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Phacelia tanacetifolia as a Promising Object for Pharmacognostic Research

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Currently, there is an increasing interest in studying the chemical composition of the above-ground part of *Phacelia tanacetifolia Benth*., honey based on the plant, individual biologically active compounds, and results of studying the pharmacological activity of this promising species are emerging.

The aim. To conduct a review and systematization of scientific data on the chemical composition, and application in medicine and pharmacy of the promising plant *Phacelia tanacetifolia.*

Materials and Methods. For searching scientific literature, data posted in the electronic databases elibrary.ru, Cyberleninka, Google Scholar, and PubMed were used. Publication search was conducted for the period from January 2001 to January 2026. The final number of works included in this review was 69.

Results. As a result of analyzing scientific literature data, the work characterizes the Boraginaceae family, the Phacelia genus, and the *Phacelia tanacetifolia* species; the main groups of biologically active compounds and the chemical composition of the studied object. The main aspects of studying *Phacelia tanacetifolia* as a honey-producing plant and green manure are presented. The results of the pharmacological activity of phacelia honey are presented. The potential pharmacological activity of *Phacelia tanacetifolia* is formulated.

Conclusion. A comprehensive search for information on *Phacelia tanacetifolia* abroad and in Russia has been conducted. Based on the results of the work, the expediency of a deeper study of the selected plant object for its application in medicine and pharmacy is justified.

Keywords: *Phacelia tanacetifolia* Benth.; phenolic compounds; chlorogenic acid; hydroxycinnamic acids; flavonoids; phenolamides; obesity; hyperlipidemia

Abbreviations: BACs — biologically active compounds; MPRMs — medicinal plant raw materials; RD — regulatory document; HPLC — high-performance liquid chromatography; DHBA — dihydroxybenzoic acid; DOPAC — dihydroxyphenylacetic acid; HBA — hydroxybenzoic acid; CA — caffeic acid; HA — hippuric acid; HPA — hydroxypicolinic acid; HVA — 4-hydroxy-3-methoxyphenylacetic acid; HPPA — hydroxyphenylpyruvic acid; FA — ferulic acid, BA — benzoic ACID; ERC — eriocitrin; ERI — eriodictyol; FIS — fisetin; HSD — hesperidin; HST — hesperetin; NAR — naringenin; NARG — naringin; NHSD — neohesperidin; NRI — narirutin; PIN — pinocembrin; QUE — quercetin; R-ERI — R-enantiomer of eriodictyol; R-NAR — R-enantiomer of naringenin; RUT — rutin; S-ERI — S-enantiomer of eriodictyol; S-HST — S-enantiomer of hesperetin; S-NAR — S-enantiomer of naringenin; TAX — taxifolin, LDLs — low-density lipoproteins.

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Фацелия пижмолистная как перспективный объект фармакогностического исследования

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На сегодняшний день наблюдается увеличение интереса к изучению химического состава надземной части фацелии пижмолистной (*Phacelia tanacetifolia* Benth.), мёда на основе растения, к отдельным биологически активным соединениям, а также появляются результаты изучения фармакологической активности этого перспективного вида.

Цель. Провести обзор и систематизацию научных данных о химическом составе, применении в медицине и фармации перспективного растения — фацелии пижмолистной (*Phacelia tanacetifolia* Benth.).

Материалы и методы. Для поиска научной литературы использовали данные, размещённые в электронных базах elibrary.ru, Киберленинка, Google Академия и PubMed. Поиск публикаций проводили за период с января 2001 по январь 2026 гг. Итоговое число работ, включённых в настоящий обзор, составило 69.

Результаты. В результате анализа данных научной литературы в работе охарактеризованы семейство бурачниковые, род Фацелия, вид фацелия пижмолистная; основные группы биологически активных соединений и химический состав изучаемого объекта. Приведены основные аспекты изучения фацелии пижмолистной как растения-медоноса и сидерата. Представлены результаты фармакологической активности фацелиевого мёда. Сформулирована потенциальная фармакологическая активность фацелии пижмолистной.

Заключение. Проведён всесторонний поиск информации о фацелии пижмолистной за рубежом и в России. На основании результатов работы обоснована целесообразность более глубокого изучения выбранного растительного объекта для применения его в медицине и фармации.

Ключевые слова: фацелия пижмолистная; *Phacelia tanacetifolia* Benth.; фенольные соединения; хлорогеновая кислота; гидроксикоричные кислоты; флавоноиды; феноламиды; ожирение; гиперлипидемия

Список сокращений: БАС — биологически активные соединения; ЛРС — лекарственное растительное сырьё; НД — нормативный документ; ВЭЖХ — высокоэффективная жидкостная хроматография; DHBA —дигидроксибензойная кислота; DOPAC — дигидроксифенилуксусная кислота; HBA — гидроксибензойная кислота; CA — кофейная кислота; HA — гиппуридная кислота; HPA —гидроксипиколиновая кислота; HVA — 4-гидрокси-3-метоксифенилуксусная кислота; HPPA — гидроксифенилпировиноградная кислота; FA — феруловая кислота, BA — бензойная кислота; ERC — эриоцитрин; ERI — эриодиктиол; FIS — физетин; HSD — гесперидин; HST — гесперетин; NAR — нарингенин; NARG — нарингин; NHSD — неогесперидин; NRI — нарирутин; PIN — пиноцембрин; QUE — кверцетин; R-ERI — R-энантиомер эриодиктиола; R-NAR — R-энантиомер нарингенина; RUT — рутин; S-ERI — S-энантиомер эриодиктиола; S-HST — S-энантиомер гесперетина; S-NAR — S-энантиомер нарингенина; TAX — дигидрокверцетин, ЛПНП — липопротеины низкой плотности.

