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# МАЗМҰНЫ — СОДЕРЖАНИЕ — CONTENT

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# БИОЛОГИЯ
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## Distribution of useful species of family Rosaceae Juss in the flora of Zhetysu Alatau

In the article the results of an analysis of the species composition of wild plants of the *Rosaceae* Juss family were presented. As a result of floristic analysis, it was established that in the northwestern part of the Zhetysu Alatau there are 91 species belonging to the *Rosaceae* family, belonging to 24 genera. The leading genera in this area are: *Potentilla* — 24, *Cotoneaster* — 9, *Rosa* -9, *Alchimilla* -7, *Crataegus* — 5, etc. According to ecological and morphological classifications, all useful species were ranked into 4 groups (trees, shrubs, subshrubs, herbaceous perennials). Spectra of useful properties were shown (use in scientific medicine and in folk medicine, such as vitamins, decorative, food, etc.). 12 groups of medicinal types were ranked according to pharmacotherapeutic activity.

*Keywords:* Zhetysu Alatau, useful plants, medicinal, vitamin, ornamental, economic importance, pharmacological activity.

### *Introduction*

Family *Rosaceae* Juss. is considered one of the most widespread families in the flora of Zhetysu Alatau in terms of relative and species composition. Climate change, urbanization and globalization can lead to serious problems. Rare fruit plants (*Malus, Armeniaca, Rubus, Crataegus*, etc.) have a number of valuable consumer qualities and resistance to abiotic and biotic environmental factors, high decorative qualities, diverse and wide potential for use in fruit growing, selection and landscaping. The purpose of our research is to study the ecological and biological characteristics of useful plants of the *Rosaceae* family. During 2020–2021, we studied the flora of the northwestern part of Zhetysu Alatau, as a result, 91 species of useful plants belonging to the *Rosaceae* family were identified. Many scientists in their research have studied plants belonging to the Juss family, their diversity, distribution, ecological and biological characteristics of rare fruit plants and the introduction of useful plants [1–3]. V.P. Mikhailova studied tanning plants, 50 species of which belong to the *Rosaceae* family. In the monograph by M.K. Kukenov "Resources of medicinal plants of the Tien Shan region of Kazakhstan" also identified the resources of medicinal plants belonging to this family [3]. Flowers of the rose family (*Rosaceae* Juss.) are regular, bisexual or unisexual. The inflorescences are varied. The leaves are simple and compound, with or without leaflets, pinnate and pinnately veined. Most plants of the *Rosaceae* family are useful (medicinal, vitamin, food, essential oil, etc.) plants. More than 100 genera and more than 3,000 species are known, widely distributed throughout the globe. In Kazakhstan there are 36 genera, more than 200 species, 12 of which are very rare plants, therefore they are protected and included in the "Red Book" of Kazakhstan. In addition, in the flora of Kazakhstan there are 76 medicinal and 53 edible species of the *Rosaceae* Juss. family [4]. Most representatives of the *Rosaceae* Juss. family, found in the Zhetysu Alatau, have important practical significance: food (*Fragaria, Malus, Rubus*, etc.), fodder (*Filipendula, Potentilla)*, medicinal (*Coluria, Comarum, Crataegus*, etc.), melliferous (*Dasiphora, Sorbus,*

etc.), decorative (*Rosa, Spiraea*, etc.), technical (*Agrimonia, Geum*, etc.), soil strengthening (*Cotoneaster, Padus*, etc.) etc. [Plant resources..., 1987]. *Rosaceae*, being an almost cosmopolitan family, are distributed in almost all areas of the globe where flowering plants can grow, but their main part is concentrated in the temperate and subtropical zones of the Northern Hemisphere. They inhabit a wide variety of landscapes and natural zones: from polar tundras and highlands to tropical forests and from swamps to semi-deserts. Representatives of the *Rosaceae* family are found in a wide variety of plant communities, although they usually do not play a dominant role in them, but in many places, they are their characteristic element or even determine the appearance of natural landscapes. *Rosaceae*, family of dicotyledonous plants. Trees, shrubs and herbs. The leaves are mostly with stipules, usually alternate. Flowers are regular, bisexual or unisexual, cyclic, collected in inflorescences, less often solitary; There are usually 5 sepals, often equipped at the base with a subcup consisting of 5 leaflets alternating with sepals; rarely 4 sepals, 5 petals, sometimes 4 or absent; there are many stamens or according to the number of petals, with loose threads; there are many pistils, less often a small number or 1–2 with one style emerging from the apex or side of the ovary, sometimes not far from the base; receptacle (hypanthium) is flat, saucer-shaped, cup-shaped, goblet-shaped or convex, sometimes when the fruit ripens it grows and becomes fleshy, forming a false fruit; carpels in the same number as sepals or 2-3 times more of them, free or fused with each other, and sometimes with the receptacle, unilocular, usually with 2 pendulous or erect reverse seed-buds, mostly separated from the stamens more or less wide glandular disc; fruits of various shapes and sizes: leaflets, achenes, drupes, which sometimes grow together to form a composite fruit, and in the case of fusion with the receptacle or growth of the latter, a false fruit [5].

## *Materials and Methods*

The objects of the study were wild useful plants of the Rosaceae Juss. family of the Zhetysu Alatau ridge's natural flora.

Materials for the study were collected during expeditions in 2020-2021. The study of the species composition and distribution of plants was carried out using the route-reconnaissance method.

Field research routes were outlined using reporting and cartographic forest management materials of land use (taxation descriptions, forest plans for dominant forest-forming species, overview plans for non-timber raw materials), geobotanical zoning and administrative maps of the Almaty region. The work also used topographic, geobotanical and agricultural maps at a scale of 1:1000000; 1: 200000; 1:100000, survey data from forestry workers. The location of the thickets was determined based on the biological characteristics and ecological location of the species being studied, as well as using herbarium material.

The identification of species was carried out according to the data of "Flora Kazakhstan" [5], the nomenclature of species is given according to the summary of S.K. Cherepanov [6] and others [7–19]. Identification of medicinal species was carried out on the basis of our own research and according to literature data [10–22], divided into types used in official and folk medicine, and groups identified according to pharmacotherapeutic action. Identified medicinal species are ranked into 4 categories according to the degree of prevalence, area of thickets and possible reserves of plant raw materials: 1) with a wide range, forming significant natural thickets and available for commercial collection of raw materials; 2) with a wide range, forming small natural thickets and suitable for supplying the needs of the local pharmacy network with raw materials; 3) species that have a wide range, but grow sporadically and do not form natural thickets suitable for collecting raw materials; and 4) species with a conservation status. The ranking of species by ecological groups was based on the attitude of plants to moisture regime, life form, in accordance with the ecological and morphological classification of the life form of seed plants, growth form and life expectancy of vegetative organs [8–9].

## *Results and Discussion*

According to V.P. Goloskokov and according to the materials of the herbarium of the Institute of Botany and Phytointroduction, the flora of the Zhetysu Alatau includes the *Rosaceae* family of 26 genera, 107 species (Fig. 1), of which 3 are endemic, found only on this ridge [12].

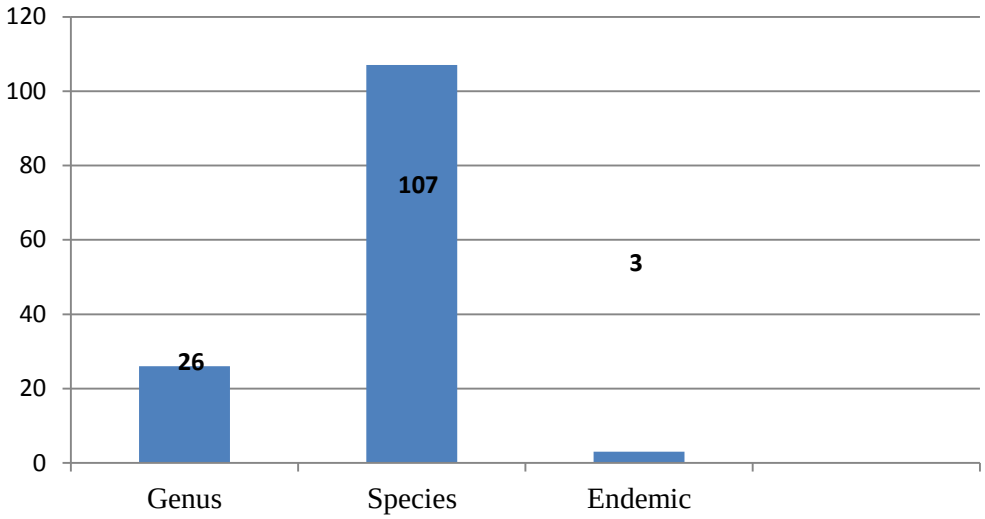


Figure 1. Distribution of plant species of the family Rosaceae Juss.

We examined the vegetation cover of the Zhetysu Alatau. In August 2020-2021, expeditionary work was carried out; as a result of field research, we identified 91 plant species of the *Rosaceae* Juss family. Of these, 49 species have medicinal properties, which is 53.8 % of the species diversity of Zhetysu Alatau. The most common among genera: *Potentilla — 24, Cotoneaster — 9, Rosa — 9, Alchimilla — 7, Crataegus — 5, Rubus — 4, Chamaerhodos — 3, Geum — 3, Spiraea — 3, Agrimonia — 2, Dasiphora — 2, Fragaria — 2, Filipendula — 2, Padus — 2, Sanguisorba — 2, Armeniaca — 1, Aflatunia — 1, Cerasus — 1, Comarum — 1, Poterium — 1, Sibbaldianthe — 1, Sorbus — 1, Sibbaldia — 1, Malus — 1* (Table 1).

Table 1

**Taxonomic analysis of the largest species of the family Rosaceae Juss. flora of the Zhetysu Alatau**

| Family | Genus | Species diversity | Percentage total number of species, % |
|---|---|---|---|
| Rosaceae Juss. | *Agrimonia* | 2 | 2,2 % |
| | *Alchimilla* | 7 | 7,6 % |
| | *Armeniaca* | 1 | 1,2 % |
| | *Aflatunia* | 1 | 1,2 % |
| | *Cerasus* | 1 | 1,2 % |
| | *Crataegus* | 5 | 6 % |
| | *Cotoneaster* | 9 | 10,5 % |
| | *Comarum* | 1 | 1,2 % |
| | *Chamaerhodos* | 3 | 3,3 % |
| | *Dasiphora* | 2 | 2,2 % |
| | *Fragaria* | 2 | 2,2 % |
| | *Filipendula* | 2 | 2,2 % |
| | *Geum* | 3 | 3,3 % |
| | *Padus* | 2 | 2,2 % |
| | *Potentilla* | 24 | 26,5 % |
| | *Poterium* | 1 | 1,2 % |
| | *Rosa* | 9 | 10,5 % |
| | *Rubus* | 4 | 5 % |
| | *Sanguisorba* | 2 | 2,2 % |
| | *Sibbaldianthe* | 1 | 1,2 % |
| | *Sorbus* | 1 | 1,2 % |
| | *Spiraea* | 3 | 3,3 % |
| | *Sibbaldia* | 1 | 1,2 % |
| | *Malus* | 1 | 1,2 % |
| | 24 | 91 | 100 % |

According to ecological and morphological classifications, all useful species were ranked into the following groups: tree — 12 species (3 %); shrubs — 25 species (11 %); subshrubs — 4 (7 %); herbaceous perennials — 50 species (64 %); (Fig. 2)

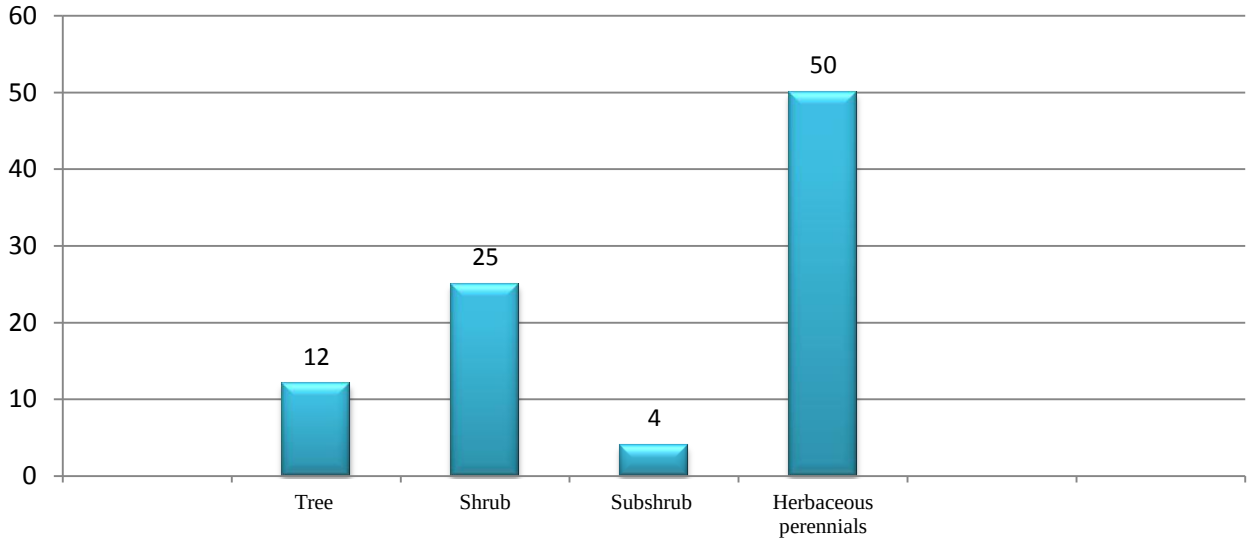


Figure 2. The ratio of life forms of medicinal plants of the flora of the Zhetysu Alatau (according to I.G. Serebryakov) [8].

