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GC–MS ANALYSIS OF TINCTURES OF *POTENTILLA ERECTA* INTRODUCED IN THE ZAPORIZHZHIA REGION

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Background. One of the major tasks of modern pharmacognosy and pharmaceutical science is the expansion of the medicinal plant raw material base and the development of effective herbal medicinal products derived from it. Particular attention should be paid to *Potentilla erecta* L. (tormentil), which has a long history of use in conventional and traditional medicine as a remedy exhibiting pronounced astringent, anti-inflammatory, and antimicrobial activities.

Aim is to perform an in-depth phytochemical profiling of biologically active compounds in tinctures obtained from rhizomes with roots and the herb of *Potentilla erecta* (L.) Raeusch. using gas chromatography–mass spectrometry in order to identify key quality markers and develop standardization criteria for a novel medicinal plant raw material.

Materials and methods. The objects of the study were tinctures prepared from the herb and rhizomes with roots of *Potentilla erecta* cultivated at the educational and research plot of medicinal plants of Zaporizhzhia State Medical and Pharmaceutical University.

Results. The obtained results are of practical significance for pharmacognostic practice and pharmaceutical science, as they substantiate the prospects for expanding the raw material base through the utilization of the aerial parts of the plant in accordance with the principles of sustainable development and rational environmental management. The established set of phytochemical parameters of the herb and rhizomes with roots of *Potentilla erecta* may be used for reliable identification, quality control, and standardization of medicinal plant raw materials and tinctures derived from them. The identified organ-specific features of the chemical composition and the proposed marker compounds create prerequisites for the development of regulatory documentation for the standardization and quality control of herbal medicinal products.

Keywords: *Potentilla erecta*, herb, rhizomes with roots, tincture, GC–MS.

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ГХ-МС АНАЛІЗ НАСТОЙОК *POTENTILLA ERECTA*, ІНТРОДУКОВАНОЇ В УМОВАХ ЗАПОРІЗЬКОГО РЕГІОНУ
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Проведено газохроматографічно-мас-спектрометричне дослідження настойок трави та кореневищ з коренями *Potentilla erecta* (L.) Raeusch., вирощеної в умовах Запорізького регіону. У настойці з трави ідентифіковано 40 сполук із 44 зафіксованих піків, у настойці з кореневищ з коренями – 26 сполук. Встановлено органоспецифічні відмінності хімічного складу: надземні органи характеризувалися більшою різноманітністю летких і кисневмісних сполук, а підземні – накопиченням жирних кислот, їхніх естерів, терпеноїдів і стероїдів. Визначено перспективні маркерні компоненти для ідентифікації та стандартизації настойок. Отримані результати обґрунтовують доцільність використання трави *P. erecta* як перспективного джерела лікарської рослинної сировини.

Ключові слова: *Potentilla erecta*, трава, кореневища з коренями, настойка, ГХ-МС.

Introduction

In the context of the growing demand for safe and effective herbal medicinal products, comprehensive pharmacognostic and phytochemical studies of promising medicinal plant species are of particular importance. One such species is *Potentilla erecta* L. (tormentil), which is widely used in traditional and official medicine as a remedy with pronounced astringent, anti-inflammatory, and antimicrobial activities [1–3].

Potentilla erecta is a perennial herbaceous plant of the *Rosaceae* family, commonly known as tormentil, traditionally used mainly for the treatment of diarrheal disorders, inflammatory diseases of mucous membranes, and as a component of dental preparations [1; 2]. Its ethnopharmacological significance has also been confirmed in regional medical practices, particularly in Ukraine [4].

