

ABSTARCT
of the dissertation by Keleke Anel Satzhankyzy on the topic
“Pharmacognostic study of Semenov’s sweetvetch (*Hedysarum semenowii* Regel & Herder) as a source of biologically active substances”, submitted for the degree of Doctor of Philosophy (PhD) in the specialty 8D10102 – “Pharmacy”

Relevance of the research topic

The Republic of Kazakhstan's strategic priorities in healthcare and pharmaceutical sector development, within the "Healthcare" section of the National Development Plan and the Healthcare Development Concept to 2029, are aimed at improving public health and disease prevention, and reflect the state's commitment to the United Nations Sustainable Development Goals. A key step toward achieving these goals is the implementation of the Comprehensive Plan for the Development of the Pharmaceutical and Medical Industry for 2020-2025, one of the priorities of which is the creation of competitive medicines and dietary supplements based on domestic plant resources. In this regard, Kazakhstan's unique flora represents a valuable resource that requires in-depth study for the search for new sources of biologically active substances. Conducting pharmacognostic studies of promising plant species will lay the foundation for expanding the resource base for new pharmacopoeial raw materials and their implementation in pharmaceutical development.

One genera of interest is *Hedysarum* L., a member of the *Fabaceae* family, comprising more than 200 species of annual and perennial herbaceous plants. Sweetvetches are found primarily in temperate climates of the Northern Hemisphere, spanning the Asian, European, North African, and North American continents. Twenty-eight species grow in Kazakhstan, more than half of which remain poorly studied. These plants have been actively used in traditional medicine for hundreds of years. Many species of the *Hedysarum* genus, such as *H. polybotrys*, *H. alpinum*, *H. vicioider*, and others, are used to strengthen the immune system, increase energy reserves, promote urination, and promote tissue regeneration. According to literary sources, the biologically active substances contained in these plants have pronounced rejuvenating, antiviral, antioxidant, antitumor, and antidiabetic effects.

The subject of this study was Semenov’s sweetvetch (*Hedysarum semenowii* Regel & Herder), a plant endemic to the Central Tien Shan and known as a forage crop. Despite the chemotaxonomic similarity of *H. semenowii* to the pharmacopoeial species *H. polybotrys*, comprehensive pharmacognostic studies to determine the species' safety profile and pharmacological activity have not been conducted. Pharmacognostic studies may facilitate the expansion of *H. semenowii*'s range of applications, its inclusion in the list of pharmacopoeial raw materials, and its cultivation for the subsequent production of plant-based pharmaceutical substances.

The aim of the dissertation research: pharmacognostic study of *Hedysarum semenowii* Regel & Herder, standardization of the plant material, and determination of prospects for its pharmaceutical application.

Research objectives:

- to establish the morphological and anatomical diagnostic characteristics of the plant material of Semenov's sweetvetch (*Hedysarum semenowii* Regel & Herder);

- to study the complex chemical composition and macro- and microelement profile of the plant material of Semenov's sweetvetch (*Hedysarum semenowii* Regel & Herder);
- to standardize the plant material of Semenov's sweetvetch (*Hedysarum semenowii* Regel & Herder) with the establishment of numerical quality indicators and determination of the shelf life;
- to investigate the safety profile and biological activity of extracts from plant raw materials of Semenov's sweetvetch (*Hedysarum semenowii* Regel & Herder);
- to conduct a resource assessment of Semenov's sweetvetch (*Hedysarum semenowii* Regel & Herder), and to substantiate the concept of plant introduction and the technology for producing the pharmaceutical substance.

Research methods: pharmacopoeial and non-pharmacopoeial methods (physical, physicochemical, pharmaceutical-technological, microbiological), as well as pharmacological, resource-assessment, and statistical methods.

Object of research: Semenov's sweetvetch (*Hedysarum semenowii* Regel & Herder), genus *Hedysarum* L. of the legume family (*Fabaceae*), its medicinal plant materials (herbs and roots) and extracts.