INTRODUCTION

Disorders of lipid and carbohydrate metabolism are leading pathogenetic factors of metabolic syndrome (obesity, dyslipidemia, diabetes mellitus, fatty liver disease, cardiosclerosis, ischemic heart disease [IHD]), which reduce both the duration and quality of life of modern humans [1].

Obesity and overweight are a widespread problem worldwide. More than 2 billion adults (approximately 30 % of the global population) are overweight or obese. In Russia, according to literature data, the number of people with excess in 2021 was 40.3 % [2, 3]. Furthermore, overweight and obesity are established risk factors for IHD. Data from a meta-analysis on the prevalence of overweight (from 3.9 % to 29.1 %) and obesity (1.2 % to 25.3 %) in the Russian Federation in the pediatric population are particularly concerning. Exogenous-constitutional obesity is the most common form in adolescence [4].

Modern research has established that

lipotoxicity accelerates apoptosis and causes inflammatory reactions, leading to chronic liver disease. In the pathogenesis of obesity, as a chronic proinflammatory disease, macrophages, oxidative stress, and hereditary predisposition play a significant role. Additionally, oxidized lipids and proteins can be cytotoxic, cause damage to membranes and membrane-bound receptors, provoke enzymatic dysfunction, disrupt signaling cascades, trigger asthma development, and activate proinflammatory processes [5, 6].

Currently, Russian scientific medicine uses about 300 species of medicinal plants. In addition to species already in demand in medicine and pharmacy, the importance of new, little-studied plant sources of biologically active compounds (BACs), including those promising for disorders of lipid and carbohydrate metabolism, should be noted [7, 8]. In this regard, plant raw materials containing phenolic compounds are of interest, as the etiology of many diseases (cardiovascular diseases, diabetes mellitus, atherosclerosis) is associated with hyperlipidemia. Hyperlipidemia is a leading factor determining the development of non-alcoholic fatty liver disease, leading to dysfunction and disruption of other bodily systems and metabolic processes [9].

According to L.V. Vasileva, et al. [10], chlorogenic and caffeic acids are involved in the regulation of adipocyte differentiation and metabolism, and chlorogenic acid is characterized by effects leading to weight loss, suppression of lipogenesis, and reduction of liver steatosis [11].

Identifying promising medicinal plants and their BACs that can exhibit hypolipidemic, hypocholesterolemic, hypoglycemic, and other types of activity is relevant. Such plants include *Phacelia tanacetifolia* Benth. (*P. tanacetifolia)*, from the *Boraginaceae* family, which is a cultivated species in the Russian Federation [12].

This plant has acclimatized in Russia and has effectively become “native,” which is due to its abundant self-seeding. One of the features of *P. tanacetifolia* is its short vegetation period. It can be grown in conditions of a short summer, therefore this plant is widely cultivated in various regions of Russia—the Omsk region and even in Siberia [13, 14].

Recently, *P. tanacetifolia* has begun to be cultivated in the North Caucasus, and especially in the Stavropol territory, where it has started being actively used as a popular honey plant [15].

In the North Caucasus, including the Caucasian Mineral Waters region, under conditions of a long, almost six-month frost-free period, *P. tanacetifolia* can yield several harvests: early sowings are possible in early April, the main vegetation and flowering period occurs in the first half of summer, late sowings are possible in June, with the main vegetation and flowering period in July–August [16].

Previously, research on this plant primarily focused on studying its morphological diagnostic features, allelopathic potential, herbicidal properties, and the use of phacelia as a honey and fodder crop. Currently, there is an increasing interest in studying the chemical composition of the above-ground part of phacelia, honey based on the plant, individual BACs contained within them, and results of studying the pharmacological activity of this promising species are emerging. In recent years, data have been obtained and published confirming the presence of aromatic acids, phenolic compounds (flavonoids, anthocyanins, hydroxycinnamic acids, tannins), amino acids (tyrosine, phenylalanine), phenylamides, and some essential minerals in the chemical composition of *Phacelia tanacetifolia*. Results have been obtained on the study of the antioxidant activity of phacelia honey [14, 17].

Given the trend of studying *P. tanacetifolia* by scientists from around the world and the discovery of new properties of the plant, we believe it is relevant to analyze the obtained information and summarize the accumulated research experience found in both scientific literature and our own work in this review.

No studies on the pharmacognostic examination of *P. tanacetifolia* cultivated in Russia have been found. The potential of using *P. tanacetifolia* from the *Boraginaceae* family as a source of medicinal plant raw material (MPRM) makes it relevant to investigate the biochemical characteristics of this plant for introduction purposes.

The use of cultivated plants as sources of MPRM ensures a stable raw material base, less variability in chemical composition, and the possibility of using mechanized sowing, processing, and harvesting.

No less important for introduced species, including *P. tanacetifolia*, is reproduction by seed, as the required amount of plant material can be obtained in the year of sowing. According to literature data and our own research, the yield of raw phytomass is established at 280–300 c/ha, and seeds at 4.5–5.5 c/ha [18–20].

The revival of medicinal plant cultivation in Russia is well-founded, as the country has significant ecologically clean territories suitable for growing about 70 % of medicinal plants for the production of phytopreparations under industrial conditions. This issue is of particular relevance in accordance with the Strategy for the Development of the Pharmaceutical Industry of the Russian Federation for the period up to 2030[1], approved by the Government of the Russian Federation, the main vector of which is the development and implementation of domestically produced medicinal drugs.

We also consider it necessary to note that the organic farming system, which is given great importance in Russia, will prevent risks of contamination of *P. tanacetifolia* raw material. The availability of domestic agricultural technology will allow influencing the quality of the harvest of the above-ground mass of *P. tanacetifolia*, the accumulation of secondary metabolites, and protect the plant from pests and diseases.