Ranking of plants by ecological groups in relation to moisture conditions revealed the predominance of mesophytes — 54 species (59.8 %), the second position is occupied by xerophytes — 17 species (18.6 %), the third position is occupied by mesoxerophytes — 10 species (10.9 %), the fourth position is occupied by xeromesophytes — 7 (7.6 %), the fifth is eupotrophytes — 2 (2.1 %), the last place is occupied by mesohygrophytes — 1 (1 %).

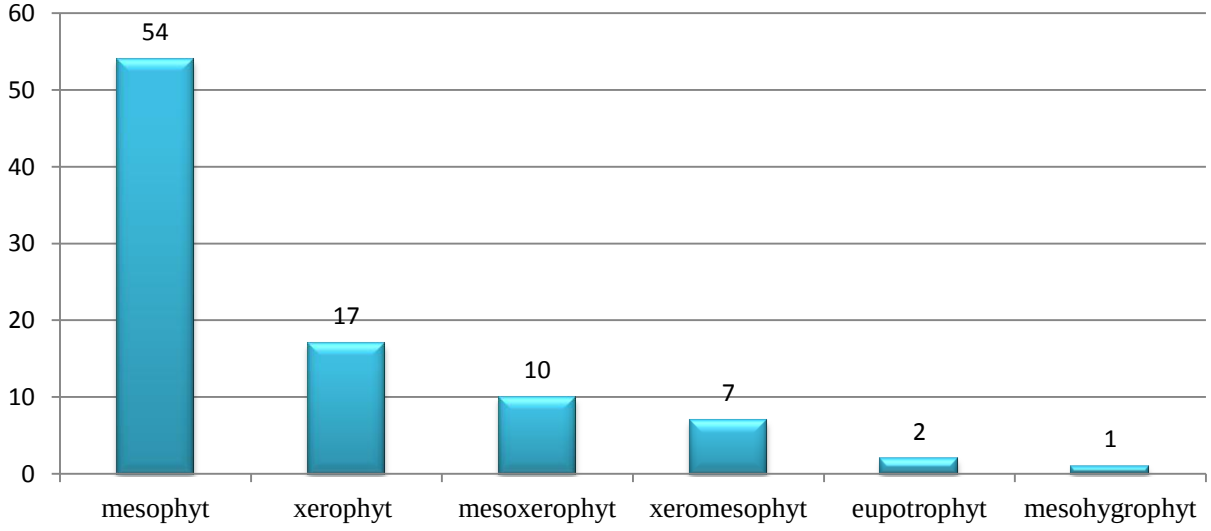


Figure 3. Ranking of plants by environmental groups

The current ratio of life forms and ecological groups shows a predominance of herbaceous mesophytic plants, which indicates a moderately humid habitat. However, other environmental groups point to the presence of a small number of ecotopes from nearby surface or groundwater. Ethnobotanical studies have shown that among the 91 species of identified useful plants, most belong to species used in folk medicine — 49 species. Among them: 15 species are used in official medicine, 27 species are used as vitamins, 4 species are used as decorative, 8 species are used as food (Table 2; Fig. 4).

Table 2

**Spectra of beneficial properties of the Rosaceae family in the flora of Zhetysu Alatau**

| Family | Genus | Species | Use in scientific medicine | Use in folk medicine | Vitamin | Decorative | Food |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Rosaceae Juss. | *Agrimonia* | *Agrimonia asiatica* | | + | | | |
| | | *Agrimonia pilosa* | | + | | | |
| | *Armeniaca* | *Armeniaca vulgaris* | + | + | + | | + |
| | *Alchimilla* | *Alchimilla rubens* | | | | | |
| | | *Alchimilla hebescens* | | | | | |
| | | *Alchimilla sibirica* | | | | | |
| | | *Alchimilla retropilosa* | | | | | |
| | | *Alchimilla cyrtopleura* | | | | | |
| | | *Alchimilla tianschanica* | | | | | |
| | | *Alchimilla pinguis* | | | | | |
| | *Aflatunia* | *Aflatunia ulmifolia* | | | | + | |
| | *Cerasus* | *Cerasus tianschanica* | | | + | | + |
| | *Crataegus* | *Crataegus songarica* | | + | + | | + |
| | | *Crataegus korolkowii* | + | + | + | | + |
| | | *Crataegus altaica* | | + | + | | + |
| | | *Crataegus sanguinea* | + | + | + | | + |
| | | *Crataegus almaatensis* | | + | + | | + |
| | *Cotoneaster* | *Cotoneaster melanocarpus* | | + | | | |
| | | *Cotoneaster antoninae* | | | | | |
| | | *Cotoneaster megalocarpa* | | | | | |
| | | *Cotoneaster uniflora* | | | | | |
| | | *Cotoneaster Pojarkovae* | | | | | |
| | | *Cotoneaster oligantha* | | | | | |
| | | *Cotoneaster multiflora* | | + | | | + |
| | | *Cotoneaster racemiflora* | | | | | |
| | | *Cotoneaster suavis* | | | | | |
| | *Comarum* | *Comarum salesovianum* | | | | + | |
| | *Chamaerhodos* | *Chamaerhodos altaica* | | | | + | |
| | | *Chamaerhodos sabulosa* | | | | | |
| | | *Chamaerhodos erecta* | | + | | | + |
| | | *Chamaerhodos songorica* | | | | | |
| | *Dasiphora* | *Dasiphora parvifolia* | | | | | |
| | | *Dasiphora phyllocalyx* | | | | | |
| | *Fragaria* | *Fragaria vesca* | + | + | + | + | + |
| | | *Fragaria viridis* | | + | | | |
| | *Filipendula* | *Filipendula ulmaria* | + | + | | | |
| | | *Filipendula vulgaris* | + | + | | | |
| | *Geum* | *Geum urbanum* | + | + | | | |
| | | *Geum rivale* | | + | | | |
| | | *Geum aleppicum* | | + | | | |
| | *Padus* | *Padus avium* | + | + | + | | + |
| | | *Padus racemosa* | | | + | | + |

Continuation of Table 1.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| | *Potentilla* | *Potentilla orientalis* | | + | | | |
| | | *Potentilla impolita* | | + | | | |
| | | *Potentilla sericea* | | + | | | |
| | | *Potentilla imbricata* | | | | | |
| | | *Potentilla biflora* | | | | | |
| | | *Potentilla multifida* | | + | | | |
| | | *Potentilla soongorica* | | | | | |
| | | *Potentilla pamiroalaica* | | | | | |
| | | *Potentilla approximata* | | | | | |
| | | *Potentilla strigosa* | | | | | |
| | | *Potentilla conferta* | | + | | | |
| | | *Potentilla nervosa* | | + | | | |
| | | *Potentilla nivea* | | + | | | |
| | | *Potentilla viscosa* | | | | | |
| | | *Potentilla recta* | | + | | | |
| | | *Potentilla regeliana* | | | | | |
| | | *Potentilla desertorum* | | | | | |
| | | *Potentilla chrysantha* | | + | | | |
| | | *Potentilla asiatica* | | | | | |
| | | *Potentilla longipes* | | | | | |
| | | *Potentilla longfolia* | | + | | | |
| | | *Potentilla Schrenkiana* | | | | | |
| | | *Potentilla gelida* | | + | | | |
| | | *Potentilla anserina* | | + | | | |
| | *Poterium* | *Poterium polygamum* | | + | | | |
| | *Rosa* | *Rosa acicularis* | + | + | + | | + |
| | | *Rosa alberti* | + | + | + | | + |
| | | *Rosa beggerana* | + | + | + | | + |
| | | *Rosa canina* | + | + | + | | + |
| | | *Rosa platyacantha* | | + | + | | + |
| | | *Rosa spinosissima* | | + | + | | + |
| | | *Rosa laxa* | + | + | + | | + |
| | | *Rosa chinensis* | | | + | | + |
| | | *Rosa schrenkiana* | | | + | | + |
| | *Rubus* | *Rubus caesius* | | + | + | | + |
| | | *Rubus idaeus* | + | + | + | | + |
| | | *Rubus saxatili* | | + | + | | + |
| | | *Rubus sachalinensis* | | + | + | | + |
| | *Sanguisorba* | *Sanguisorba officinalis* | + | + | | | |
| | | *Sanguisorba alpina* | | + | | | |
| | *Sibbaldianthe* | *Sibbaldianthe adpressa* | | | | | |
| | *Sorbus* | *Sorbus tianschanica* | | + | + | | + |
| | *Spiraea* | *Spiraea hypericifolia* | | + | | | |
| | | *Spiraea chamaedryfolia* | | + | + | | |
| | | *Spiraea lasiocarpa* | | | + | | |
| | *Sibbaldia* | *Sibbaldia procumbens* | | | | | |
| | *Malus* | *Malus sieversii* | | + | + | | + |

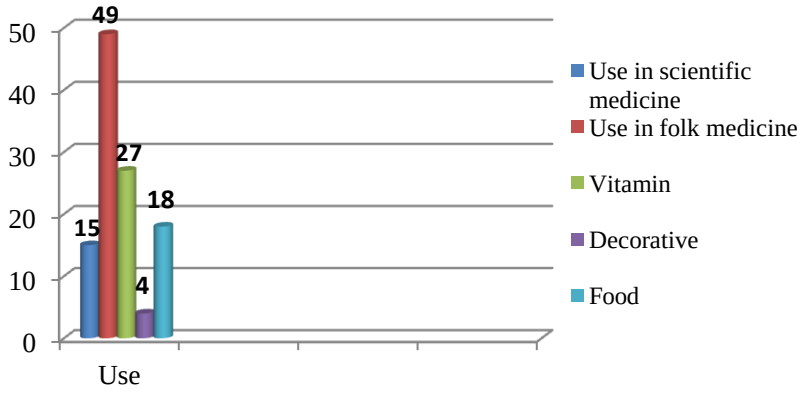


Figure 4. Distribution of useful plants of the *Rosaceae* family in the Zhetysu Alatau.

The *Rosaceae* family has a wide range of pharmacological activity, so we analyzed the possibility of using medicinal plants from the Zhetysu Alatau for the treatment of various diseases, dividing them into 12 groups according to pharmacotherapeutic activity.