Subject of the research: pharmacognostic (morphological and anatomical) characteristics, phytochemical profile, resource-assessment data, and standardization parameters for Semenov's sweetvetch raw material, as well as the production technology, biological activity, and safety profile of pharmaceutical substances based on it.

The main provisions submitted for defense

- Results of a pharmacognostic study of the medicinal plant materials of *Hedysarum semenowii* Regel & Herder, combining an established set of diagnostic morphological and anatomical features, chemical composition, quality indicators for standardization, and shelf life.
- Results of an experimental substantiation of the safety profile of *Hedysarum semenowii* Regel & Herder extracts and determination of their antioxidant and antimicrobial activity.
- Results of a resource-based study and the development of a phytointroduction concept for *Hedysarum semenowii* Regel & Herder, ensuring the conservation of natural populations and serving as the foundation for the development of a technology for producing a pharmaceutical substance.

Description of the main results of the research

Microscopic analysis established distinct diagnostic features distinguishing *H. semenowii* from closely related species – features essential for detecting raw material adulteration. Specifically, the stem anatomy is characterized by an oval shape with well-developed sclerenchyma at the ribbed angles (up to 6–7 layers) and a complete absence of trichomes and mangiferin-containing idioblasts in the pith parenchyma. The leaves exhibit marked cuticular asymmetry (the abaxial side is 1.5–2 times thicker than the adaxial side) and a loose mesophyll with few layers of palisade cells (1–3 layers). The root system of *H. semenowii* is yellow-brown and nearly cylindrical.

Preliminary phytochemical screening indicates that the aerial part of the plant contains higher levels of polyphenolic compounds than the roots. To determine the qualitative composition of individual flavonoid components, in-depth chromatographic profiling using high-performance liquid chromatography (HPLC) was required. A total of 53 compounds were identified in the raw material: 36 in the herb and 27 in the roots. The herb is characterized by a predominance of quercetin and kaempferol derivatives, whereas the roots are sites of selective accumulation of isoflavonoids (formononetin, ononin, calycosin, and afrormosin) and pterocarpan. Medicarpin and its 3-O-glucoside were found exclusively in the roots, making them reliable chemotaxonomic markers for the plant's underground portion. A significant scientific discovery was the identification of the xanthone mangiferin in both the aerial and underground parts of *H. semenowii* – a finding recorded for the first time for this species.

Analysis of primary metabolites revealed the mechanisms behind the plant's adaptation to the abiotic stresses of a mountainous environment. Eleven amino acids were identified in the aerial parts, and thirteen in the roots. High levels of proline, arginine, and the branched-chain amino acids leucine, isoleucine, and valine were observed. These compounds act as osmoprotectants, enhancing the plant's drought tolerance and adaptive capacity. The fatty acid profile obtained via initial gas chromatographic screening showed a predominance of caproic acid in the aerial parts, whereas long-chain saturated fatty acids (with arachidic acid predominating) prevailed in the roots.

The aerial organs of *H. semenowii* actively accumulate B-group vitamins (niacin, riboflavin), macroelements (potassium, calcium, phosphorus, magnesium), and microelements (iron, copper, zinc). Although the total vitamin concentration in the aerial parts exceeds that of the roots, the root system is characterized by a distinct predominance of vitamin E (tocopherol), which protects cells against oxidative stress.

A quality specification has been developed for *H. semenowii* herb. For identification purposes, data from macroscopic and microscopic examinations of the raw material were systematized, a cyanidin test for flavonoids was implemented, and a thin-layer chromatography (TLC) method using the marker compound mangiferin was optimized. Acceptance criteria were established in accordance with the requirements of the State Pharmacopoeia of the Republic of Kazakhstan and approved regulatory acts regarding universal tests. For routine analysis, the "quantitative determination" parameter is based on the pharmacopoeial method for determining total flavonoids (calculated as rutin), with a set limit of not less than 0.8 %. Determination of mangiferin content via HPLC – with a justified regulatory limit of not less than 0.1 % – was proposed as the primary quantitative test method for the herb. The analytical method underwent full validation, confirming its specificity, linearity, accuracy, robustness, and precision.