The practical significance of *P. erecta* is further supported by its use in registered medicinal products. On the Ukrainian pharmaceutical market, medicinal products containing extracts or tinctures of the underground organs

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of *Potentilla erecta* are available, including Hemorol (marketing authorization No. UA/7628/01/01) and Wundehil (marketing authorization No. UA/7236/01/01). In addition, the State Register of Medicinal Products of Ukraine includes the registered pharmaceutical substance Potentilla Tincture (marketing authorization No. UA/6765/01/01), which is prepared from *P. erecta* rhizomes using a drug-to-extractant ratio of 1:5 with 70 % ethanol as the extraction solvent. According to the relevant regulatory specification, this tincture should contain not less than 2.0 % of total polyphenols, expressed as pyrogallol. In contrast to the registered pharmaceutical substance, the present study investigated tinctures prepared not only from rhizomes with roots but also from the aerial parts (herb) of *P. erecta*. The rhizome-with-roots tincture was prepared at a 1:10 drug-to-extractant ratio, whereas the herb tincture was prepared at a 1:5 ratio using 70 % ethanol as the extraction solvent. These differences in the plant material used and the extraction procedure may substantially influence the phytochemical composition of the tinctures, thereby justifying a comparative phytochemical investigation.

The chemical composition of *Potentilla erecta* is characterized by considerable variability depending on environmental conditions and geographical origin. It has been established that the tannin content in the rhizomes may exceed 15–30 % [2; 5]. The principal biologically active compounds include hydrolyzable and condensed tannins (ellagitannins and proanthocyanidins), as well as derivatives of gallic and ellagic acids, which largely determine the pharmacological properties of the plant [2; 3].

Phytochemical investigations have confirmed the presence of a broad spectrum of secondary metabolites, including phenolic acids, flavonoids, and triterpenoids [6; 7]. It has been demonstrated that the profile of biologically active compounds depends on the extraction solvent: ethanolic extracts are characterized by the highest content of polyphenolic compounds, whereas ethyl acetate extracts are enriched with flavonoids and phytosterols and exhibit enhanced antioxidant activity [8].

The pharmacological properties of *Potentilla erecta* are mainly associated with its polyphenolic complex. Pronounced antioxidant, antimicrobial, and antibiofilm activities of the extracts have been demonstrated, particularly against bacteria of the genus *Staphylococcus* and fungi of the genus *Candida* [9; 10]. In addition, the antitumor activity of the extracts against colorectal cancer cells has been reported [11; 12].

An important aspect is also the bioavailability and metabolism of the components of *Tormentillae rhizoma*. It has been shown that polyphenolic compounds undergo transformation under the influence of intestinal microbiota, resulting in the formation of biologically active metabolites [13; 14].

Recent studies have further expanded the prospects for the application of Pot*entilla erecta* in dermatology and biomedical technologies. In particular, plant extracts are considered promising components of preparations for the treatment of rosacea [15], as well as constituents of bioactive materials and pharmaceutical formulations intended for wound healing [16–18].

Environmental factors, particularly altitude above sea level, have a significant influence on the formation of the plant's chemical profile [5].

Thus, *Potentilla erecta* represents a promising source of biologically active compounds, which substantiates the expediency of its in-depth pharmacognostic investigation. Although the underground organs (rhizomes) are recognized as official pharmacopoeial raw material and have been sufficiently studied, their chemical composition and pharmacological activity still require further standardization, taking into account the influence of environmental factors and metabolite variability. At the same time, the aerial part (herb) of *Potentilla erecta* remains insufficiently investigated, although it may be considered an alternative and more accessible source of biologically active compounds. The species is characterized by broad ecological plasticity; however, within the steppe zone of Ukraine, its distribution is local and fragmented, which justifies the expediency of its cultivation for the preservation of resource potential and the implementation of sustainable development principles. Therefore, comprehensive comparative studies of the underground and aerial organs of the plant are highly relevant for expanding the medicinal plant raw material base, optimizing the use of natural resources, and substantiating the possibility of introducing new types of medicinal plant raw materials into pharmaceutical practice.

Aim is to perform an in-depth phytochemical profiling of biologically active compounds in tinctures obtained from the rhizomes with roots and the herb of *Potentilla erecta* (L.) Raeusch. using gas chromatography–mass spectrometry in order to identify key quality markers and develop standardization criteria for a novel medicinal plant raw material.