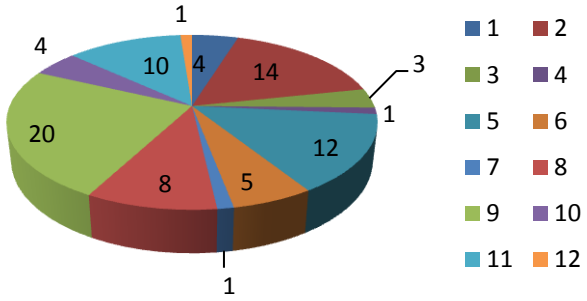


Figure 5. Ranking of pharmacotherapeutic activity of medicinal plants of the Zhetysu Alatau by pharmacotherapeutic groups: 1 — Laxatives, 2 — gastrointestinal tract, 3 — tonic, 4 — respiratory tract, 5 — antipyretic and anti-inflammatory, 6 — cardiovascular system, 7 — homeopathy, 8 — analgesic and wound healing, 9 — antibacterial, 10 — antitumor, 11 — Vitamin, 12 — Hemostatic.

The following plants are recommended for the treatment of the gastrointestinal tract recommended: *Agrimonia asiatica, Armeniaca vulgaris, Cotoneaster melanocarpus, Fragaria vesca, Fragaria viridis, Filipendula ulmaria, Geum aleppicum, Potentilla longfolia, Rosa acicularis Rosa beggerana, Rosa canina, Rosa laxa, Rubus saxatilis, Spiraea hypericifolia,* laxatives: *Armeniaca vulgaris, Geum aleppicum, Rubus caesius Sorbus tianschanica, tonic: Geum rivale, Geum aleppicum, Padus avium,* respiratory tract: *Rubus idaeus,* antipyretic and anti-inflammatory *Fragaria vesca, Fragaria viridis, Filipendula ulmaria, Filipendula vulgaris, Geum urbanum, Geum aleppicum, Rosa acicularis, Rosa canina, Rubus caesius, Rubus idaeus, Rubus saxatilis, Rubus sachalinensis,* the cardiovascular system: *Crataegus songarica, Crataegus korolkowii, Crataegus altaica, Crataegus sanguinea, Crataegus almaatensis,* homeopathy: *Potentilla recta,* analgesic and wound healing: *Fragaria vesca, Filipendula ulmaria, Geum urbanum, Potentilla anserina, Poterium polygamum, Rubus idaeus, Rubus sachalinensis, Sanguisorba officinalis,* antibacterial: *Agrimonia asiatica, Agrimonia pilosa, Cotoneaster melanocarpus, Filipendula vulgaris, Geum urbanum, Padus avium, Potentilla multifida, Potentilla conferta, Potentilla nervosa, Potentilla nivea, Potentilla chrysantha, Potentilla gelida, Potentilla anserina, Rosa acicularis, Rubus idaeus, Rubus sachalinensis, Sorbus tianschanica, Spiraea hypericifolia, Spiraea chamaedryfolia, Malus sieversii, antitumor: Agrimonia pilosa, Cotoneaster multiflora, Filipendula vulgaris, Sanguisorba officinalis,* vitamine: *Armeniaca vulgaris, Rosa alberti, Rosa beggerana, Rosa platyacantha, Rosa laxa, Rubus idaeus, Rubus saxatilis, Sorbus tianschanica, Spiraea lasiocarpa, Malus sieversii,* hemostotic: *Sanguisorba alpina* (Fig. 5).

During the field research, we marked and examined 6 points of several species of the *Rosaceae* family. *Rosa platyacantha* of the Zhetysu Alatau, pebble terrace on the right bank of the Gorbushka River. N 45°28’14, 4» E 80°33’37, 1» Height 1120m. It grows on the steppe slopes of mountains and at the bottom of gorges. Economic importance: In the city of Almaty, it is grown as a decorative plant. Associated species *Veronica spuria, Achillea Biebersteinii.*

*Potentilla impolita* Wahlenb. Northern macroslope of the Zhetysu Alatau, Southern slope of the Small Baskan. Left bank of the Maly Baskan river. Petrophytic series on the Southern Rocky Slope. N 45°20’05, 7» E 80°08’12, 2» Height 1214m. Grows in steppes, steppe meadows and grassy slopes. Associated species: *Ajania fastigiata, Sedum alberti, Allium petraeum, Artemisia sublessingiana.*

*Padus avium* Mill. Northern part of the Zhetysu Alatau. The valley of the Black River in the area of the forester's cardona. Aspen forest. Grass-forb. N 45°31’16, 760» E 80°42’54, 965» Height 1216 m. Grows on the banks of rivers and streams, in riverine forests and bush thickets, as well as in sparse forests along the edges. Associated species: *Angelica decurrens, Papulus Laurifolia, Milium effusum, Cardamine impatiens, Alfredia Cernua, Geum urbanum.*

*Filipendula ulmaria* (L.) Maxim. Northern part of the Zhetysu Alatau. The valley of the Black River in the area of the forester's cardona. Aspen forest. Grass-forb. N 45°31’16, 760» E 80°42’54, 965» Height 1216 m. Grows in floodplains of rivers, near lakes, streams in damp forests and shrubs in meadows. Economic importance: it has medicinal value as an astringent for bleeding and diarrhea. Associated species: *Impatiens parviflara, Stachys sylvatica, Angelica decurrens, Festuca gigantea, Papulus Laurifolia, Milium effusum, Cardamine impatiens.*

*Rubus caesius* L. Northern part of the Zhetysu Alatau. The valley of the Black River in the area of the forester's cardona. High grass with bird cherry and apple trees. N 45°31’16, 760» E 80°42’54, 965» Height 1216 m. Grows in forests, bushes, on the banks of rivers and streams, in meadows in gardens, along roads and along hedges. It is found in all regions of Kazakhstan and quite high in the mountains. Economic value: The fruits are edible, but have almost no industrial value. Associated species: *Bunios orientalis, Pulmonaria molissima, Inula helenium, Trifolium pratense, Lonicera tatarica.*

*Rubus saxatilis* L. Northern part of the Zhetysu Alatau. The valley of the Black River in the area of the forester's cardona. The watershed between the Chernaya River and Lepsy in the area of the apple genetic reserve. Hawthorn-apple forest. N 45°31’04, 121» E 80°43’14, 605» Height 1298 m. Grows in birch forests, spruce forests, pine forests, shrubs, on rocky mountain slopes and swamps. Economic importance: the berries are edible, but have no industrial importance. Associated species: *Rhamnus cathartica, Brachypodium sylvaticum, Serratula coronata, Allium obliquum.*

*Crataegus korolkowii* L. Northern part of the Zhetysu Alatau. The valley of the Black River in the area of the forester's cardona. The watershed between the Chernaya River and Lepsy in the area of the apple genetic reserve. Petrophytic steppe community. N 45°31’03, 907» E 80°43’16, 321» Height 1300 m. Related species *Polemonium caucasicum, Serratula coronata, Allium obliquum.*

## *Conclusion*

As a result of floristic analysis, it was established that in the northwestern part of the Zhetysu Alatau there are 91 species of plants belonging to the Rosaceae Juss family, belonging to 24 genera. The leading genera in this area are *Potentilla* — 24, *Cotoneaster* — 9, *Rosa* — 9, *Alchimilla* — 7, *Crataegus*— 5, etc.

According to ecological and morphological classifications, all useful species were ranked into the following groups: tree — 12 species (3 %); shrubs — 25 species (11 %); subshrubs — 4 species (7 %); herbaceous perennials — 50 species (64 %). In relation to moisture, vascular plants are distributed into ecological groups. Among them, the leading position is occupied by mesophytes (54 species), and the lagging position is occupied by mesohygrophytes (1 species).

The spectrum of beneficial properties (use in scientific medicine, in folk medicine, as medicinal, vitamin, decorative, food) of the *Rosaceae* family in the flora of Zhetysu Alatau has been shown. Medicinal plants were ranked according to their properties and pharmacotherapeutic activity into 12 groups: laxatives, tonic, antipyretic and anti-inflammatory, cardiovascular system, homeopathy, analgesic and wound healing, antibacterial, antitumor, vitamin, hemostatic. Ethnobotanical studies have shown that 49 species are used in folk medicine. Thus, in the *Rosaceae* Juss family, all species are useful plants (medicinal, vitamin, food, etc.).

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## Жетісу Алатауының флорасында *Rosaceae* Juss. тұқымдасының пайдалы түрлерінің таралуы

Мақалада *Rosaceae* Juss. тұқымдасының жабайы өсімдіктерінің түрлік құрамын талдау нәтижелері берілген. Флористикалық талдау нәтижесінде Жетісу Алатауының солтүстік-батыс бөлігінде 24 туысқа жататын раушангүлділер тұқымдасының 91 түрі бар екені анықталды. Бұл аймақта жетекші тұқымдастары: *Potentilla* — 24, *Cotoneaster* — 9, *Rosa* — 9, *Alchimilla* — 7, *Crataegus* — 5 және т.б. Экологиялық және морфологиялық жіктелуі бойынша барлық пайдалы түрлер 4 топқа (ағаштар, бұталар, шала бұталар, көпжылдық шөптесін өсімдіктер) бөлінді. Пайдалы қасиеттерінің спектрлері көрсетілген (ғылыми медицинада және халықтық медицинада қолданылуы, дәрумендік, сәндік, тағамдық ретінде және т.б.). Фармакотерапиялық белсенділігі бойынша дәрілік өсімдіктер түрлері 12 топқа жіктелді.

*Кілт сөздер:* Жетісу Алатауы, пайдалы өсімдіктер, дәрілік, дәрумендік, сәндік, шаруашылық маңызы, фармакологиялық қызметі.

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# Распространение полезных видов семейства *Rosaceae* Juss. во флоре Жетысуского Алатау

В статье представлены результаты анализа видового состава дикорастущих растений семейства *Rosaceae* Juss. В результате флористического анализа установлено, что в северо-западной части Жетысуского Алатау встречается 91 вид растений, относящихся к семейству *Rosaceae*, принадлежащих к 24 родам. Ведущими родами в этой области являются: *Potentilla* — 24, *Cotoneaster* — 9, *Rosa* — 9, *Alchimilla* — *7*, *Crataegus* — 5 и др. По экологическим и морфологическим классификациям все полезные виды были ранжированы на 4-е группы (деревья, кустарники, полукустарники, травянистые многолетники). Показаны спектры полезных свойств (использование в научной медицине и народной медицине: витаминные, декоративные, пищевые и др.). По фармакотерапевтической активности ранжированы 12 групп лекарственных видов.

*Ключевые слова:* Жетысуский Алатау, полезные растения, лекарственные, витаминные, декоративные, хозяйственное значение, фармакологическая активность.

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# Search for antibiotic-resistant strains of Gram-positive and Gram-negative microorganisms in poultry products

Research on the search for antibiotic-resistant strains of Gram-positive and Gram-negative microorganisms in poultry products is an urgent and important topic in modern medicine and the food industry. Antibiotics are widely used in poultry farming for the prevention and treatment of infections, but this also contributes to the development of antibiotic resistance in microorganisms. The purpose of this study is to identify and assess the level of antibiotic resistance of Gram-positive and Gram-negative bacteria present in meat and poultry-derived products. The methods include analyzing food samples, namely chicken fillets and chicken eggs, for the presence and identification of resistant strains, as well as testing their sensitivity to various antibiotics. During the study, it was found that 19.05 % of Gram-positive strains and 26.09 % of Gram-negative strains isolated from farm products exhibit resistance or multi-resistance properties. At the same time, 58.28 % of Gram-positive and 59.42 % of Gram-negative microorganisms also exhibit resistance or multi-resistance properties.

*Keywords*: antibiotic resistance, epidemiology, sanitary microbiology, poultry farming, food safety.

## *Introduction*

The discovery of antibiotics is one of the most significant discoveries in the field of clinical and preventive medicine. The first antibacterial drug was discovered by the winner of the Nobel Prize in Physiology or Medicine (1945) by Alexander Fleming in 1929. Since then, antibiotics have become one of the most essential components of the treatment of infectious diseases [1]. Nevertheless, at the moment, the world community is facing a global challenge in the face of antibiotic resistance, a phenomenon that allows microbial agents to survive and multiply despite the use of antibacterial agents [2].

The study of the development and spread of resistant strains plays a key role in ensuring global biological safety and poses a serious threat to practical medicine. According to the World Health Organization (WHO), every year, the effectiveness of antibiotics decreases, which makes it impossible to use them further [3]. At the same time, according to experts, about 230,000 people die annually in the world from infectious diseases caused by multi-resistant bacteria [4]. At the same time, special attention is paid to the study of the sources of resistant strains, which are medical institutions, clinical and bacteriological laboratories, as well as agricultural entities [5].