A similar approach was taken to develop the quality specification for *Hedysarum semenowii* roots; identification involves determining macroscopic and microscopic characteristics, performing TLC (for isoflavonoids), and conducting a qualitative precipitation test for polysaccharides. The specification incorporates universal tests for medicinal plant materials and an assessment of "extractive substances," with the methodology harmonized against pharmacopoeial requirements for the official species

H. polybotrys.

Long-term stability testing of the herb and roots was conducted under regulated climatic conditions (temperature $25 \pm 2^{\circ}\text{C}$, relative humidity $60 \pm 5\%$). Monitoring over a 12-month period confirmed the absence of statistically significant degradation in physicochemical properties, as well as the stability of flavonoid and extractive substance content. Based on the obtained data and ICH Q1E guideline requirements, the shelf life of the raw material was set at 24 months. Additionally, statistical forecasting and regression analysis indicated a high theoretical stability period, reaching 60–70 months.

Antimicrobial screening revealed that extracts from the aerial parts possess moderate to weak antibacterial activity, showing the greatest efficacy against Gram-positive (*Staphylococcus epidermidis*, *S. aureus*) and Gram-negative (*Pseudomonas aeruginosa*) pathogenic strains. The antimicrobial effect of the herb correlates with its rich flavonol profile. In contrast, the roots exhibited weak antibacterial activity. However, extracts from both plant parts demonstrated equivalent fungicidal potential against yeast-like fungi of the genus *Candida*.

Extracts from the aerial parts of *Hedysarum semenowii* – particularly ethanolic and highly concentrated methanolic extracts – demonstrated free-radical scavenging activity (with an antioxidant activity index reaching 2.07 for the 50% ethanol extract). Conversely, all samples derived from the underground parts showed consistently low antioxidant activity; this is attributed to the accumulation of isoflavonoids in the roots, which do not exhibit significant antioxidant effects.

Preclinical *in vivo* screening studies on laboratory animals demonstrated that extracts derived from the herb and roots of *H. semenowii* fall into the category of substances with low toxicity upon single administration. In acute toxicity studies, oral administration of the extracts at doses up to 5000 mg/kg resulted in no fatalities or neurotoxic abnormalities, indicating an LD₅₀ value exceeding 5000 mg/kg.

A 28-day subacute toxicity study revealed that somatic status parameters – including body weight gain and feed and water consumption – remained within physiological norms ($p > 0.05$). However, microscopic examination of the liver and kidneys showed dose-dependent morphological changes of a reactive nature. Given that initial reactions were observed at a dose of 500 mg/kg, the NOAEL for these extracts is below 500 mg/kg.

Assessment of local irritant effects confirmed good dermatological tolerability of the extracts. Daily topical application over 30 days caused no scaling, micro-fissures, or clinically significant erythema (scoring 0 to 1 on the Draize scale). Local allergenic potential, evaluated via the conjunctival test, was also found to be negligible; isolated cases of mild, transient hyperemia resolved spontaneously. A study of natural *H. semenowii* populations in the Kungei Alatau Range revealed a low harvestable raw material stock, not exceeding 46.2 kg of air-dry mass per year. The primary limiting factors include the small area of the populations (2.5 to 4.5 hectares), the scattered distribution of individual plants, low generative shoot density, and the logistical challenges of harvesting on steep mountain slopes. These findings provide a scientific basis for the conclusion that harvesting wild *H. semenowii* is economically unviable and that the species should be brought into cultivation.