The noted characteristics allow us to consider *P. tanacetifolia* as a promising plant for industrial production.

THE AIM. To review and systematize scientific data on the chemical composition, use in medicine and pharmacy, and to justify the need for further study of the promising plant *Phacelia tanacetifolia* Benth.

MATERIALS AND METHODS

For this review, texts from available scientific information sources, located in the electronic databases eLibrary, CyberLeninka, Google Scholar, and PubMed, were analyzed. The search for publications was conducted for the period from January 2001 to January 2026, with a search depth of 25 years. The period of search and analysis of scientific literature was 23 months, with the first query made in March 2024 and the last in January 2026. To identify relevant publications, combinations of terms in Russian and English were used. During the analysis, searches were conducted using the following keywords: фацелия, Phacelia, *Phacelia tanacetifolia* Benth., фацелия пижмолистная, виды фацелии, фенольные соединения, phenolic compounds, «гидроксикоричные кислоты, флавоноиды, flavonoids, феноламиды, фенилпропаноиды, гидроксициннаматы, ожирение, гиперлипидемия.

Using the main keyword «Phacelia» in the PubMed database, with the filter set for data from 2021–2026, 103 articles were found. During the process, articles were excluded after specifying the query to «*Phacelia tanacetifolia*» (*n* = 53), removing duplicates (*n* = 10), and excluding non-full-text articles (*n* = 21). A total of 19 articles were included in the review. In the CyberLeninka database, 391 articles were found. After specifying the query («*Phacelia tanacetifolia*»), 320 articles were excluded, duplicates were removed (*n* = 15), and works not relevant to the given keyword query were discarded (*n* = 7). A total of 49 articles were selected for acceptability assessment, of which 5 sources were included in the review. For the same keyword query in the eLibrary, 1602 scientific works were found (2001–2026). After specifying the query («*Phacelia tanacetifolia*»), 1263 articles were excluded due to irrelevance to the given query (*n* = 267), duplicates were removed (*n* = 34), and non-full-text articles were excluded (*n* = 22). A total of 16 articles were studied, of which 2 scientific articles were included in the review. In the Google Scholar database, 15,300 works were found for the query «Phacelia». During the process, articles were excluded after specifying the query to «*Phacelia tanacetifolia*» (*n* = 9290), removing duplicates (*n* = 2096), discarding sources not relevant to the given query (*n* = 3150), and excluding non-full-text articles (*n* = 456). A total of 308 scientific works were analyzed, 11 of which were included in the review.

The process of selecting literature sources and preparing the review was conducted according to the PRISMA 2020[2]. Figure 1 shows a flowchart reflecting the publication search strategy.

A total of 6 492 sources of information were found, in accordance with our specified search query («фацелия» and «*Phacelia*») after it was refined to the query *«Phacelia tanacetifolia»,* and the final number of works included in this review was 37. Data from our own research on the study of the phytochemical properties, quantitative determination of the main groups of biologically active substances of *Phacelia tanacetifolia*, and its pharmacological activity were also used; a total of 10 works were included in the review. The remaining 22 sources were used to justify the relevance of studying *Phacelia tanacetifolia*, its potential pharmacological activity, and its possible application for the treatment and prevention of diseases associated with excess body weight.

[1] Government Decree No. 1495-r dated June 7, 2023 "Strategy for the Development of the Pharmaceutical Industry of the Russian Federation for the period up to 2030". Available from: http://static.government.ru/media/files/HqCzKkoTf7fzVdKSYbhNiZHzWTEAAQ3p.pdf. Russian

[2] The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. Available from: https://www.equator-network.org/reporting-guidelines/prisma/

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RESULTS AND DISCUSSION

Characteristics of the families *Hydrophyllaceae* and *Boraginaceae*

To date, the status of the family *Hydrophyllaceae* is not defined and is debatable.

According to the classification of A.L. Takhtajan (1982)[3], it is an independent family belonging to the order *Polemoniales*, subclass *Asteridae*. In later classifications by A.L. Takhtajan, the family was assigned to the order *Solanales*, subclass *Lamiidae*, then to the order *Boraginales* of the same subclass[4].

Following Western systems of flowering plant classification, the family *Hydrophyllaceae* is either not distinguished at all, or is distinguished at the rank of subfamily within the family *Boraginaceae*, order *Boraginales*[5]. Plants of the World[6] also adheres to this status. Representatives of the family *Hydrophyllaceae* are exclusively American species, not found in the natural flora of the Old World.

Previously, in our works, we indicated *Phacelia tanacetifolia* as a representative of the family *Hydrophyllaceae*. However, the APG IV (Angiosperm Phylogeny Group, 4th ed.) system of flowering plants is currently considered current, according to which *Phacelia tanacetifolia* belongs to the family *Boraginaceae* [21].

Characteristics of the genus *Phacelia* Juss.

The genus *Phacelia* is the most numerous genus of the family *Boraginaceae*, including up to 209 species (according to Plants of the World).

All phacelias are annual or perennial herbs (biennials are possible) with a height of 60 cm to 120 cm. The habitat of Phacelia extends from Alaska in the north to Argentina in the south and is more concentrated in the western half of the American continent. At the same time, phacelia is not found on the Labrador Peninsula (Canada) and in the tropical forests of Brazil, Venezuela, and Colombia. The natural habitats of Phacelia are dry forests, steppes, and semi-deserts, including mountainous areas [22].

Phacelia are characterized by a cymose inflorescence—a scorpioid cyme or helicoid cyme, collected in an umbellate thyrse. The flowers are regular, the perianth is double, pentamerous, the corolla is often brightly colored in blue, purple, or pink. There are 5 stamens; in some species, the stamens protrude from the throat of the corolla. The fruit is a capsule [13, 17]. The leaves of different species of *Phacelia* vary from simple rounded leaves to complex odd-pinnately dissected leaves.