At the same time, a separate role is assigned to the study of the role of agricultural facilities. The conditions of keeping livestock are one of the main reasons for the use of antibacterial drugs. The large crowding of animals in relatively small spaces creates a favorable environment for the spread of infectious diseases, which is a factor in the forced use of antibacterial drugs, both for therapeutic and preventive purposes [6]. The study by Van Boeckel and co-authors indicates that countries such as China, which could lead to China becoming a consumer of about 30 % of global antibiotic production by 2030. The other most “dangerous” country is India, according to researchers, 95 % of the population are carriers of microorganisms producing extended-spectrum beta-lactamases, which may be mediated by the uncontrolled use of antibiotics, both in medicine and in agriculture [7]. Poultry farming is also an integral part of agriculture. According to the Food and Agriculture Organization (FAO), global poultry consumption, including meat and eggs, continues to grow rapidly, and it is expected to increase by 20 % by 2030 [8]. At the same time, the subjects of poultry farming are also one of the main consumers of antibiotics. A review of scientific publications conducted by Ma and co-authors directly indicates the growing antibiotic resistance in poultry farming and the transfer of R-plasmids from animals to humans [9].

In an experiment conducted by Liu, Y. -Y. and co-authors, it is reported that a detailed genomic analysis of E.coli isolated from humans and birds revealed similarities in the structure of ColV/ColBM plasmids containing the mcr-1 gene (MCRPEC), which may indicate the spread of antibiotic resistance from birds to humans [10]. When comparing the genetic differences between E. coli strains in humans and poultry, it was found that ciprofloxacin-resistant *E. coli* strains in humans are associated with birds [11]. A study conducted by Dutil, L and co-authors showed that the temporary cessation of ceftiofur significantly reduces the resistance of Salmonella isolates in birds and humans, however, with the resumption of use, the trend has changed [12]. These studies have confirmed the transmission of antibiotic-resistant bacteria from animals to farm workers. The results revealed a high prevalence of resistance among farmers before and after the introduction of antibiotics in their workplaces. Despite the fact that this limited transmission does not seem to pose a threat to public health, the introduction of genes responsible for drug resistance into society and the hospital environment may pose a potential threat [13].

Kazakh scientific research in the field of antibiotic resistance in animal husbandry continues to develop. At the same time, there are already a number of studies that indicate the detection of resistant strains in farm animals. For example, the work of Madiev and Pimenov covers the study of antibiotic resistance of stains gathered from sows. The study indicates the sensitivity of the isolated strains to such groups of antibiotics as carbapenems, cephalosporins, polymyxins, tetracyclines, beta-lactams, penicillins, sulfonamides, aminoglycosides, tetracyclines [14]. Also, in Matchanova's work, it is indicated that the inappropriate use of antibacterial drugs in animal husbandry can lead to the rapid and sustainable development of antibiotic resistance, which will become a global challenge for Kazakhstan [15]. Thus, the search for antibiotic-resistant strains isolated from poultry products is an important step in ensuring biological safety, and the data obtained during the study can be used in making recommendations to counteract the development of global antibiotic resistance.

## *Materials and Methods*

An exploratory, promising, experimental study was conducted. The object of the study is poultry products in the territory of the Karaganda region. 64 samples of products (n=64) were selected for the study, including 44 carcasses of broiler fillets and 20 chicken eggs purchased in supermarkets and farms of the Karaganda region. The exclusion criterion is: expired shelf life, violation of the integrity of the package, violation of the storage conditions of the product. The study was conducted according to the design shown in Figure 1.


Figure 1. Design of the study “Search for antibiotic-resistant strains of Gram-positive and Gram-negative microorganisms in poultry products”

Primary sowing was carried out on pre-prepared, sterile nutrient media — yolk-salt agar (Sentral drug house) and endo medium (FBUN State Scientific Center for Applied Microbiology and Biotechnology). The cups with primary seeding were incubated in a microbiological thermostat for 24 hours. The isolation of pure culture was carried out by the depletion stroke method [16]. After obtaining pure crops, the isolates were divided into 2 groups: the first group includes isolates strains from farm products, the second group contains strains isolated from products of retail trade facilities. The identification of isolated microorganisms was carried out using a MALDI-TOF mass spectrometer located at the INOZH Research Institute of the Karaganda Medical University. To determine the sensitivity, Muller-Hinton agar (Condalab) was used, and a separate set of antibiotics for Gram-positive and Gram-negative microorganisms indicated in Table 1 and Table 2.

Table 1

**A set of antibiotics used to determine sensitively Gram-positive isolates**

| Atibiotic group | The name of the antibiotic | Disc load, mcg/disk |
|---|---|---|
| Aminoglycosides | Tobramycin (TOB) | 10 |
| | Gentamicin (GEN) | 10 |
| Macrolides | Erythromycin (E) | 15 |
| Glycopeptides | Vancomycin (VA) | 30 |
| Penicillins | Oxacillin (OX) | 1 |
| Polyketides | Tetracycline (TE) | 30 |

Table 2

**A set of antibiotics used to determine sensitively Gram-negative isolates**

| Atibiotic group | The name of the antibiotic | Disc load, mcg/disk |
|---|---|---|
| Penicillins | Ampicillin/Sulbactam (AMP) | 10 |
| | Amoxicillin/Clavunate (AMC) | 30 |
| Cephalosporins | Cefotaxime (CTX) | 5 |
| | Cefepim (CPM) | 30 |
| | Cefuroxime (CXM) | 30 |
| | Ceftazidime (CZA) | 30 |
| | Cefoxitin (FOX) | 30 |
| Carbapenems | Meropenem (MEM) | 10 |
| | Imipenem (IMP) | 10 |
| Fluoroquinolones | Ciprofloxacin (CIP) | 10 |
| Aminoglycosides | Tobramycin (TOB) | 10 |
| | Gentamicin (GEN) | 10 |
| | Amikacin (AK) | 10 |

At the same time, discs with CTX, AMC, and CXM were placed at a distance of no more than 1 cm from each other, to determine the production of extended-spectrum beta-lactamases, the selection of antibacterial drugs for research was carried out taking into account the popularity of use and species specificity. The cups with crops and antibiotics were incubated for 24 hours in a microbiological thermostat at a temperature of 37.0 C.

The growth delay values were taken from the manual of the European Committee on Antimicrobial Susceptibility Testing, Breakpoint tables for interpretation of MICs and zone diameters, Version 13.1, valid from 2023–06–29 [17]. Chi-square adjusted for continuity were chosen as statistical criteria to compare results that lack strains with questionable sensitivity [18]. Statistical data analysis was performed using the Microsoft Office professional software package: Exel2019, STATISTICA 12.5.192.7(trial version) and the matplotlib and pandas libraries for python 3.12.0.

*Results and Discussion*

As part of our study, we isolated and analyzed in detail 147 bacterial isolates (n=147). Of this total, 92 isolates (k1=92), which is 62.59 % (95 %CI:54.23 %-70.42 %), were classified as Gram-negative microorganisms. Gram-negative strains taken from poultry products account for 75.00 % (95 % CI:64.89 %-83.45 %), the remaining 25.00 % (95 % CI: 16.88 %- 34.66 %) are gathered from farm products. The remaining 55 isolates (k2=55), or 37.41 % (95 %CI:29.58 %-45.77 %), were identified as Gram-positive bacteria. At the same time, the share of isolates from products purchased at retail outlets accounts for 61.82 % (95 %CI:47.73 %-74.59 %), and the share of isolated strains from farm products is 38.18 % (95 % CI:25.41 %-52.27 %).

Table 3

**Gram-positive strains of bacteria isolated from the studied products**

| The genus of isolates | The proportion in relation to the total number of strains extracted,% | Confidence intervals, % |
|---|---|---|
| *Staphylococcus* | 81,82 % | 59,04 % — 83,86 |
| *Streptococcus* | 18,18 % | 9,08 % -30,90 |

Table 4

**Gram-negative bacterial strains isolated from the studied products**

| The genus of isolates | The proportion in relation to the total number of strains extracted,% | Confidence intervals, % |
|---|---|---|
| *Escherichia* | 50,00 % | 39,39 %-60,61 |
| *Salmonella* | 10,87 % | 5,34 %- 19,08 |
| *Citrobacter* | 7,61 % | 3,57 %-15,76 |
| *Aeromonas* | 7,61 % | 3,11 %-15,05 |
| *Serratia* | 4,35 % | 1,20 %-10,76 |
| *Acinetobacter* | 3,26 % | 0,68 %-9,23 |
| *Proteus* | 3,26 % | 0,68 %-9,23 |
| *Moraxella* | 3,26 % | 0,68 %-9,23 |
| *Enterobacter* | 3,26 % | 0,68 %-9,23 |
| *Erwinia* | 2,17 % | 0,26 %-7,63 |
| *Hafnia* | 2,17 % | 0,26 %-7,63 |
| *Pantonea* | 2,17 % | 0,26 %-7,63 |

As can be seen from the data in Table 3, the genus *Staphylococcus* prevails among the Gram-positive microflora, and less than 20 % of the isolates were assigned to the genus Streptococcus. Among Gram-negative isolates, the genus Escherichia prevails, which accounts for half of all isolated microorganisms, slightly more than 10 % of the isolates are represented by the genus Salmonella, isolates assigned to the genus *Citrobacter* and *Aeromonas* have the same amount, the proportions of the remaining isolates are shown in Table 4.

When analyzing Gram-positive microflora (Fig. 2) isolated from farm products, it became known that the isolates have absolute sensitivity to gentamicin, ciprofloxacin and vancomycin. At the same time, 4.76 % (95 %CI: 0.12 %-23.82 %) are sensitive to tobramycin, tetracycline, erythromycin and oxacillin. At the same time, it is important to note that these strains do not have multi-resistance, and are sensitive to other types of antibiotics. An interesting fact is that 75.00 % of resistant strains isolated from farm products belong to the genus *Staphylococcus*, and the remaining 25 % are representatives of the genus *Streptococcus*. Thus, it can be noted that the proportion of resistant strains among isolates from farm products is not large, and there are no multi-resistant strains at all. It should be noted that no pathogenic coagulase-negative microbiological agents have been identified, and accordingly, there is reason to believe that the extracted isolates belong to the normal microflora of broiler chicken fillets and chicken eggs.

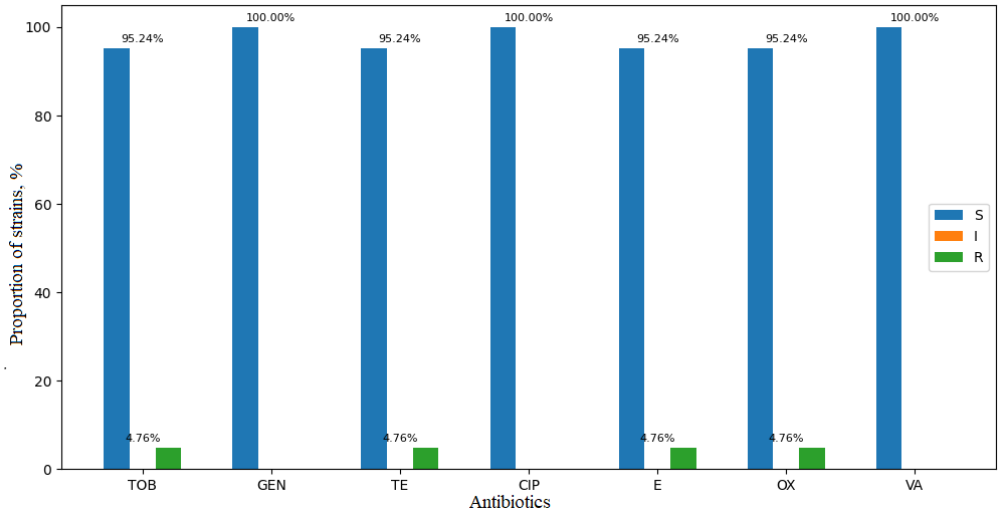


Figure 2. Sensitivity of Gram-positive strains isolated from farm products

At the same time, when studying the sensitivity of Gram-positive isolates from poultry products (Fig. 3), 32.35 % (95 %CI:17.39 %-50.53 %) show resistance to tobramycin, and 23.53 % (95 %CI:10.75 %-41.17 %) to gentamicin. At the same time, 45.45 % are resistant to both tobramycin and gentamicin, and all of them belong to the genus *Staphylococcus*. An interesting fact is that among the strains showing resistance to all studied aminoglycosides, 60.00 % of the strains are multi-resistant, and show resistance to other antibacterial drugs.