Materials and Methods

The objects of the study were tinctures prepared from the rhizomes with roots and the herb of *Potentilla erecta* cultivated at the educational and research plot of medicinal plants of Zaporizhzhia State Medical and Pharmaceutical University during 2024–2025. The aerial parts (herb) of *P. erecta* were collected in July 2024 and 2025 during the full flowering stage, whereas the rhizomes with roots were harvested in October 2024, after the completion of the vegetation period, in accordance with the requirements of the State Pharmacopoeia of Ukraine.

The tinctures were prepared according to the industrial formulation using 70 % ethanol as the extraction solvent from rhizomes with roots (1:10) and herb (1:5) of *Potentilla erecta* (L.) Raeusch. (State Pharmacopoeia of Ukraine, 2015). The component composition of the tinctures was determined by gas chromatography–mass spectrometry (GC–MS) using an Agilent 7890B gas chromatograph coupled with a 5977B mass spectrometric detector at the Gas Chromatography-Mass Spectrometry Laboratory of the Educational and Scientific Medical Laboratory Center with Vivarium of Zaporizhzhia State Medical and Pharmaceutical University.

Chromatographic conditions were as follows: DB-5ms capillary column, 30 m × 250 μm × 0.25 μm; carrier gas – helium, flow rate 1.3 mL/min; injection volume – 0.5 μL; split ratio – 1:5; injector temperature – 265°C. The oven temperature program was set at 70 °C (held for 1 min),

increased to 150 °C at a rate of 20 °C/min (held for 1 min), and then increased to 270 °C at a rate of 20 °C/min (held for 4 min). Component identification was performed using the NIST14 mass spectral library in combination with AMDIS and NIST identification software.

The relative content of the identified constituents was determined using the peak area normalization method without applying response correction factors. The proportion of each compound (%) was calculated as the ratio of the corresponding chromatographic peak area to the total area of all recorded chromatographic peaks. The results are expressed as relative content (%).

Research results and their discussion

As a result of gas chromatography–mass spectrometry analysis of the tincture prepared from the herb of *Potentilla erecta* (Table 1), the composition of volatile and semi-volatile components reflecting the phytochemical

Table 1

Volatile and semi-volatile compounds of the tincture prepared from the herb of *Potentilla erecta* L. identified by GC–MS

No.	Rt, min	Compound name	Relative content, %
1	1.839	1,1-Diethoxyethane	0.78
2	2.822	(E)-3-Hexen-1-ol	0.49
3	4.180	–*	0.51
4	4.378	Tetrahydro-3-furanol	0.55
5	4.927	Benzyl alcohol	0.39
6	5.623	2-Nonanone	0.89
7	6.019	Phenethyl alcohol	0.55
8	6.306	(E)-3-Nonen-2-one	0.91
9	7.107	Allyl 2-ethylbutyrate	0.57
10	7.439	2-Octenoic acid	4.13
11	7.478	2,3-Dihydrobenzofuran	0.44
12	7.820	Ethyl (E)-2-octenoate	0.48
13	7.912	1-Ethyl-1-isopropoxy-1-silacyclohexane	0.55
14	8.067	*meta*-Methoxybenzenethiol	0.80
15	8.773	1-(2-Hydroxy-5-methylphenyl)ethanone	0.51
16	8.976	Ethyl ester of 3-hydroxyhexanoic acid	0.98
17	9.235	2,6-Dimethoxyphenol	1.83
18	9.718	4-Ethylbenzene-1,3-diol	1.36
19	11.937	5-Pentylbenzene-1,3-diol	0.53
20	12.584	Ethyl-*α*-D-glucopyranoside	0.77
21	12.776	Ethyl-*α*-D-glucopyranoside	9.32
22	13.153	Ethyl-*α*-D-glucopyranoside	1.33
23	14.533	Ethyl tetradecanoate	0.44
24	14.950	–	0.46
25	15.053	6,10,14-Trimethyl-2-pentadecanone	0.48
26	15.759	2-Thioxo-2,3-dihydro-1,3-dimethyl-4(1H)-quinazolinone	0.94
27	16.260	*n*-Hexadecanoic acid (palmitic acid)	3.41
28	16.497	Ethyl ester of 9-hexadecenoic acid	1.06
29	16.575	Ethyl hexadecanoate	7.67
30	16.610	cis-2-Benzofuranmethanol, hexahydro-	0.64
31	17.230	4-(3-Mercapto-4-methyl-5-(4H-1,2,4-triazolyl))pyridine	1.64
32	17.569	Isoprenoid sesquiterpene hydrocarbon	6.39
33	17.688	Phytol	3.85
34	17.778	4-Cyclohexylidene-3,3-diethyl-2-pentanone	0.84
35	17.953	9,12,15-Octadecatrienoic acid	1.93
36	18.152	Ethyl linoleate	3.82
37	18.213	Ethyl ester of 9,12,15-octadecatrienoic acid	13.59
38	18.410	Isoprenoid sesquiterpene hydrocarbon	5.07
39	19.370	–	0.65
40	19.553	–	14.86
41	19.747	Stanolone	2.00
42	22.406	*γ*-Sitosterol	0.76
43	22.845	Acetylated polyhydroxylated azulene terpene (azulene derivative)	0.40
44	24.650	*α*-Tocospiro A	0.40