Some species of phacelia have been introduced into cultivation in Russia. Currently, 5 species are cultivated in our country: *Phacelia sericea* (Graham) A.Gray, *Phacelia campanularia* A.Gray, *Phacelia congesta* Hook., *Phacelia purshii* Buckley, and *Phacelia tanacetifolia* Benth. The first four species are known only as ornamental and are not widely cultivated [23].

Characteristics of the *Phacelia tanacetifolia* Benth.

The native region of *Phacelia tanacetifolia* is the western part of North America: the states of California, Arizona (USA), Baja California and Sonora, and adjacent territories (Mexico) [23, 24]. It grows in a dry subtropical climate. It ascends into the mountains (1500 meters above sea level). The plant collector David Douglas (1798–1834) brought the plant to Scotland from his travels in North America and California in 1832. In 1837, it was described by the English botanist G. Bentham. From England, Phacelia soon reached Germany and then spread throughout Europe, including Russia [24].

Despite the fact that the natural range of *Phacelia tanacetifolia* is located in the subtropical geographical zone, the plant is easily introduced into cultivation in countries with a temperate climate, up to the Arctic Circle. Currently, *Phacelia tanacetifolia* is distributed almost throughout the USA and most of Canada [24, 25]. It has been introduced into cultivation in almost all European countries.

Phacelia tanacetifolia is an annual herbaceous plant, the height of which can vary from 60 cm to 120 cm. The plant is completely covered with dense short and sparse long white hairs. It has an erect stem, branching in the upper part. The leaves are alternate, pinnately dissected, 8–9 cm long, 4–5.5 cm wide, with unevenly serrated-dentate margins [26, 27].

The leaves, in their shape and dissection, resemble the leaves of common tansy, which led to the specific name [28]. The inflorescence of *Phacelia tanacetifolia* can be characterized as cymose, which is typical for

[3] Plant Life: In 6 volumes. Vol. 5; part 2. Flowering plants; A.A. Fedorov, chief editor; A.L. Takhtajyan, editor. Moscow: Prosveshchenie; 1981. 511 p. Russian

[4] Takhtajan System of Angiosperm Classification; 1997.

[5] The Plant List (2013). Version 1.1. Available from: http://www.theplantlist.org/

[6] POWO (2025). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Available from: https://powo.science.kew.org/

plants of the family *Hydrophyllaceae*. The inflorescence is a thyrse of large spike-like scorpioid cymes [17, 29].

The flowers are collected in a dense one-sided inflorescence—a spike-like scorpioid cyme. The flowers are actinomorphic, sometimes slightly zygomorphic in inflorescences, the perianth is double [29]. The calyx is gamosepalous, 6–7 mm long, consisting of five sepals. The corolla is gamopetalous, 8 mm long, bell-shaped, with auricles, five petals, the corolla color is light blue-violet. It can change slightly depending on the flowering phase. There are 5 clearly visible, long stamens. The color of the stamens is similar to the color of the petals, which can be a characteristic diagnostic feature of this species [13, 17, 28, 29]. The gynoecium is syncarpous, consisting of two carpels forming a pistil. The fruit is a bivalve capsule, spherical or ovoid [13, 29].

The habit of the plants is important for raw material harvesting. *Phacelia tanacetifolia* has an erect stem, which allows for mechanized harvesting on an industrial scale. Characterizing its biological features, the plant is very productive; in our climatic conditions, it is possible to harvest raw materials twice in one summer season, as the seeds of *Phacelia tanacetifolia* have high germination energy. The high viability of the plant in the conditions of southern Russia is ensured by self-seeding, which we have repeatedly observed in the Botanical Garden of the Pyatigorsk Medical Pharmaceutical Institute — branch of Volgograd State Medical University [30].

Our study of the morphological and anatomical characteristics of the raw material—Phacelia tanacetifolia herb—allowed us to establish the main macro- and microscopic diagnostic features [31].

Chemical composition of *Phacelia tanacetifolia*

Until recently, searching for information on the chemical composition of the plant in scientific literature was a difficult task. Due to the expansion of areas where *P. tanacetifolia* is grown, not only abroad but also in Russia, researchers are increasingly studying the chemical composition of various parts of the plant.

Thus, the study of the composition of roots, leaves, stems, and flowers of *P. tanacetifolia* using high-performance liquid chromatography (HPLC) established the presence of phenolic compounds: some phenolic acids and flavonoids [32]. As a result, researchers S. Bajkacz, et al. discovered phenolic acids: gallic, caffeic, 4-hydroxybenzoic, 3,4-dihydroxybenzoic; and flavonoids: rutin, quercetin, hesperidin, naringin, eriocitrin (Fig. 2) [32]. The detection of phenolic compounds was carried out using alcoholic extracts obtained from the flowers, leaves, stems, and roots of *P. tanacetifolia*. The amount of phenolic compounds (phenolic acids and flavonoids) in the *P. tanacetifolia* extracts was 21.9 μg/g.

In all studied samples of phacelia analyzed by HPLC-MS/MS, rutin (flavonoid) and 4-hydroxybenzoic acid (phenolic acid) predominated; however, no significant difference was found in their content in flowers and leaves. The highest content of flavonoids was found in the flowers of phacelia (from 0.16 ng/g to 13.922 ng/g). The compounds with the highest concentrations in the flower samples were rutin, followed by hesperidin and neohesperidin. A higher content of phenolic acid (4-hydroxybenzoic acid) was also observed in the flowers of phacelia (from 0.80 ng/g to 4784 ng/g). Data obtained for hippuric acid, 3-hydroxybenzoic acid, and 3-hydroxypicolinic acid mainly indicated lower concentrations compared to other acids [32].