To develop a reliable primary processing method for *H. semenowii* raw material, the "Quality by Design" (QbD) methodology was successfully applied for the first time in conjunction with design-of-experiments (DoE) tools. Mass loss on drying was identified as the key critical quality attribute, with regulated upper limits of no more than 13.0% for the herb and 16.0% for the roots. Pareto charts demonstrated that temperature was the most significant factor in achieving the target moisture level. Using a response optimizer, the final process parameters for convective drying were mathematically determined: 60°C for 5 hours for the herb, and 60°C for 12 hours for the roots. Selecting this mild temperature optimum theoretically maximizes the preservation of thermolabile metabolites, although direct analytical confirmation of this remains a subject for future research. Based on an analysis of the species' bioecological characteristics, a scientifically grounded concept for introducing *H. semenowii* into cultivation at the "Fitoleum" LLP production plantations has been developed; this concept aligns with the UN Sustainable Development Goals and GACP requirements. Within the framework of a sustainable resource utilization strategy, the priority harvesting of above-ground biomass has been established as a fundamental principle, as this biomass concentrates the valuable xanthone mangiferin and a rich complex of flavonoids. The structured concept comprises the following stages: botanical authentication and seed stock establishment, soil analysis and preparation, seed preparation for sowing, planting and maintenance, harvesting and processing of raw plant material, and packaging, labeling, and storage. As part of the concept's development, a preliminary assessment of *H. semenowii* seed germination was conducted using various scarification methods, revealing the superiority of mechanical seed treatment.

To ensure the proper extraction of the complex of biologically active substances from the *H. semenowii* herb, a method for producing the pharmaceutical substance was conceptually designed and optimized. A three-stage gradient extraction method was employed, featuring a sequential reduction in extractant concentration combined with ultrasonic treatment. Subsequent purification, vacuum-evaporation concentration at mild temperatures (40–50°C), and lyophilization ensure maximum extraction and preservation of native compounds. Given that initial pharmacological screening was performed on individual fractions, the specific activity and safety of the resulting final complex substance require verification in subsequent research stages.

Justification of scientific novelty

For the first time:

1. pharmacopoeial morphological and anatomical identification characteristics for the herb and roots of *Hedysarum semenowii* Regel & Herder have been determined (Copyright Object No. 67778 dated February 20, 2026: "Macroscopic and microscopic characterization of *Hedysarum semenowii* Regel & Herder plants");
2. a secondary metabolite profile comprising 53 identified compounds has been established for the herb and roots of *Hedysarum semenowii*. It has been demonstrated that the xanthone mangiferin accumulates in both the aerial and underground parts of the plant, and the use of medicarpin and its 3-O-glucoside as specific chemotaxonomic markers for the roots has been substantiated (Copyright Object No. 44765 dated April 17, 2024: "Determination of mangiferin in *Hedysarum semenowii* Regel & Herder raw

material");

3. comprehensive profiling of the primary metabolites, vitamins, and macro- and microelements of *Hedysarum semenowii* has been conducted: the presence of 11 amino acids in the herb and 13 in the roots was established; the fatty acid spectrum of the aerial parts (9 compounds) and underground parts (16 compounds) was characterized; and the presence of vitamins C (ascorbic acid), E (tocopherol), and the B group (B1, B2, B3, B5, B6, Bc) was confirmed; the content of 10 macro- and microelements (Fe, Cu, Zn, Na, Mg, Ca, K, P, Se, N) was determined (Copyright Object No. 77564 dated August 19, 2026: "Chemical composition of *Hedysarum semenowii* Regel & Herder");

4. the safety and biological activity profile of *Hedysarum semenowii* herb and root extracts was scientifically substantiated: low acute toxicity ($LD_{50} > 5000$ mg/kg) and the absence of clinically significant local irritant or allergenic potential were established. Based on subacute toxicity assessment results, the No-Observed-Adverse-Effect Level (NOAEL < 500 mg/kg) was determined for the first time. Pronounced antioxidant action and moderate antibacterial activity of the herb extracts against pathogenic strains of *Staphylococcus* and *Pseudomonas aeruginosa* were demonstrated;

