (1), 115–118. https://doi.org/10.1177/1934578x1701200133

36. Tao, C., Wu, J., Liu, Y., Liu, M., Yang, R., Lv, Z. (2017). Antimicrobial activities of bamboo (Phyllostachys heterocycla cv. Pubescens) leaf essential oil and its major components. European Food Research and Technology, 244 (5), 881–891. https://doi.org/10.1007/s00217-017-3006-z

Received 19.12.2024
Received in revised form 21.01.2025
Accepted 19.02.2025
Published 28.02.2025

Liliia Tuzin, Assistant**,** Department of Pharmaceutical Management, Drug Technology and Pharmacognosy**,** Ivano-Frankivsk National Medical University**,** Halytska str., 2, Ivano-Frankivsk, Ukraine, 76018

Andriy Grytsyk, Doctor of Pharmaceutical Sciences, Professor, Head of Department, Department of Pharmaceutical Management, Drug Technology and Pharmacognosy, Ivano-Frankivsk National Medical University, Halytska str., 2, Ivano-Frankivsk, Ukraine, 76018

Thanh Tung Nguyen, PhD, Lecturer, Department of Pharmacognosy, Hanoi University of Pharmacy, Le Thanh Tong, 15, Ha Noi, Vietnam, 100000

Raal Ain, PhD, Professor**,** Institute of Pharmacy**,** University of Tartu, Nooruse str., 1, Tartu, Estonia, 50411

Oleh Koshovyi, Doctor of Pharmaceutical Sciences, Professor**.** Department of Pharmacognosy**.** National University of Pharmacy**.** Hryhoriia Skovorody str., 53, Kharkiv, Ukraine, 61002**,** Institute of Pharmacy**.** University of Tartu**.** Nooruse str., 1, Tartu, Estonia, 50411

***Corresponding author:** Oleh Koshovyi, e-mail: oleh.koshovyi@gmail.com*