J. Kruk, et al. in their study investigated the distribution of some flavanones (eriodictyol, liquiritigenin, naringenin, hesperetin)—enantiomers in free form and bound to glycosides in different parts of *P. tanacetifolia* (Fig. 3).

As a result, the highest content of hesperetin was determined in the leaves of phacelia (0.38 μg/g), where it was present as a glycoside and only as the (S)-enantiomer [33].

The results of the analysis of the chemical composition of different parts of *P. tanacetifolia* are presented in Table 1.

Thin-layer chromatography confirmed the presence of flavonoids (rutin, quercetin), phenolic acids (caffeic, gallic, chlorogenic) in the herb of *P. tanacetifolia*. Hydrolyzable tannins and flavonoids were detected by qualitative reactions [34]. Quantitative spectrophotometric analysis allowed for the determination of the main active substances in the herb of the studied plant: flavonoids (2.3 % ± 0.17), phenolic acids (2.9 % ± 0.15), anthocyanins in flowers (0.53 % ± 0.09) [35, 36].

HPLC analysis of *P. tanacetifolia* herb was used to identify and quantify phenolic compounds (hydroxycinnamic acids—gallic (2.02 mg%), chlorogenic (9.48 mg%), ferulic (7.50 mg%), caffeic (4.27 mg%); flavonoids—quercetin (1.4 mg%), luteolin, apigenin, rutin (0.9 mg%), hyperoside; coumarins—umbelliferone) [37, 38].

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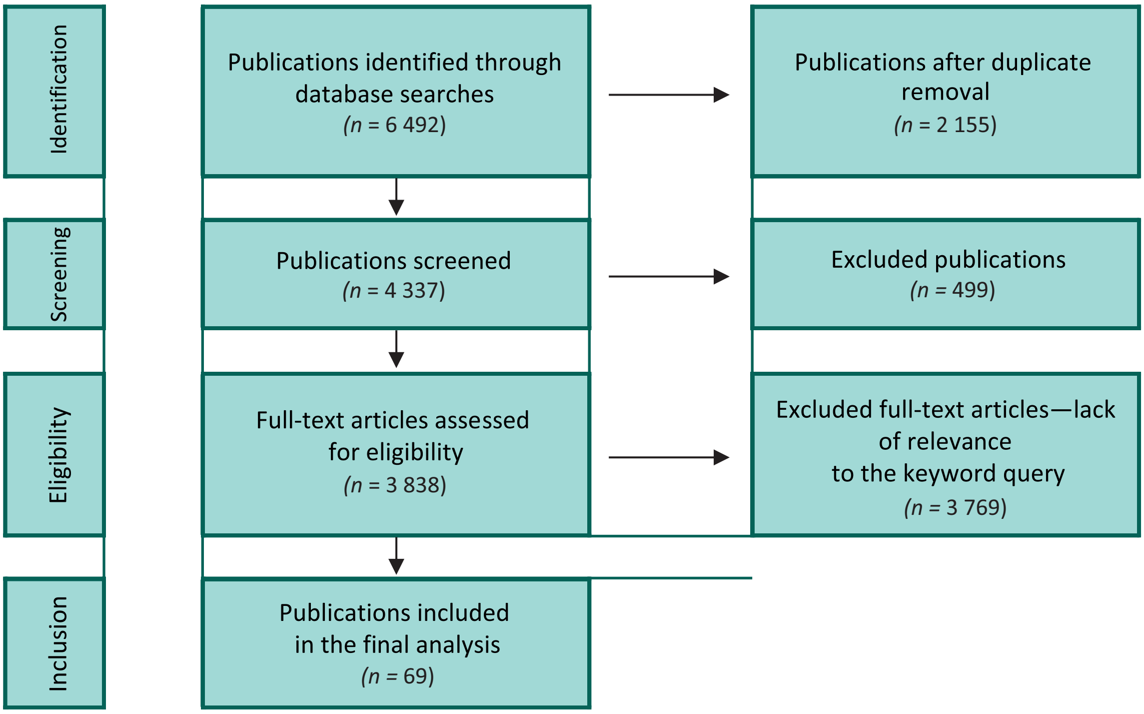

Figure 1 — Flowchart of literature source selection.