5. a resource assessment of natural *Hedysarum semenowii* raw material stocks in the gorges of the Kungei Alatau range was conducted; the results revealed limited stock volumes, leading to the development of a concept for its introduction into cultivation. To optimize the raw material harvesting process for *Hedysarum semenowii*, the "Quality by Design" pharmaceutical paradigm was applied for the first time (Copyright Object No. 38239 dated August 3, 2023: "Method for collecting and processing parts of the *Hedysarum semenowii* Regel & Herder plant");

6. a technology was developed to produce a pharmaceutical substance in the form of a dry extract from *Hedysarum semenowii* herb using a three-stage gradient extraction process – facilitated by mathematical design-of-experiments tools—which enables the maximum and selective extraction of the complex of biologically active substances. The novelty of the developed method is confirmed by utility model patent No. 9815: "Method for producing a plant extract from *Hedysarum semenowii* Regel & Herder herb."

Practical significance of the obtained results

A technology for the collection and harvesting of *Hedysarum semenowii* plant material has been developed and implemented at the pharmaceutical enterprise Fitoleum LLP (Esik, Kazakhstan) (Copyright Certificate No. 38239 dated August 3, 2023; Implementation Act dated October 9, 2023; SOP "Collection, drying, and storage of *Hedysarum semenowii*").

Quality specifications for the medicinal plant material *Hedysarum semenowii* Regel & Herder have been developed; based on these, draft regulatory quality documents for "*Hedysarum semenowii* herb" and "*Hedysarum semenowii* roots" have been prepared.

Results from the resource assessment of natural *Hedysarum semenowii* populations in the Kungei Alatau mountain range have been implemented at the "Kolsai Kolderi" State National Natural Park (Implementation Act).

A method for producing a pharmaceutical substance in the form of a dry extract from *Hedysarum semenowii* Regel & Herder medicinal plant material has been developed and implemented at the pharmaceutical enterprise Fitoleum LLP (Esik, Kazakhstan) (Utility Model Patent No. 9815 and Implementation Act dated April 8, 2024).

The research findings have been incorporated into the educational curriculum at the Department of Pharmaceutical and Toxicological Chemistry, Pharmacognosy, and Botany of the S.D. Asfendiyarov Kazakh National Medical University (NJSC) (Implementation Act dated October 27, 2023), the Department of Pharmaceutical Microbiology at the Medical University of Lublin (Implementation Act), the Research Center for Pharmacy and the Department of Drug Technology and Pharmacognosy at JSC "South Kazakhstan Medical Academy" (Implementation Act dated August 7, 2026), and the Department of Pharmacognosy at Lokman Hekim University (Turkey, Implementation Act); and incorporated into the pharmacognosy course textbook at the Bashkir State Medical University under the Ministry of Health of the Russian Federation, the "Higher Medical College" (municipal state enterprise operating under the right of economic management, Almaty Public Health Department), and the "Professor Ruzuddinov Higher Medical and Stomatological College" LLP (Implementation Acts).

Personal contribution of a doctoral student

The presented results are the outcome of the author's independent work, which included: a review of scientific literature (Web of Science, Scopus, PubMed) and study design; field-based resource assessment; comprehensive pharmacognostic analysis of the raw material (macro- and microscopy, metabolite profiling using physicochemical methods); evaluation of antimicrobial and antioxidant activity as well as toxicity; statistical data analysis (Microsoft Excel, GraphPad Prism, Minitab); and the preparation of publications. The findings are consistent with data from leading global studies on the genus *Hedysarum*.

Conclusions

1. The macroscopic and microscopic characteristics of the herb and roots required for the reliable species identification of *Hedysarum semenowii* have been systematized for the first time. The plant's aerial part is distinguished by an oval stem cross-section featuring angular ridges and a complete lack of pubescence, a well-developed sclerenchyma layer (6–7 layers thick), a pith composed of large spherical cells lacking idioblasts, rounded leaves with pronounced cuticular asymmetry, and a yellow corolla reaching 14 mm in length. The roots of *H. semenowii* are cylindrical and possess a distinctive yellow-brown outer bark, allowing them to be differentiated from the reddish root systems of other officinal species within the same section, such as *H. polybotrys* and *H. neglectum*.