Note: * – unidentified compound.

specificity of the aerial part of the plant was established. The chromatogram revealed 44 chromatographic peaks, of which 40 compounds were identified, while 4 peaks remained unidentified, which may be attributed to the low concentration of the compounds, partial co-elution, or the absence of corresponding spectra in the mass spectral libraries.

The high level of component identification (more than 90 %) indicates the adequacy of the analytical conditions and confirms the informativeness of the GC–MS method for the investigation of ethanolic extracts obtained from the herb of *Potentilla erecta*.

According to their chemical nature, the identified compounds belong to several major classes of biologically active substances:

– fatty acids and their ethyl esters, which constitute the dominant group in terms of total content. Among them, ethyl esters of saturated and polyunsaturated fatty acids, particularly palmitic, linoleic, and linolenic acids, predominated;

– terpenoids and isoprenoid compounds, including phytol and sesquiterpene hydrocarbons, which are characteristic constituents of photosynthetically active tissues;

– phenolic compounds and their derivatives, represented by alkylresorcinols, methoxy-substituted phenols, benzyl alcohol, and phenethyl alcohol;

– carbohydrates and their derivatives, particularly ethyl-*α*-D-glucopyranoside, formed during the ethanolic extraction of mono- and oligosaccharides;

– heterocyclic and nitrogen-containing compounds, detected in minor quantities and potentially representing secondary metabolites or products of biotransformation;

– phytosterols and steroid compounds, including *γ*-sitosterol and stanolone, which are typical constituents of the cell membranes of plants belonging to the Rosaceae family.

The greatest contribution to the total chromatographic profile of the herb tincture was provided by the ethyl ester of 9,12,15-octadecatrienoic (linolenic) acid (13.59 %); an unidentified compound (Rt 19.553 min) (14.86 %); ethyl-*α*-D-glucopyranoside (up to 9.32 %); ethyl hexadecanoate (palmitic acid ethyl ester) (7.67 %); isoprenoid hydrocarbons and terpenoids (more than 10 % in total); and phytol (3.85 %). Such a distribution of compounds indicates the amphiphilic nature of the tincture, which is determined by the use of ethanol as the extraction solvent and by the presence of both lipophilic and hydrophilic compounds in the herb of *Potentilla erecta*.