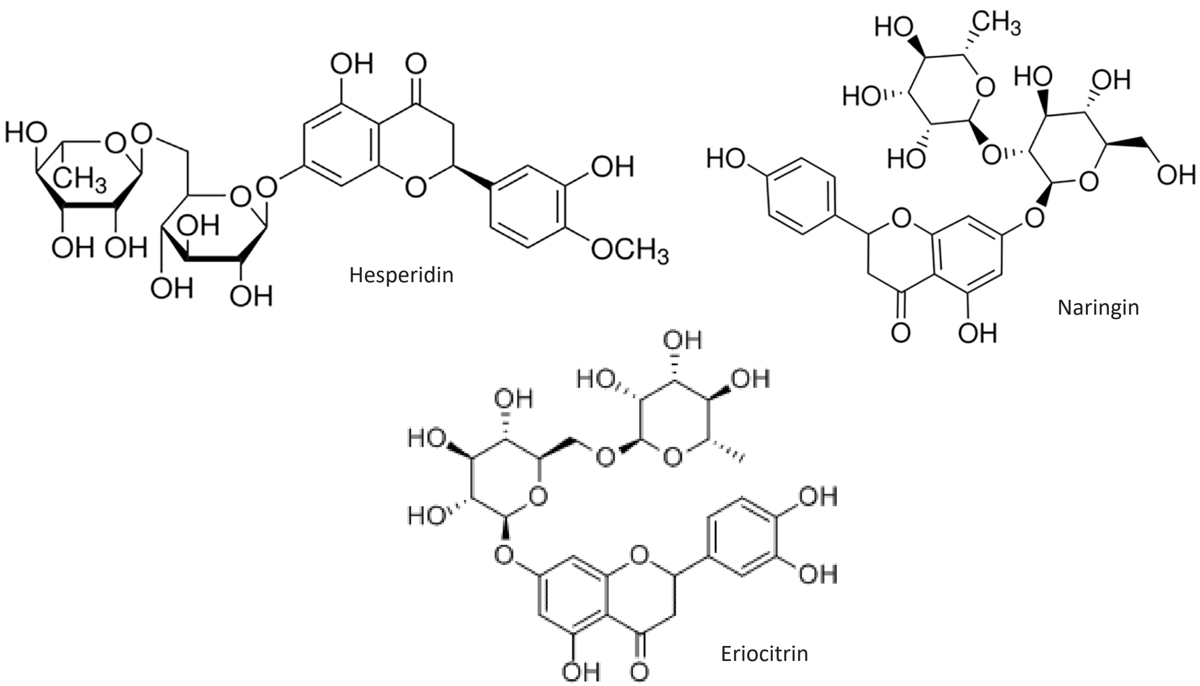

Figure 2 — Structural formulas of hesperidin, naringin, eriocitrin.

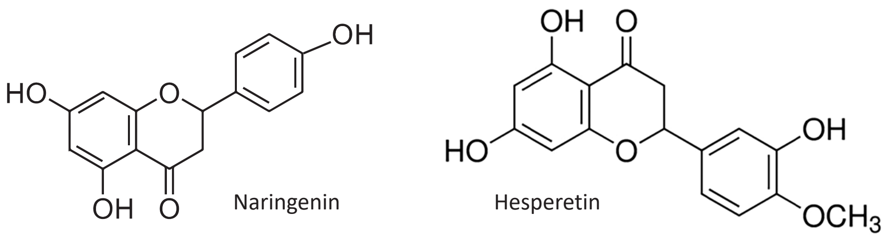

Figure 3 — Structural formulas of naringenin, hesperetin.

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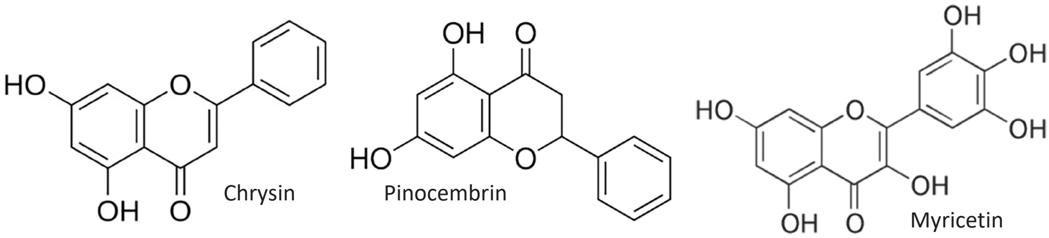

Figure 4 — Structural formulas of chrysin, pinocembrin, myricetin.

Table 1 — Content of chemical substances in different parts of *P. tanacetifolia*

Chemical composition	Concentration, ng/g-1			
	Roots	Stems	Leaves	Flowers
		Aromatic acids		
3,4-DHBA (3,4-dihydroxybenzoic)	211.90 (B)	212.90 (B)	230.20 (B)	347.50 (B)
DOPAC (3,4-dihydroxyphenylacetic)	380.60 (B)	1199.0 (B)	1956.0 (B)	868.90 (B)
4-HBA (4-hydroxybenzoic)	4049.0 (B)	3809.0 (B)	3915.0 (B)	4784.0 (B)
CA (caffeic acid)	1444.0 (B)	873.0 (B)	911.90 (B)	404.10 (B)
HA (hippuric acid)	0.73(B)	0.76 (B)	27.10 (B)	0.80 (B)
3-HBA (3-hydroxybenzoic)	2.47(B)	0.27 (B)	0.34 (B)	21.60 (B)
3-HPA (3-hydroxypicolinic)	0.22 (B)	0.20 (B)	1.37 (B)	7.90 (B)
HVA (4-hydroxy-3-methoxyphenylacetic)	43.50 (B)	25.0 (B)	13.0 (B)	24.10 (B)
3,4-HPPA (4-hydroxyphenylpyruvic)	237.20 (B)	141.40 (B)	161.50 (B)	77.90 (B)
p-CA (para-caffeic acid)	324.80 (B)	11778.0 (B)	297.90 (B)	173.40 (B)
FA (ferulic acid)	823.80 (B)	608.10 (B)	610.10 (B)	385.60 (B)
BA (бензойная кислота)	197.30 (B)	170.90 (B)	360.90 (B)	648.50 (B)
		Flavonoids		
ERC (eriocitrin)	–	–	3,09 (B)	3,09 (B)
ERI (eriodictyol)	0.19 (B)	2.50 (B)	25.80 (B)	21.30 (B)
FIS (fisetin)	–	–	–	14.70 (B)
HSD (hesperidin)	0.97 (B)	57.60 (B)	66.50 (B)	93.10(B)
HST (hesperetin)	0.42 (B)	–	0.67 (B)	0.16 (B)
NAR (naringenin)	1.00 (B)	0.99 (B)	1.88 (B)	1.60 (B)
NARG (naringin)	–	0.31 (B)	–	0.78 (B)
NHSD (neohesperidin)	0.52 (B)	34.10 (B)	22.20 (B)	62.10 (B)
NRI (narirutin)	4.75 (B)	7.60 (B)	3.60 (B)	7.80 (B)
PIN (pinocembrin)	–	–	0.33 (B)	0.24 (B)
QUE (quercetin)	0.27 (B)	74.30 (B)	58.10 (B)	20.60 (B)
R-ERI (R-enantiomer of eriodictyol)	–	365.0 (K)	2574.0 (K)	1502.0 (K)
R-NAR (R-enantiomer of naringenin)	–	141.0 (K)	230.0 (K)	311.0 (K)
RUT (rutin)	2336.0 (B)	1129.0 (B)	10296.0 (B)	13992.0 (B)
S-ERI (S-enantiomer of eriodictyol)	–	460.0 (K)	4752.0 (K)	4461.0 (K)
S-HST (S-enantiomer of hesperetin)	–	210.0 (K)	380.0 (K)	244.0 (K)
S-NAR (S-enantiomer of naringenin)	–	724.0 (K)	1298.0 (K)	1656.0 (K)
TAX (dihydroquercetin)	4.00 (B)	1.59 (B)	5.90 (B)	0.79 (B)

Note: The table is compiled according to S. Bajkacz et al. [32] — (B), and J. Kruk et al. [33] — (K).