When examining the sensitivity of the isolated strains to tetracycline, it was found that 20.59 % (95 %CI:8.70 %-37.90 %) are not sensitive to this antibacterial drug. At the same time, all of them belong to the genus Staphylococcus, and in 50.00 % of cases they are multi-resistant, and in 14.29 % they are absolutely resistant to aminoglycosides.

At the same time, it was found that the isolated Gram-positive strains do not show resistance to ciprofloxacin, but at the same time 8.82 % (95 %CI:1.86 %-23.68 %) are questionably sensitive, although there is no reason to believe that these strains will not soon become sensitive to this drug.

In the case of erythromycin, it was found that 23.35 % (95 %CI:10.75 %-41.17 %) are resistant to this drug. At the same time, half of them are multi-resistant, and show resistance to both aminoglycosides and penicillins.

Upon detailed analysis of the sensitivity of the isolates to oxacillin, it became known that 17.65 % (95 %CI:6.76 %-34.53 %) exhibit resistance properties, while 66.67 % are classified as multi-resistant. It should be noted that all these isolates are assigned to the genus *Staphylococcus.*

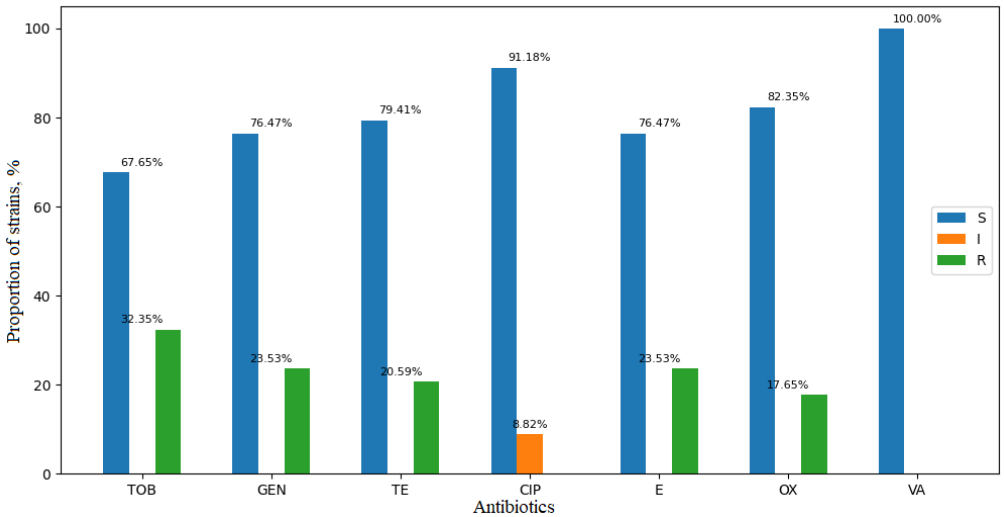


Figure 3. Sensitivity of Gram-positive strains isolated from poultry farm products.

When analyzing the sensitivity of Gram-negative strains isolated from farm products (Fig. 4), 91.30 % (95 % CI:89.42 %-98.80 %) were sensitive to ampicillin/sulbactam and amoxicillin/clavunate. It is worth noting that 8.70 % (95 %CI:1.07 %-28.04 %) are classified as resistant, while it is noted that these strains belong to the genus *Escherichia* and *Serratia*, and show resistance to two antibacterial drugs simultaneously. At the same time, the Serratia strain is multi-resistant, and does not show sensitivity to ceftazidime and amoxicillin/clavunate. At the same time, when studying the resistance of strains isolated from poultry products (Fig. 5), the sensitivity of the obtained isolates to ampicillin/sulbactam is only 79.71 % (95 % CI:70.45 %-87.14 %), and to amoxicillin/clavunate 94.20 % (95 % CI:87.53 %-97.96 %), the rest are classified as stable, however, in this case, only 50 % (95 %CI:6.76 %- 93.24 %) are absolutely resistant to the group of penicillins studied, these strains belong to the family *Escherichia* and *Aeromonadaceae*, at the same time, these strains show resistance to other types of antibacterial drugs, and the *Aeromonadaceae* strain is pan-resistant, and shows resistance to all groups of antibacterial drugs.

During the test to assess sensitivity to cephalosporins, it was found that strains isolated from farm products are absolutely sensitive to cefotaxime and cefepime and cefoxitin, but at the same time, the proportion of sensitive strains to cefuroxime is 96.65 % (95 %CI:78.05 %-99.89 %), and the proportion of resistant strains is 4.35 % (95 %CI:0.11 %-21.95 %). This strain is a representative of the genus *Escherichia*, and is resistant only to this antibacterial drug, at the same time, the proportion of strains sensitive to ceftazidime is 82.61 % (95 % CI:61.22 %-95.05 %), doubtfully resistant is 4.35 % (95 % CI: 0.11 %-21.95 %), and The proportion of resistant strains was 13.04 % (95 % CI:2.78 %-33.59 %). The strain showing questionable sensitivity belongs to the genus Escherichia, and does not show resistance to the rest of the studied antibiotics. In the case of resistant strains, 66.67 % of them also belong to the genus *Escherichia*, and do not show resistance to other antibacterial drugs, while the remaining 33.33 % are the aforementioned *Serratia* strain. At the same time, the proportion of strains isolated from poultry farm products is 94.20 % (95 % CI: 85.82 %-98.40 %), and the proportion of resistant strains is 5.80 %(95 % CI:1.60 %- 14.18 %), it should be noted that sensitive strains belong to the genus *Proteus* and *Citrobacter*, and also show resistance, or questionable sensitivity to cefotaxime, and are also multi-resistant to penicillins and aminoglycosides. At the same time, the proportion of strains sensitive to cefipime is only 86.76 % (95 %CI: 76.68 %- 93.86 %), and the proportion of resistant strains is 4.41 % (95 %CI:0.91 %-12.18 %) — the remaining strains are classified as doubtfully sensitive.

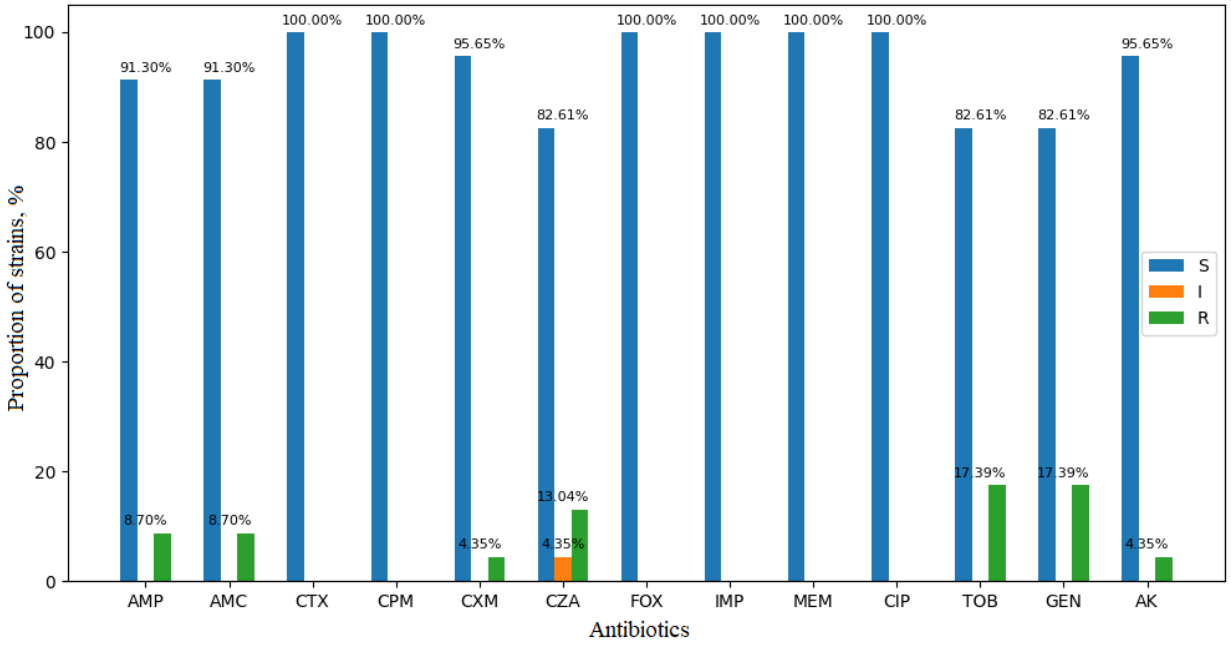


Figure 4. Sensitivity of Gram-negative strains isolated from farm products

Upon detailed study, it became known that most of the isolated strains, namely 66 % of *Escherichia*, are multi-resistant. These strains exhibit resistance to aminoglycosides, the remaining 33 % are the aforementioned pan-resistant strain of *Aeromonadaceae*. It is worth noting that the strains isolated from poultry products exhibit the least resistance to cefuroxime, namely 73.91 % (95 %CI:61.94 %-83.75 %), while the pro-

portion of strains exhibiting resistance is 18.84 %(95 %CI:10.43 %-30.06 %). During a detailed analysis, it became known that, in addition to the pan-resistant strain, from the genus *Aeromonas*, resistance to cefuroxime is manifested by isolated multi-resistant strains of *Proteus*, *Citrobacter*, and *Aeromonas*, and an interesting fact is that in 100 % of cases, these strains are also resistant to aminoglycosides and penicillins. The proportion of strains showing sensitivity to ceftazidime is 88.41 % (95 %CI:78.43 %-94.86 %), resistant — 8.70 % (95 % CI:3.26 %-17.97 %), the rest are classified as strains showing questionable resistance. Of the resistant strains, 60 % belong to the *Enterobacteriaceae* family, the rest are classified as *Aeromonas*. An interesting fact was that 50.00 % of strains resistant to this antibiotic were isolated from poultry products and 66.67 % show resistance to both penicillins and aminoglycosides, in the remaining 33.33 % of observations, the strains do not show multi-resistance properties. At the same time, 100 % of the isolated *Aeromonas* strains are multi-resistant, and in addition to the pan-resistant strain, they also exhibit 100 % resistance to aminoglycosides and penicillins. At the same time, 1 strain of *Aeromonas* was noted, which shows resistance to ciprofloxacin. The last studied antibacterial drug from the group of cephalosporins was cefoxitin, 79.71 % (95 % CI:68.31 %-88.44 %) of the isolated strains are sensitive to it, while 20.29 % (95 %CI:11.56 %-31.69 %) are resistant. Among the resistant strains, 1 *Citrobacte*r strain and 1 *Salmonella* strain have been isolated, which show resistance only to this antibiotic, the remaining strains belong to the *Enterobacteriaceae* and *Aeromonas* family, and are multi-resistant, but at the same time, in addition to the pan-resistant *Aeromonas* strain, all the above-mentioned strains show sensitivity to ciprofloxacin.