2. In-depth profiling of secondary metabolites was conducted using HPLC coupled with high-resolution mass spectrometry. A total of 53 compounds were identified, significantly expanding fundamental knowledge regarding the chemotaxonomy of the species under study. Pronounced phytochemical heterogeneity between the morphological parts was demonstrated: the aerial part is characterized by a predominance of flavonols, phenolic acids, and xanthenes, whereas the underground

part contains a specific array of isoflavonoids, chalcones, and pterocarpanes that determine its potential biological activity profile. A significant scientific discovery was the identification of the xanthone mangiferin in both the aerial and underground parts of the plant—a finding reported for the first time for this endemic species. Furthermore, the use of the pterocarpan medicarpin and its 3-O-glucoside as highly specific and reliable chemotaxonomic markers for the underground part of *H. semenowii* has been substantiated for the first time.

The high potential biological value of the raw material has been demonstrated through the comprehensive determination of a wide range of primary metabolites. Profiles of amino acids (11 compounds in the herb, 13 in the roots), macro- and microelements (with calcium, potassium, and phosphorus predominating), and vitamins were identified. The observed prevalence of arginine and proline in the plant—compared to related species—along with the accumulation of methionine, serine, leucine, and valine, correlates directly with the mechanisms of the plant's biochemical adaptation to high-altitude abiotic stressors. Fatty acid profiling revealed the dominance of caproic acid in the herb and specific long-chain acids (such as arachidic acid) in the roots, which serve membrane-stabilizing and barrier functions.

3. Draft quality specifications for *H. semenowii* herb and roots were developed based on the requirements of the State Pharmacopoeia of the Republic of Kazakhstan and the Pharmacopoeia of the Eurasian Economic Union. Scientifically justified numerical acceptance criteria were established for key quality parameters. An HPLC analytical method was proposed and validated for the precise quantitative determination of the marker component in the herb, with a specified minimum mangiferin content of 0.1%. The developed specifications formed the basis for the draft regulatory documents "Semenov's sweetvetch Herb" and "Semenov's sweetvetch Roots," approved by Fitoleum LLP.

The physicochemical and microbiological stability of the raw material was demonstrated based on data from ongoing long-term studies spanning 12 months, in accordance with approved national requirements. In compliance with ICH Q1E guidelines, the regulatory shelf life for the herb and roots has been set at 24 months at the current stage of research. Additionally, regression analysis of key quality indicators using the Minitab Stability Study module substantiated a theoretical predictive stability period of 60–70 months (70 months for the herb, 67 months for the roots), indicating the potential for extending the regulatory shelf life in the future.

4. *In vivo* preclinical screening tests demonstrated that *H. semenowii* extracts belong to the class of low-toxicity substances. The acute toxicity (LD₅₀) upon oral administration was found to exceed 5000 mg/kg; the extracts do not exhibit clinically significant local irritant or allergenic potential. No systemic lethality was observed during the subacute (28-day) toxicity assessment, and the animals' physiological parameters remained within normal limits. However, detailed histomorphological analysis revealed dose-dependent reactive changes in excretory organs at high dosage levels. Based on these data, a No-Observed-Adverse-Effect Level (NOAEL) of less than 500 mg/kg was established for the first time; this is a crucial parameter for safely calculating the therapeutic window and equivalent doses when planning future studies.

In vitro screening revealed pronounced antioxidant and moderate antibacterial

activity in extracts derived from the aerial parts of *H. semenowii*. The highest efficacy was observed against Gram-positive and Gram-negative pathogenic strains (*Staphylococcus* and *Pseudomonas aeruginosa*), a result attributed to the high content of flavonol complexes. Conversely, extracts obtained from the roots of *H. semenowii* consistently demonstrated weak antimicrobial and trace antioxidant activity—findings consistent with their phytochemical profile, which is predominantly composed of isoflavonoids.