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Scientific works on the study of *P. tanacetifolia* by Russian researchers are increasingly encountered. For example, D.N. Olennikov, et al., using HPLC analysis with a photodiode detector and a time-of-flight mass detector (HPLC-DAD-TOF-MS), discovered flavonoids, hydroxycinnamates, and phenolidamides in the herb of *P. tanacetifolia* [14]. Among the flavonoids, tiffaneoside, kaempferol 3-O-neohesperidoside, calendoflavoside, isoquercitrin, nicotiniflorin, narcissin, astragalin, isorhamnetin 3-O-glucoside, isoorientin, cosmosiin, and quercetin 3'-O-glucoside were identified for the first time. The hydroxycinnamates found in the herb of *P. tanacetifolia* were cinnamoylquinic acids (monocaffeoylquinic: 1-O-caffeoylquinic (trans-), 4-O-caffeoylquinic (trans-), 5-O-caffeoylquinic (trans-), 3-O-caffeoylquinic (trans-), 5-O-caffeoylquinic (cis-) and monoferuloylquinic: 1-O-feruloylquinic (trans-), 4-O-feruloylquinic (trans-), 5-O-feruloylquinic (trans-), 5-O-feruloylquinic (cis-), 3-O-feruloylquinic (cis-). Among the identified phenolidamides, spermidine derivatives (safflospermidins A and B) can be distinguished, and a new phenolidamide, phaceliazide, was isolated, which had the highest content [14].

Quantitative assessment of these groups of substances in 8 domestic varieties of Phacelia tanacetifolia allowed for the determination of the content of flavonoids (from 0.99 to 3.61 mg/g), phenylpropanoids (from 1.53 to 15.69 mg/g), hydroxycinnamates (from 0.57 to 5.71 mg/g), and phenolidamides (from 0.89 to 9.5 mg/g) [14].

Phacelia tanacetifolia is a honey plant

Phacelia honey is highly valued for its aroma and taste. The valuable properties of phacelia honey are known worldwide. According to research on this product, the main natural compounds responsible for its therapeutic activity have been identified, its mineral composition is known, and the properties of phacelia honey have been described in detail [39, 40–42].

The antioxidant, antibacterial, antiviral, anti-inflammatory, antithrombotic, and antiallergic properties of honey are explained by many factors, such as pH, sugar content, hydrogen peroxide level, and phenolic compound content, most of which are present as flavonoids [26]. The beneficial effect of flavonoids on human health is due to their antioxidant activity against divalent transition metal cations involved in radical formation processes [26, 43, 44]. Foreign researchers have studied the antioxidant activity of *P. tanacetifolia* pollen [45]. Using spectrophotometry, they determined the total content of phenols and flavonoids and calculated the index of relative antioxidant capacity. The study found that phacelia pollen exhibits a high level of antioxidant activity, which the authors attribute to the presence of phenolic compounds [45]. The main compounds responsible for the antioxidant activity of honey are flavonoids (chrysin, pinocembrin, quercetin, galangin, kaempferol, hesperidin, and myricetin), phenolic acids (caffeic, coumaric, ellagic, ferulic, and chlorogenic acids), ascorbic acid, catalase, peroxidase, and carotenoids (Fig. 4) [43, 44].

Studies of the chemical composition of honey were conducted in Poland. In 2019, an analysis of the chemical composition of phacelia honey was carried out, which qualitatively and quantitatively detected phenolic acids: gallic, caffeic, ferulic, chlorogenic, as well as flavonoids: quercetin, kaempferol, myricetin, naringenin, apigenin [13]. The compounds with the highest content in honey were quercetin (0.293 ± 0.008 mg) and kaempferol (0.304 ± 0.036 mg) per 100 g of honey. They also studied the antioxidant activity of phacelia honey using a spectrophotometric method based on the interaction of antioxidants with the stable chromogen radical 2,2-diphenyl-1-picrylhydrazyl. Ultra-HPLC method allowed to identify the following chemical substances in phacelia honey: 6 nitrogen compounds, including aromatic amino acids (tyrosine [14.66 ± 10.22 mg/kg], phenylalanine [20.41 ± 11.99 mg/kg]), purine derivatives (adenine [18.45 ± 4.63 mg/kg], xanthine [10.53 ± 2.98 mg/kg]), nucleoside uridine (42.84 ± 9.26 mg/kg) [39].

The main component of Hungarian phacelia honey is the flavanone hesperidin, and the mineral composition is represented by potassium (102–130 mg/kg), magnesium (4.09–5.16 mg/kg), calcium (9.12–12.5 mg/kg), and sodium (3.02–3.81mg/kg) [41–43].

The use of phacelia honey is mentioned in Chinese traditional medicine. It was used there as a diuretic, disinfectant, and for the treatment of burns [46]. Phacelia honey has estrogenic effects, a strong rejuvenating effect, and also maintains blood cholesterol levels [46–48]. Honey based on phacelia is especially valued by healers in Western Siberia. Phacelia honey is used in folk medicine for the treatment of gastrointestinal diseases, cardiovascular system diseases, for the normalization of metabolic processes, strengthening immunity, and as a general tonic [49–51].