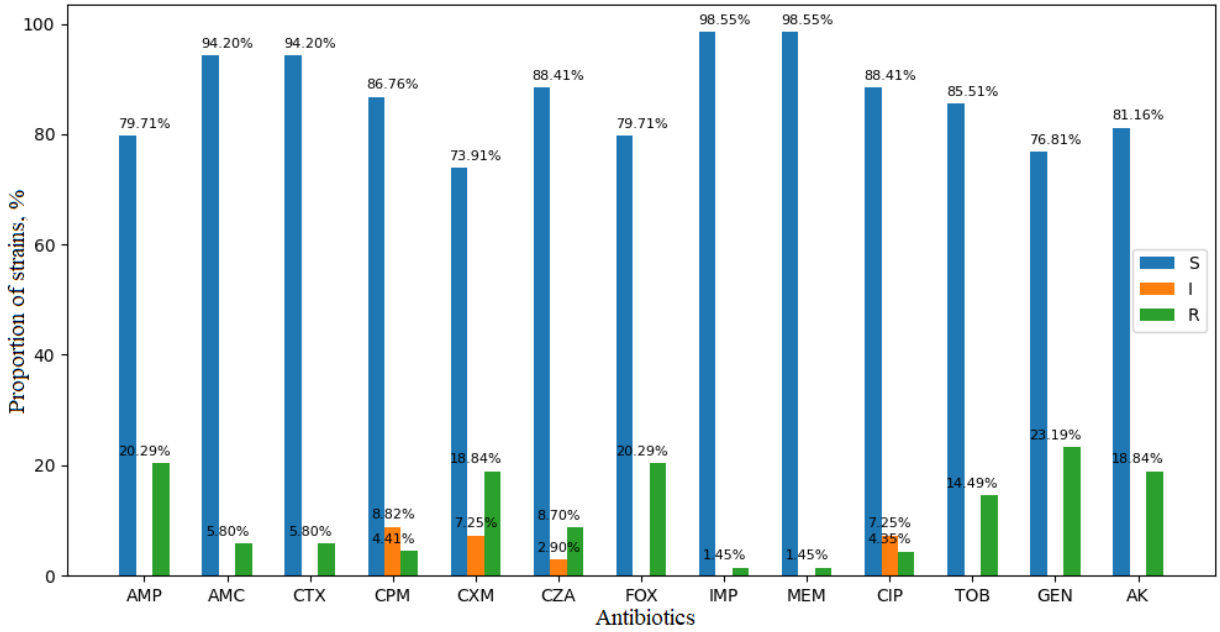


Figure 5. Sensitivity of Gram-negative strains isolated from poultry farm products.

In the study of sensitivity to carbapenems, it became known that strains isolated from farm products are absolutely sensitive to meropenem and imipenem. At the same time, strains isolated from poultry farm products are only 98.55 % (95 %CI:92.19 %-99.96 %) sensitive to meropenem and imipenem. At the same time, only the pan-resistant *Aeromonas* strain shows resistance.

Analyzing resistance to ciprofloxacin, it became known that strains isolated from farm products are also absolutely sensitive. At the same time, the proportion of sensitive strains isolated from poultry farm products is only 88.41 % (95 % CI: 78.43 %- 94.86 %), resistant — 7.25 % (95 % CI: 2.39 %-16.11 %), the rest are classified as strains showing questionable sensitivity. With the exception of the pan-resistant *Aeromonas* strain, the remaining *Enterobacter*and *Acinetobacter*, at the same time, exhibit multi-resistance properties only in half of the cases, and are multi-resistant to all groups of antibiotics, except carbapenems.

In the study of resistance to aminoglycosides, it was found that most of the strains isolated from poultry products exhibit resistance to gentamicin, namely -23.19 % (95-CI: 13.87 %- 34.91 %), the remaining 76.81 % (95 %-CI: 65.09 %-86.13 %) strains are classified as sensitive. At the same time, the strains show the greatest sensitivity to tobramycin, namely 85.51 % (95 %CI: 74.96 %-92.83 %), the rest are resistant. The proportion of strains sensitive to amikacin in this group of isolates is 81.16 % (95 % CI: 69.94 %-

89.57 %), the remaining 18.84 %(95 % CI: 10.43 %-30.06 %) are classified as resistant. It is noteworthy to note that sensitivity to gentamicin is only 25.00 % accompanied by concomitant sensitivity to amikacin, and the proportion of strains absolutely resistant to aminoglycosides is 18.75 %. It is worth noting that the proportion of strains that are absolutely sensitive to aminoglycosides is 75.00 % resistant to cephalosporins, and in 25.00 % of cases it is absolutely sensitive to penicillins.

At the same time, it was found that the proportion of sensitive strains to tobramycin and gentamicin in the group of isolates gathered from farm products is the same, and amounts to 82.61 % (95 %CI: 61.22 %-95.05 %), and resistant — 17.39 % (95 %CI: 4.95 %-38.78 %). It should be noted that the same strains belonging to the *Enterobacteriaceae* family exhibit paired sensitivity. At the same time, 95.65 % (95 % CI: 78.05 %-99.89 %) of the isolated strains are classified as sensitive, and only 4.35 % (95 % CI: 0.11 %-21.95 %) are resistant. This strain belongs to the genus *Serattia*, is multi-resistant, and exhibits resistance properties to ampicillin/sulbactam and ceftazidime.

When analyzing the production of extended-spectrum beta-lactamases, in addition to the aforementioned pan-resistant strain *Aeromonas*, a strain belonging to the genus Proteus was identified that exhibits resistance to ampicillin/sulbactam, cefotaxime and cefuroxime. An important fact is that the genus Proteus is not a representative of the normal microflora of the chicken body, and was presumably introduced from outside. At the same time, it should be noted that bacteria of this genus are identified in food mainly in violation of storage or production conditions. At the same time, this isolate also shows resistance to all aminoglycazides, which can serve as confirmation that this strain was introduced during transportation or production of the product. Another isolate that causes alertness is the *Citrobacter* strain. This isolate exhibits resistance to ampicillin/sulbactam and cefuroxime, as well as tobramycin and gentamicin, but is sensitive to cefotaxime. An important fact is that all the above-mentioned microorganisms were isolated from poultry products. During statistical processing, using the Chi-square statistical criterion adjusted for continuity, it was found that there is no statistical difference between isolates from poultry farm products and isolates from farm products producing broad-spectrum beta-lactamases ($p=0.747$ at $\alpha=0.05$). Accordingly, it can be assumed that the isolated, that the fact of the detection of these strains in poultry products is rather a special case.

Examining the resistance of gram-positive strains of bacteria isolated from farm products, it was found that only 19.05 % (95 %CI:5.45 %- 41.91 %) exhibit resistance properties to certain types of antibacterial drugs, while the number of resistant and multi-resistant strains isolated from poultry products is the same, and it is 29.41 % (95 %CI: 14.64 %- 46.30 %) for each of the groups. When analyzing the stability of Gram-negative microorganisms and farm products, it was found that only 21.74 % (95 %CI:7.46 %- 43.70 %) are stable, and only 4.35 % (95 %CI: 0.11 %- 21.95 %) exhibit multi-resistance properties. When considering Gram-negative isolated strains and poultry farm products, it became known that 31.88 %(95 %CI:21.17 %-44.21 %) exhibit resistance properties, while 27.54 %(95 %CI: 17.46 %- 39.62 %) are multi-resistant, with the vast majority belonging to the family *Enterobactereace*.

In the study of statistical differences between Gram-positive strains isolated from farm products and isolates from poultry products, significant differences were found (Chi-squared $p=0.005$, at $\alpha=0.05$). Accordingly, it can be assumed that resistant and multi-resistant strains in products produced in poultry farms will occur more often than in farm products. At the same time, significant differences between Gram-positive strains isolated from poultry and farm products are also present (Chi-squared $p=0.04$, at $\alpha=0.05$). Thus, it can be assumed that non-compliance with the rules for the use of antibacterial drugs in poultry farms may contribute to the spread of antibiotic resistance among both animals and humans.

## *Conclusion*

The data of the conducted study indicate a high prevalence of resistant and multi-resistant strains of Gram-positive and Gram-negative microorganisms in poultry products produced in the Karaganda region. Among resistant and multi-resistant strains, bacteria of the *Enterobacteriaceae* and *Staphylococcaceae* families predominate. However, despite this fact, a pan-resistant strain of a bacterium belonging to the genus *Aeromonas* was isolated from poultry farm products. When comparing strains isolated from farm products and poultry products, a statistical difference was established, due to this, it can be assumed that the excessive use of antibacterial drugs in industrial poultry farming can serve as a precedent for the spread of antibiotic-resistant strains, both among animals and among end users.

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## Құс өнімдерінде грамоң және грамтеріс микроорганизмдердің антибиотикке төзімді штамдарын іздеу

Құс өнімдеріндегі грамоң және грамтеріс микроорганизмдердің антибиотикке төзімді штамдарын іздеу бойынша зерттеу қазіргі заманғы медицина мен тамақ өнеркәсібіндегі өзекті және маңызды тақырып. Антибиотиктер құсшаруашылығында инфекциялардың алдын алу және емдеу үшін кеңінен қолданылады, бірақ бұл микроорганизмдерде антибиотикке төзімділіктің дамуына ықпал етеді. Зерттеудің мақсаты құсшаруашылығынан алынған ет пен өнімдерде болатын грамоң және грамтеріс бактериялардың антибиотикке төзімділік деңгейін анықтау және бағалау. Әдістерге төзімді штамдардың бар-жоғын анықтау және анықтау үшін тағам үлгілерін, атап айтқанда тауық еті мен тауық жұмыртқасын талдау және олардың әртүрлі антибиотиктерге сезімталдығын тексеру кіреді. Зерттеу нәтижесінде ауылшаруашылық өнімдерінен бөлінген грамоң штамдардың 19,05 %-ы және

грамтеріс штамдардың 26,09 %-ы төзімділік немесе көп төзімділік қасиеттерін көрсететіні анықталды. Сонымен қатар грамоң микроорганизмдердің 58,28%-ы және грамтеріс микроорганизмдердің 59,42 %-ы да төзімділік немесе көп төзімділік қасиеттерін көрсетеді.

*Кілт сөздер*: антибиотикке төзімділік, эпидемиология, санитарлық микробиология, құсшаруашылығы, тамақ қауіпсіздігі.

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## Поиск антибиотико-резистентных штаммов грамположительных и грамотрицательных микроорганизмов в продуктах птицеводства

Исследование по поиску антибиотико-резистентных штаммов грамположительных и грамотрицательных микроорганизмов в продуктах птицеводства представляет собой актуальную и важную тему в современной медицине и пищевой промышленности. Антибиотики широко используются в птицеводстве для профилактики и лечения инфекций, однако это также способствует развитию антибиотикорезистентности у микроорганизмов. Целью данного исследования является выявление и оценка уровня антибиотикорезистентности грамположительных и грамотрицательных бактерий, присутствующих в мясе и продуктах, производных от птицеводства. Методы включают в себя анализ образцов продуктов, а именно куриных филе и куриных яиц, на предмет наличия и идентификации резистентных штаммов, а также тестирование их чувствительности к различным антибиотикам. В ходе исследования было выяснено, что 19,05 % грамположительных штаммов и 26,09 % грамотрицательных штаммов, выделенных из продуктов фермерских хозяйств, проявляют свойства резистентности или мультирезистентности. В то же время 58,28 % грамположительных и 59,42 % грамотрицательных микроорганизмов также проявляют свойства резистентности или мультирезистентности.

*Ключевые слова:* антибиотикорезистентность, эпидемиология, санитарная микробиология, птицеводство, пищевая безопасность.

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# Frequency of rs35803318 single nucleotide polymorphism of ACE2 gene among the Kazakhs

The article presents the results of genotyping of DNA samples obtained from the study participants on the single nucleotide polymorphism (SNP) rs35803318 (C/T) of the ACE2 gene. Genotyping was carried out by real-time polymerase chain reaction (PCR) using the technique Amplification of the Refractory Mutation System (ARMS). The frequencies of rs35803318 (C/T) genotypes and alleles in 96 representatives of the Kazakh ethnic group living in the Karaganda region were analyzed. According to the results of our study, the CT genotype (63.5%) is the most common among Kazakhs, the CC genotype was 20.8% and the TT genotype was 15.6%. The distribution of polymorphism alleles is as follows: allele C – 52.6%, allele A – 47.4%.

*Keywords:* ACE2, receptor, gene, SNP, single nucleotide polymorphism, ARMS, genetic variants, Kazakhs.

## *Introduction*

One of the most important proteins in the human body, angiotensin-converting enzyme 2 (ACE), plays a vital role in the regulation of biological processes. ACE2 was first described in 2000 [1] and is a glycoprotein mainly expressed in the lungs, intestines, kidneys and heart [2]. ACE2 primarily functions in the regulation of the renin-angiotensin system (RAS), which plays a role in controlling blood pressure, hydroelectrolyte balance and cardiovascular homeostasis [3].

The interest in ACE2 has surged with the emergence of COVID-19, which is caused by the SARS-CoV-2 coronavirus. Research indicates that SARS-CoV-2 utilizes ACE2 as an entry receptor to infect body cells [4]. This discovery led to the development of many studies aimed at studying the interaction of SARS-CoV-2 with ACE2 and the development of therapeutic methods and vaccines [5].