5. Field studies indicated that natural reserves of this endemic species are insufficient for industrial-scale use (with an annual harvestable yield of approximately 46 kg), rendering the exploitation of wild populations both ecologically and economically unviable. To address this issue, a scientifically grounded concept for the phyto-introduction of *H. semenowii* onto "Fitoleum" LLP's commercial plantations has been proposed; this approach is based on precision agriculture principles (Industry 4.0) and international GACP and GMP standards. Within the framework of this concept, post-harvest processing was optimized using the "Quality by Design" approach and mathematical design of experiments. Based on these methods, optimal conditions for the convective drying of raw materials were established to achieve target mass-loss parameters: 60°C for 5 hours for the aerial parts (herbs) and 60°C for 12 hours for the roots.

A conceptual method was developed and optimized for producing a pharmaceutical substance—specifically a dry extract—from the aerial parts of *H. semenowii*. A three-stage gradient extraction process, involving the sequential reduction of extractant concentration (using anhydrous ethanol, followed by 70% and 50% ethanol) combined with pulsed ultrasonic treatment, enables the selective isolation of hydrophobic and hydrophilic fractions while preventing the coagulation of ballast polysaccharides.

Thus, the comprehensive research conducted—ranging from resource assessment and phytochemical profiling to *in vivo* testing, as well as the development of a scientifically grounded concept for plant introduction and a production technology utilizing "Quality by Design" principles—successfully fulfilled all the study's objectives. The results establish a robust scientific, practical, and regulatory foundation for preserving the natural gene pool of *H. semenowii* and creating a renewable, standardized raw material base for the pharmaceutical industry.

Approbation of the results of the dissertation

The main results of the dissertation were presented at international conferences: VIII International Scientific Conference "Research Retrieval and Academic Letters" (Warsaw, Poland, 2025); XIII International Scientific and Practical Conference "Priorities in Pharmacy and Dentistry: From Theory to Practice" (Almaty, Kazakhstan, 2024); Second International Forum "Asfen.Forum, New Generation - 2024" (Almaty, Kazakhstan, 2024); XIV All-Russian Scientific Conference with International Participation of the Youth Scientific Society "Young Pharmacy - Potential of the Future" (St. Petersburg, Russia, 2024); XII International Scientific and Practical Conference "Priorities in Pharmacy and Dentistry: From Theory to Practice" dedicated to the 70th anniversary of Professor R.A. Omarova (Almaty, Kazakhstan, 2023); The V International Scientific and Practical Conference dedicated to the memory of

Professor R. Dilbarkhanov "Formation and Development Prospects of the Scientific School of Pharmacy: Continuity of Generations" (Almaty, Kazakhstan, 2023); I International Forum "Asfen.Forum, New Generation - 2023" (Almaty, Kazakhstan, 2023); the XVIII International Scientific and Practical Conference of Young Scientists and Students of the State Educational Institution Tajik State Medical University named after Abu Ali ibn Sino "Science and Innovations in Medicine - 2023" (Dushanbe, Tajikistan, 2023); the XI International Scientific and Practical Conference "Priorities of Pharmacy and Dentistry: from Theory to Practice" (Almaty, Kazakhstan, 2022).

Publications

Based on the research findings, the following works have been published: 2 articles in international peer-reviewed journals indexed in Scopus; 2 articles in journals included in the list recommended by the Committee for Quality Assurance in Science and Higher Education (Ministry of Science and Higher Education of the Republic of Kazakhstan); 9 articles and abstracts in the proceedings of international scientific and practical conferences (Kazakhstan, Tajikistan, Russia, Poland); 1 utility model patent of the Republic of Kazakhstan; and 4 certificates of copyright registration.

Structure and scope of the dissertation:

The dissertation comprises 168 pages of typewritten text (computer-generated) and includes 29 tables, 38 figures, 146 bibliographic references, and 25 appendices. The structure of the work consists of an introduction, a literature review, research materials and methods, four chapters detailing experimental research, chapter-specific conclusions, and a general conclusion.