In the tincture prepared from the rhizomes with roots of *Potentilla erecta*, GC–MS analysis (Table 2) enabled the identification of 26 individual compounds belonging to different classes of organic substances. One chromatographic zone with a retention time of

Table 2

Volatile and semi-volatile compounds of the tincture prepared from the rhizomes with roots of *Potentilla erecta* L. identified by GC–MS

No.	Rt, min	Compound name	Relative content, %
1	3.127	2-Heptanone	0.94
2	8.785	Ethanone, 1-(2-hydroxy-5-methylphenyl)-	0.58
3	8.932	Cyclohexanone, 5-methyl-2-(1-methylethylidene)-	0.83
4	9.371	3-Cyclohexen-1-one, 2-isopropyl-5-methyl-	1.98
5	9.497	(4aS,7S,7aR)-4,7-Dimethyl-5,6,7,7a-tetrahydrocyclopenta[c]pyran-1(4aH)-one	3.41
6	9.918	(4aR,7S,7aS)-4,7-Dimethyl-5,6,7,7a-tetrahydrocyclopenta[c]pyran-1(4aH)-one	19.51
7	10.200	2,3,4,4a,5,6,6a,7,8,9-Decahydropyrano[3,2-h]chromene-5,5,6,6-tetracarbonitrile	2.09
8	10.291	Caryophyllene	1.29
9	10.338	4-Methoxy-1-methylbicyclo[2.2.2]octan-2-one oxime	1.42
10	10.645	4-Hexenoic acid, 2-acetyl-2-methyl-, ethyl ester, (E)-	1.96
11	10.991	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	2.28
12	11.291	1H-Cyclopropa[a]naphthalene, octahydro-1,1,7,7a-tetramethyl-	1.25
13	11.383	2,4,6-Cycloheptatrien-1-one, 2-hydroxy-5-(1-methylethyl)-	2.71
14	12.176	Benzene, 2-ethyl-1,4-dimethyl-	1.17
15	12.734	Ethyl-*α*-D-glucopyranoside	9.49
16	13.101	(S,Z)-2-Methyl-6-(p-toluyl)hept-2-en-1-ol	0.89
17	15.761	4(1H)-Quinazolinone, 2,3-dihydro-1,3-dimethyl-2-thioxo-	0.85
18	16.247	Palmitic acid	0.79
19	16.496	Ethyl 9-hexadecenoate	1.03
20	16.573	Hexadecanoic acid, ethyl ester	10.43
21	17.688	Phytol	5.22
22	17.940	*α*-Linolenic acid	0.85
23	18.150	Linoleic acid, ethyl ester	3.09
24	18.209	9,12,15-Octadecatrienoic acid, ethyl ester, (Z,Z,Z)-	20.49
25	19.545	–*	3.84
26	19.741	Androstan-3-one, 17-hydroxy- (5β,17β)-	0.67
27	22.390	*γ*-Sitosterol	0.96

Note: * – unidentified compound.

19.545 min remained unidentified. In general, the obtained chromatographic profile indicates a high chemical diversity of the tincture derived from the underground organs and reflects the specificity of the secondary metabolism of this species.

The identified compounds were represented by several major chemical classes, among which ketones and cyclic oxygen-containing compounds, terpenoids and their derivatives, fatty acids and their ethyl esters, aromatic compounds, steroid structures, as well as individual glycosidic and heterocyclic derivatives predominated. A significant part of the chromatographic profile was formed by terpenoid compounds, particularly caryophyllene, phytol, and derivatives of naphthalene and pyran systems, which are typical constituents of the underground organs of many representatives of the *Rosaceae* family. The presence of phytol, a degradation product of chlorophyll, indicates the involvement of the isoprenoid biosynthetic pathway in the formation of the chemical composition of the investigated raw material.

As a result of the GC–MS analysis of tinctures prepared from the herb and underground organs of *Potentilla erecta*, it was established that the dominant fraction of the chromatographic profile consisted of fatty acids and their esters. Among these compounds, the highest content was observed for the ethyl ester of 9,12,15-octadecatrienoic (linolenic) acid, amounting to 20.49 % in the tincture from rhizomes with roots and 13.59 % in the herb tincture, while the ethyl ester of hexadecanoic (palmitic) acid accounted for 10.43 % and 7.67 %, respectively. An important characteristic of the tinctures was the high content of ethyl-*α*-D-glucopyranoside, the total proportion of which reached 9.49 % in tinctures from underground organs and 11.42 % in tinctures from aerial organs, as well as phytol, the content of which amounted to 5.22 % and 3.85 %, respectively.