In addition, ACE2 has become an object of research in the context of other diseases. For example, its role in pathologies associated with the cardiovascular system has been studied in detail [6]. ACE2 has also been linked to infections such as severe acute respiratory syndrome (SARS) [7] and associated with metabolic [8], renal [9].

The ACE2 gene encodes the angiotensin-converting enzyme 2. The ACE2 gene (Gene ID: Gene ID: 59272) is located in the short arm of human X chromosome (Xp22.2) and consists of 22 exons (ACE2 Angiotensin Converting Enzyme 2 [Homo Sapiens (Human)] — Gene — NCBI, n.d.) [5].

These changes can affect the structure, function, or regulation of genes. Gene polymorphisms are a natural and important aspect of genetic diversity and can have a variety of effects on organisms and their phenotypes.

The ACE2 receptor is a surprisingly interesting object of research in the field of biology and medicine. Its role in the regulation of RAS, its effect on diseases and pathologies, as well as its association with SARS-CoV-2 infection make it one of the key proteins requiring further study to better understand its functions and possible medical applications.

## *Materials and Methods*

This study includes participants who are over the age of 18 and are representatives of the Kazakh ethnic group. The total number of participants was 96, of which 27 (28.1 %) — men, 69 (71.9 %) — women. The age range is 18–78 (Mean±SD 43.44±14.22).

The study was conducted in accordance with the recommendations of Helsinki ethical principles and approved by the local bioethics committee non-commercial joint-stock company "Karaganda Medical University" (protocol No. 2 dated 11 October 2022). Every participant provided written consent after being informed.

"RIBO-prep" kit (AmpliSens, Russia) was used to extract genomic DNA from venous blood samples. The isolation procedure was conducted in accordance with the manufacturer's instructions. To identify the target single nucleotide polymorphism (SNP) rs35803318 C>T the isolated DNA was analyzed using real-time polymerase chain reaction (Real-time PCR) using the technique Amplification of the Refractory Mutation System (ARMS). Real-time PCR was conducted using a DTlite amplifier (DNA Technology, Russia). The real-time PCR conditions and sequences of four primers (Lumiprobe, Russia) are presented in Table.

Table

**rs35803318 primers list for ARMS-PCR**

| Direction | Primer Sequence | Real-time PCR conditions (denaturation, annealing cycles) |
|---|---|---|
| FIP (T allele) | 5′-CAATGCCAACCACTATCACTCCCCTT-3′ | 94 °C/3 min (94 °C/15 sec, 68 °C/30 sec) × 40 |
| RIP (C allele) | 5′-CCATATGGCTGATTGTTTTTGGAGTTTTG-3′ | |
| FOP | 5′-AAGTCTAGGAAAGGCCACTTACTTCTTCCG-3′ | |
| ROP | 5′-TTTCTGGGGATACAGCAACACTTGGAC-3′ | |

The percentages were used to characterize the categorical variables. The $\chi 2$ test was employed to assess the Hardy-Weinberg equilibrium (HWE), and deviations from HWE were deemed significant at a p-value threshold of less than 0.05. The statistical analysis of the research results was conducted using the GraphPad Prism 8 program.

*Results and Discussion*

rs35803318 genotypes frequency did not correspond to the Hardy-Weinberg equilibrium (p=0.0271). According to the database dbSNP NCBI, the frequency of allele C (0.95043) is higher than allele T (0.04957) [10]. We identified alleles C and T, the frequency of their distribution was 52.6 % and 47.4 %, respectively (Fig. 1).

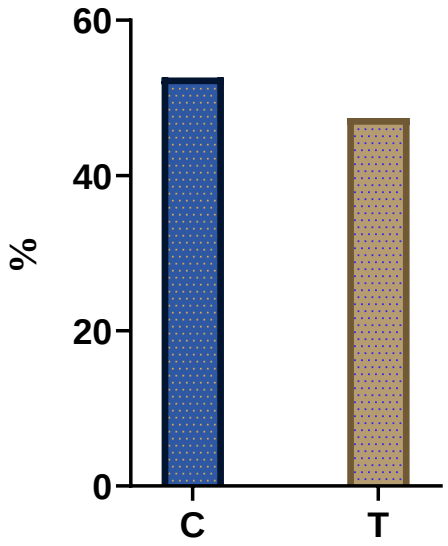


Figure 1. Frequency of rs35803318 alleles among Kazakhs

According to studies [11, 12], the rs35803318 genetic variant exhibits a higher frequency in Italian, European and American populations compared to the extremely low frequency seen in African and Asian groups.

The results of the study showed that among Kazakhs, the most common polymorphism genotype was CT, making up 63.5 % of the total number of examined participants, the CC genotype was 20.8 % and the TT genotype was 15.6 % (Fig. 2).

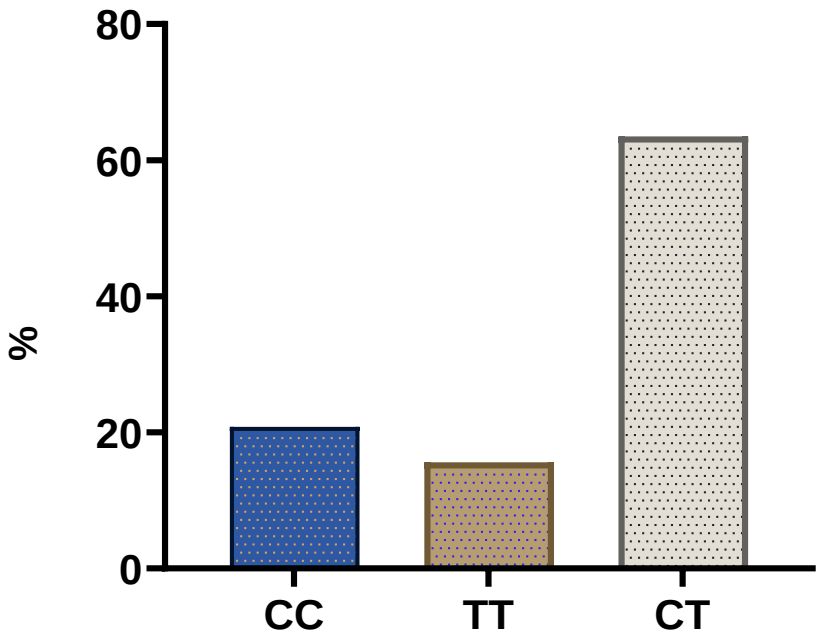


Figure 2. Frequency of rs35803318 genotypes among Kazakhs

The authors of this study [13] showed that the rs35803318 genetic variant is absent in Asian and practically absent in African populations, however, the frequency of polymorphism is higher in the indigenous peoples of the Amazon than in other populations. The data presented in this study [14] on the genetic variant rs35803318 in the synonymous coding region indicate interesting patterns of polymorphism distribution in different populations. Based on this data, it can be concluded that this variant is more polymorphic among American and European populations. Interestingly, in contrast to American and European populations, South Asians show less genetic variability in this synonymous coding region. This observation emphasises genetic variability and diversity between ethnic groups.

*Conclusions*

As a result of our study of the frequencies of rs35803318 genetic polymorphism in the Kazakh population, we have made an important conclusion. Among Kazakhs, the CT genotype was the most common, accounting for 63.5 %, while the CC genotype was 20.8 %, and the TT genotype was 15.6 %. In the Kazakh population, the C allele predominates at 52.6 % and the T allele at 47.4 %. These results provide valuable information about the genetic diversity in this population and can serve as a basis for further research on the relationship of this polymorphism with various diseases.

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## Қазақтардағы ACE2 генінің бір нуклеотидті полиморфизмнің rs35803318 жиілігі

Мақалада ACE2 генінің rs35803318 (C/T) бір нуклеотидті полиморфизмі бойынша зерттеуге қатысушылардан алынған ДНҚ үлгілерін генотиптеу нәтижелері келтірілген. Генотиптеу полимеразды тізбекті реакция (ПТР) әдісімен нақты уақыт режимінде «Рефракторлық мутациялық жүйені күшейту» әдісін қолдана отырып жүзеге асырылды. Қарағанды облысында тұратын қазақ этникалық тобының 96 өкілінде rs35803318 (C/T) генотиптері мен аллельдерінің жиіліктерінің таралуы талданды. Біздің зерттеу нәтижелерімізге сәйкес қазақтар арасында CT генотипі (63.5%) ең көп таралған, ал CC генотипі 20.8% және TT генотипі — 15,6% құрады. Полиморфизм аллельдерінің таралуы: C аллелі — 52,6%, A аллелі — 47,4%.

*Кілт сөздер:* ACE2, рецептор, ген, SNP, бір нуклеотидті полиморфизм, ARMS, генетикалық нұсқалар, қазақтар.

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## Частота однонуклеотидного полиморфизма rs35803318 гена ACE2 среди казахов

В статье представлены результаты генотипирования образцов ДНК, полученных от участников исследования по однонуклеотидному полиморфизму rs35803318 (C/T) гена ACE2. Генотипирование осуществлялось методом полимеразной цепной реакции (ПЦР) в режиме

реального времени с использованием методики «Амплификация рефракторной мутационной системы». Проанализировано распределение частот генотипов и аллелей rs35803318 (C/T) у 96 представителей казахской этнической группы, проживающих в Карагандинской области. Согласно результатам нашего исследования среди казахов генотип CT (63,5 %) — наиболее распространенный, генотип CC составил 20,8 % и генотип TT — 15,6 %. Распределение аллелей полиморфизма выглядит следующим образом: аллель C — 52,6 %, аллель A — 47,4 %.

*Ключевые слова:* ACE2, рецептор, ген, SNP, однонуклеотидный полиморфизм, ARMS, генетические варианты, казахи.

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# The importance of bacteria of the genus *Bifidobacterium* in intestinal microbiocenosis

Bifidobacteria are the most common microorganisms in the intestines of healthy breastfed children. The genus *Bifidobacterium* includes bacteria characterized by probiotic properties, such as the induction of immunomodulators, increasing the nutritional value of products due to the assimilation of substrates that are not broken down by the host, anticarcinogenic activity, synthesis of vitamins, production of antimicrobial drugs, which contribute to the promotion of health. Bifidobacteria demonstrate physiological and genetic characteristics including adhesion to the intestinal epithelium, as well as metabolism of glycans in the host body. Multitrophic interaction is formed based on various mechanisms of substrate recognition in the surrounding environment and the transmission of molecular and genetic information, which contributes to survival in the human gastrointestinal tract. Representatives of the *Bifidobacterium bifidum* species constitute a dominant taxon among bifidobacteria, demonstrating significant probiotic properties and extensive potential for the treatment and prevention of various diseases. Currently, a large number of *Bifidobacterium bifidum* species have been sequenced, which are of interest to medicine, biotechnology, and agriculture. Their genetic strategies for colonizing and persisting in the human intestine have been identified. Cross-interaction mechanisms of *Bifidobacterium bifidum* with the host and other microorganisms have been demonstrated using various structures. In this review, we discuss current knowledge about the biology of the genus *Bifidobacterium*, including the biological characteristics of *Bifidobacterium bifidum* species, which exhibit specific adaptations to the human intestine.

*Keywords:* bifidobacteria, *Bifidobacterium bifidum*, probiotics, human gut microbiota, microbiome, bifidobacterial metabolism, phylogeny, taxonomy.

## *Introduction*

Bacteria of the genus *Bifidobacterium* are anaerobic, Gram-positive microorganisms belonging to the *Actinobacteria* phylum. They have a high G+C content and are common inhabitants of the gastrointestinal tracts of mammals, birds, and some ectothermic animals. The "intestinal microbiota" represents the collective population of microbes residing in the gastrointestinal tract, forming a highly complex microbial community, functions of which exert a significant influence on the physiological processes of the human body [1, 2].

Bifidobacteria were first isolated by Tissier. Members of the *Bifidobacteriaceae* family exhibit various cell shapes, including curved, short, and bifurcated Y-shaped forms. These cells lack capsules, do not form spores, and are non-motile and non-filamentous bacteria [3].