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Potential pharmacological activity of *Phacelia tanacetifolia*

No scientific data on the pharmacological activity of *P. tanacetifolia* has been found. However, based on the available information on the study of the antioxidant activity of phacelia honey, as well as data on the use of honey in folk medicine as a remedy for cardiovascular diseases and for lowering cholesterol levels, it can be stated that *P. tanacetifolia* is a potential source of BACs with hypolipidemic and antioxidant activity.

It has been established by many scientists that the most pronounced antioxidant, hepatoprotective, and antitoxic effects are characteristic of a complex of BACs from MPRMs where phenolic compounds, including hydroxycinnamic acids and flavonoids, are the dominant components [44, 52, 53]. The mechanism of the therapeutic effect of chlorogenic acid in animals with progressive alcoholic steatohepatitis (administration of ethanol at a dose of 4 g/kg for 8 weeks) and a high-fat diet has been established due to its antioxidant and anti-inflammatory effects [54].

It is known that chlorogenic acid, by reducing the level of malondialdehyde in blood plasma and in low-density lipoproteins (LDL), reduces the susceptibility of LDL to oxidation, thereby lowering the risk of cardiovascular diseases [55, 56].

There is information that various flavonoids reduce LDL oxidation, inhibit platelet aggregation, slow the rate of atherosclerotic plaque formation, reduce the expression of adhesion molecules in endothelial cells, cause vasodilation, and lower blood pressure [57, 58].

These assumptions about the potential pharmacological activity of *P. tanacetifolia* are confirmed by pharmacological studies [59]. It has been shown that prophylactic administration of *P. tanacetifolia* extract in a model of acute hyperlipidemia induced by ethanol demonstrates a hypolipidemic effect, due to a decrease in triglycerides and total cholesterol in blood serum and liver homogenate [60]. *P. tanacetifolia* extract has an anti-atherogenic effect, inhibiting the humoral manifestation of athero-arteriosclerosis: it reduces hyperlipidemia, prevents the activation of lipid peroxidation, apparently by enhancing the antioxidant system and providing a protective effect on local vascular mechanisms of atherogenesis [60].

Excess body weight and obesity in humans can reflect modern negative processes—early disqualification for certain professions, an expanding spectrum and rejuvenation of diseases, and a reduction in active professional activity. Based on the foregoing, it is advisable to use current approaches of modern medicine, the concept of occupational health, which is based on the principle of prevention, contributing to the solution of the main task—extending professional longevity.

In this regard, the study of *P. tanacetifolia* as a potential source of pharmaceutical substances with hypolipidemic and hepatoprotective activity is of both scientific and practical interest. Information about the potential pharmacological activity of *P. tanacetifolia* can be the basis for the development of medicines as well as dietary supplements (DSs), the market for which is continuously growing [61].

Phacelia tanacetifolia is a green manure

As noted by A. Schappert, et al., *P. tanacetifolia* covers the soil more effectively when grown as a monoculture rather than in mixtures, which greatly influences the reduction of surface erosion [62]. Furthermore, it suppresses weed growth [63] and improves soil structure [64]. N. Tursun, et al. proved that *P. tanacetifolia* as a cover crop in apricot orchards eradicates weeds by almost 75 % [65]. Live phacelia is less effective than, for example, glyphosate or mechanical weed control, but after mowing or plowing, it is more effective than these treatments[7]. Some authors indicate that a plot after *P. tanacetifolia*, compared to white mustard (*Sinapis alba* L.), is characterized by a greater number and biodiversity of associated plants, for example, in organic oat cultivation [66]. Based on the study of drought stress in plants in a greenhouse experiment, it was found that *P. tanacetifolia* has much higher resistance to reduced water content compared to *Sinapis alba* L. and *Avena strigosa* Schreb. (bristly oat) [67, 68]. M. Handlířová, et al. found that in an agroecosystem with a high average annual temperature and low rainfall, *P. tanacetifolia* achieves higher and more stable yields compared to buckwheat (*Fagopyrum esculentum* Moench.) [69].

[7] Lipinski M. Pożytki pszczele. Zapylanie i miododajność roślin; PWRiL: Warszawa, Poland; 2010.

CONCLUSION

MPRMs containing phenolic compounds, as well as preparations based on them, are of particular importance in phytotherapy due to their wide range of applications and broad spectrum of therapeutic activity. According to the scientific data studied and summarized in the article, *P. tanacetifolia* is a promising plant for study. The effectiveness of extracts obtained from Phacelia MPRMs has been proven, namely antioxidant, hypolipidemic, and hepatoprotective activities. *P. tanacetifolia* can become a valuable source of BACs used for the treatment of major cardiovascular diseases (atherosclerosis, etc.) and liver diseases. Furthermore, the plant's value as a honey plant and green manure indicates the need for further study of *P. tanacetifolia*.

Considering the information from the provided literature, it should be noted that the chemical composition and spectrum of biological activity of the main BAS of *P. tanacetifolia* can serve as a basis for the development of new medicines with predictable pharmacological properties for the prevention and treatment of socially significant diseases.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

Patimat A. Sheykhmagomedova — data curation, formal analysis, visualization, writing—original draft;
Olga I. Popova — conceptualization, data curation, formal analysis, visualization, writing—review & editing;
ivan V. Popov — data curation, formal analysis, visualization, writing—original draft, writing—review & editing.
All authors made an equivalent and equal contribution to the preparation of the publication. All authors confirm that their authorship meets the international ICMJE criteria (all authors made a significant contribution to the development of the concept and preparation of the article, read and approved the final version before publication).

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