Based on the quantitative content, stability, and available literature data, the following compounds may be considered marker constituents of the tincture prepared from the herb of *Potentilla erecta* L.: phytol; ethyl esters of linolenic and linoleic acids; ethyl-*α*-D-glucopyranoside; alkylresorcinols (benzene diol derivatives); and *γ*-sitosterol, which is consistent with the findings reported by M J. Jamai and M.M. Sami [8]. The presence and ratio of these compounds may be used as criteria for the chemical identification and standardization of the tincture prepared from the herb of *Potentilla erecta*.

An important place in the composition of the tincture prepared from the underground organs is occupied by fatty acids and their esters, among which hexadecanoic (palmitic) acid, linoleic acid, 9,12,15-octadecatrienoic (*α*-linolenic) acid, and the corresponding ethyl esters were identified, which is consistent with the findings of A. Ivanovska et al. [16]. These compounds are characterized by high lipophilicity and significantly influence the total chromatographic peak area. The highest relative content was established for the ethyl ester of 9,12,15-octadecatrienoic acid (20.49 %), as well as for cyclopenta[*c*]pyran derivatives (19.51 %), hexadecanoic acid ethyl ester (10.43 %), and ethyl-*α*-D-glucopyranoside (9.49 %). Collectively, these compounds account for more than two-thirds of the total chromatographic profile of the tincture, indicating their dominant role in the chemical composition of the underground organs of *Potentilla erecta*.

Particular attention should be paid to the presence of steroid compounds, especially *γ*-sitosterol and androstane derivatives, which are characteristic constituents of the underground organs of medicinal plants and may be regarded as pharmacognostically significant compounds. Plant sterols are known to enhance membrane stability and exhibit anti-inflammatory and hypocholesterolemic properties, which is consistent with the traditional use of preparations obtained from the rhizomes of *Potentilla erecta* and has also been confirmed by other researchers [1; 13].

Conclusions

As a result of the GC–MS analysis of the tincture prepared from the herb of *Potentilla erecta*, 40 compounds were identified out of 44 recorded chromatographic peaks. In the tincture prepared from the rhizomes with roots of *Potentilla erecta*, 26 individual compounds were identified, while only one component remained unidentified. The chromatographic profile of the underground organs was characterized by a lower number of compounds but a considerably higher concentration of several dominant constituents. The chemical composition of the herb tincture was characterized by substantial diversity of components represented by fatty acids and their ethyl esters, terpenoids, phenolic and aromatic compounds, carbohydrates and their derivatives, as well as steroid structures.

Comparative analysis demonstrated a clear organ-specific differentiation of the chemical composition of the tinctures. The aerial organs of *Potentilla erecta* were characterized by a greater diversity of volatile and oxygen-containing low-molecular-weight compounds, whereas the rhizomes with roots were characterized by the accumulation of lipophilic constituents, including fatty acids, their esters, terpenoids, and steroid compounds. The content of steroids (*γ*-sitosterol – 0.96 %; androstan-3-one, 17-hydroxy-(5β,17β)- – 0.67 %) was a characteristic feature of the underground organs and was practically absent in the herb tincture.

Based on quantitative content, stability, and reproducibility, the following compounds may be considered marker constituents of the tincture prepared from the herb of *Potentilla erecta:* phytol, ethyl esters of linolenic and linoleic acids, ethyl-α-D-glucopyranoside, alkylresorcinol derivatives, and *γ*-sitosterol. For the tincture prepared from the rhizomes with roots, the most informative markers were the ethyl ester of 9,12,15-octadecatrienoic acid, cyclopenta[c]pyran derivatives, ethyl hexadecanoate, phytol, and *γ*-sitosterol.

The obtained results confirm the expediency of separate phytochemical analysis of the aerial and underground organs of *Potentilla erecta* and indicate the prospects for expanding the medicinal plant raw material base through the utilization of the aerial part of the plant in accordance with the principles of sustainable development and rational use of natural resources. The obtained data may be used to improve approaches to the standardization and quality control of tinctures prepared from different morphological parts of the plant.

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