Currently, various ecological relationships have been identified between bacteria of the genus *Bifidobacterium* and their hosts, ranging from pathogenic *(Bifidobacterium scardovii)* to commensal *(Bifidobacterium dentium)* interactions and even those contributing to health promotion *(Bifidobacterium bifidum, Bifidobacterium breve)* [4–6]. Bifidobacteria are among the earliest and most important colonizers of the neonatal human gastrointestinal tract, exerting a broad influence on the early development of the host organism [7, 8]. Among the known health-promoting probiotic microorganisms, bifidobacteria represent one of the most dominant groups, and some species of bifidobacteria are frequently used as probiotic ingredients in various functional food products [9].

An analysis of publications from the last 10 years was conducted using databases such as PubMed, Web of Science, Scopus, and Elsevier. The following terms were employed: “bifidobacteria”, “*Bifidobacterium bifidum”*, “probiotics”, “human gut microbiota”, “microbiome”, “bifidobacterial metabolism”, phylogeny”, “taxonomy”, “bifidobacterial genome”, and “bifidobacterial glycome”. Over 100 publications were examined, and for this review, 67 articles were selected, including randomized, blind, and unbiased studies.

The Bifidobacteriaceae family comprises nine genera: Bifidobacterium, Aeriscardovia, Alloscardovia, Bombiscardovia, Gardnerella, Neoscardovia, Parascardovia, Pseudoscardovia, and Scardovia, encompassing a total of 69 species [10].

Classification and phylogenetic studies of bifidobacteria until the end of the last century were based on the type of peptidoglycans, morphological and physiological properties, biochemical reactions, including carbohydrate fermentation patterns, enzyme activities, DNA G+C content, DNA-DNA hybridization, and 16S rRNA gene sequences [11]. A universal phylogenetic marker applicable to the entire *Bifidobacteriaceae* family has not yet been developed. *Glaeser et al.* argue that phylogeny based on the 16S rRNA gene sequence cannot provide sufficient resolution down to the species level. However, they suggest it should remain a fundamental approach in prokaryotic taxonomy as it reflects common prokaryotic relationships, enables the determination of the phylogenetic placement of both cultivated and uncultivated bacteria, generally provides initial genus assignments, and can reflect the overall phylogenetic diversity of the investigated bacteria. To achieve higher-resolution results in phylogenetic relationships between species within a genus or genera within a family, the authors propose considering a multilocus sequence analysis (MLSA) [12].

*Killer et al.* proposed a candidate gene for phylogenetic studies within the *Bifidobacteriaceae* family—the gene encoding cytidine triphosphate synthase, which catalyzes the ATP-dependent amination of uridine-5'-triphosphate to cytidine triphosphate, using L-glutamine or ammonia as a nitrogen source. Cytidine triphosphate synthase plays an essential role in RNA synthesis during transcription. It is ubiquitous in bacteria, homologous, exists as a single copy in the genome, undergoes stabilizing selection, is stable concerning rapid genetic modification, and is capable of constructing a reliable phylogenetic tree that maximally reflects the species evolution [13].

Current understanding of the complexity and diversity of bifidobacteria aims to utilize both 16S rRNA gene sequence analysis and sophisticated molecular methods for species and subspecies differentiation [14].

*Jarocki et al.* conducted an assessment of four molecular methods: ARDRA, RAPD-PCR, rep-PCR, and SDS-PAGE fingerprinting, widely used for the rapid differentiation of bifidobacteria down to the strain level. The results showed that BOX-PCR was the most suitable procedure for accurate identification of 21 strains of bifidobacteria compared to (GTG)5-PCR [15].

*Jena et al.* also noted the effectiveness of the BOX-PCR method, identifying the taxonomic status of 93 species of bifidobacteria isolated from various human and animal fecal samples [16].

Therefore, alternative molecular methods such as RAPD, MLSA, AFLP, ribotyping, PFGE, RFLP, and rep-PCR have been at the forefront of research for species identification within the *Bifidobacterium* genus. For example, the RAPD method characterized the following bifidobacteria: *Bifidobacterium bifidum, Bifidobacterium infantis, Bifidobacterium adolescentis, Bifidobacterium longum, Bifidobacterium animalis, Bifidobacterium breve* [62]. Some of these protocols are labor-intensive and time-consuming, especially when working with a large number of isolates [14, 15, 17].

Microbial interactions, either microbe-microbe and/or microbe-host, play a crucial role in the successful establishment and maintenance of microbial populations. They occur through the recognition of the environment and the transmission of molecular and genetic information, involving numerous mechanisms that lead to the formation of multitrophic interactions, aiding in survival and adaptation in the complex environment of the human gastrointestinal tract [18].

These mechanisms may include secondary metabolites, siderophores, quorum-sensing systems, biofilm formation, and cell transduction signal transmission. The ultimate unit of interaction is the gene expression of each organism in response to biotic or abiotic stimuli, responsible for the production of molecules involved in these relationships [19]. Microorganisms produce a wide variety of compounds known as secondary metabolites, which do not play a significant role in the growth, development, and reproduction of the producer organism. However, they represent biologically active compounds that can perform crucial functions such as protection, competition, signal transmission, and ecological interactions. Secondary metabolites and their functions have been studied through mass spectrometry and metabolomics [20, 21].

Siderophores are associated with competitive and cooperative interactions among microorganisms and may also play a role in signal transduction and antibiotic activity of microbes [22]. Many bacteria also em-

ploy intercellular communication, known as quorum sensing. It coordinates changes in microbial behavior based on population density. As a result of this system's response, it produces diffusible or secreted signals that vary significantly among different bacterial types. In some species, quorum sensing modulates virulence and is of significant importance for pathogenesis [23].

The formation of biofilms by various microorganisms occurs as a result of ecological stresses, such as insufficient nutrients, the action of antibiotics, pH, bile, and its induction by the quorum sensing system. *Kelly et al.* demonstrated that biofilm formation in *Bifidobacterium* bacteria is induced by high concentrations of bile, as well as individual bile salts, rather than due to acid or osmotic stress. An adaptive response to high bile concentrations was the formation of a biofilm, which included the production of exopolysaccharides, proteins, and the release of extracellular DNA, representing a crucial strategy to avoid the bactericidal effects of bile [24].

The interaction of bifidobacterial chaperones with human proteins suggests the modulating potential of bifidobacteria towards human proteins. It has been revealed that bifidobacterial proteins, capable of interacting with each other and with the host system, play a significant role and can be utilized as therapeutic targets for desired immunomodulation. In other words, probiotics can be used as therapeutic molecules to induce changes in the expression of these proteins, which can be employed to modify their cross-interaction with the human system within the context of prognostic, preventive, and personalized medicine [25].

Bifidobacteria exhibit a diverse range of hosts and demonstrate beneficial properties for their hosts. *Rodriguez et al.*'s study of 400 strains of bifidobacteria revealed that their diversity is highly adapted to specific hosts and the surrounding environment. Strains isolated from the same host showed phylogenetic relatedness, whereas strains from different sources exhibited differences in genome size, auxiliary gene composition, as well as specific features related to amino acid production and carbohydrate degradation [26].

The adaptation of bifidobacteria to hosts is reflected in the evolutionary history of the core genome, as well as in the composition of their auxiliary genes and specific gene sets. At the same time, within the genus, there is insufficient information regarding specialization in specific human habitats or developmental stages, which may be associated with limitations in sample selection or a higher degree of bacterial spread among humans than initially assumed. Thus, the assembly of bifidobacteria in their habitats is determined by a combination of ecological (host filtration) and evolutionary (host adaptation) forces [27].

In some studies, it is noted that the phylogeny of bifidobacteria differs from the phylogeny of hosts. This discrepancy may be associated with niche-specific evolution and the dietary carbohydrates of the hosts. *Satti et al.* investigated the evolutionary relationship between bifidobacteria and animal hosts based on the link between the host's diet and bacterial glycoside hydrolases (GH). Bifidobacterial strains were categorized into 5 groups based on their GH genes, determining differences in the host's diet. The study showed that species isolated from hosts with complex dietary habits had significantly more GH genes than species with simpler dietary patterns [28].

The genus *Bifidobacterium* contains one of the largest collections of representatives of the GH13, GH43, and GH51 families, indicating their ability to outcompete other microbiota for undigested plant-derived dietary fibers in the gut. Members of the GH13 (32.9 % of extracellular GH), GH43 (24 %), and GH51 (12 %) families are typical extracellular enzymes that can benefit the host in gaining access to dietary fibers. Bifidobacteria also have broad enzyme profiles, indicating a preference for mucin glycans, especially O-linked glycans, which may make a significant contribution to their adaptation to the host's lifestyle [29].

There have been several studies attempting comparative genomic analysis of the genus *Bifidobacterium* to explore evolutionarily conserved functional features. It was found that the core functions were associated with adaptation to specific environments or interactions with them. Some of the most common core functions included carbohydrate metabolism, cell wall biogenesis, amino acid biosynthesis, and transport, as well as nucleotide biosynthesis and transport [28, 30, 31].

Representatives of the genus *Bifidobacterium* demonstrate inter-species variations in the sizes of their genomes, reflecting differences in their metabolic capabilities [32].

In several studies, it has been shown that the genus *Bifidobacterium* contains between 400 to 500 core genes. The composition of auxiliary genes (approximately 6400 genes) has been linked to both the source of bacterial isolation and the phylogeny of bifidobacterial strains [26, 30, 31, 32].

The study of specific features, such as amino acid biosynthesis genes, revealed variations among different strains. For instance, strains isolated from bees showed the lowest diversity in amino acid biosynthesis genes, while strains isolated from other host categories carried from 86 to 90 genes. The search for carbohy-

drate-active enzymes showed that strains isolated from the oral cavity encoded the highest number of genes, whereas strains isolated from the adult intestine encoded the lowest number of genes [26].

Thus, the genomes of bifidobacteria also demonstrate adaptation to the host's environment through auxiliary genes and specific gene sets. *Sun et al.* identified that bifidobacteria isolated from bees, pigs, and humans share common unique gene sets. However, the correlation between auxiliary genes and isolation sources was weaker than the connection with phylogeny based on core genes for the entire genus [31]. Consequently, it is suggested that the specialization of bifidobacteria to host species is primarily determined by vertically inherited traits, while horizontal gene transfer of features captured through auxiliary gene composition plays a secondary role. Deb's study also showed that horizontal gene transfer, genome expansion, and reduction events lead to divergence in the metabolic functions of *Bifidobacterium* bacteria [33].

The primary approach providing both taxonomic assignments and information on functional capabilities is "metagenomics" ("metatranscriptomics"), used to determine which genes are present or expressed. Since such studies analyze sequences directly from the sample and do not require an intermediate amplification stage, they provide a relatively objective representation of the genomes present and reveal a set of functional genes that may play a specific role in the host's biology. Sequencing DNA from community samples is straightforward, and the homology of the sequenced genes with enzymes of known function is easily established using bioinformatics methods and constantly improving databases [34].

*Lugli et al.* also highlight the role of next-generation sequencing, which has provided access to the genome sequences of all currently known bacterial taxa, as well as publicly available databases allowing the comparison of genome sequences among microorganisms, providing information for genomic, phylogenomic, and evolutionary analyses. The authors suggest a phylogenomic approach to confirm new bacterial taxa within the genus Bifidobacterium [35].

The importance of microbial communities lies significantly in their metabolic capabilities, which can potentially be utilized by hosts to expand their ecological range. Examples of such capabilities include the digestion or detoxification of food components, the use of new energy sources, and the production of toxins that can affect the host or pathogenic organisms. Gut microbial interactions constitute a biological network that influences the growth of specific bacterial groups [36].

*In vivo* studies have identified correlational relationships between the 50 most dominant microbes, of which 38 bacterial genera were directly correlated with the growth of *Bifidobacterium* bacteria — 23 genera with positive correlation and 15 genera with negative correlation [37].

*Fernandez-Julia et al.* analyzed various types of β-glucans, which have beneficial effects such as reducing energy consumption and cholesterol levels, supporting the immune system, and serving as fermentable substrates for *Bacteroides* and bifidobacteria. The authors demonstrated syntrophic relationships between Bacteroides spp., specializing as primary degraders in the metabolism of complex carbohydrates, and *Bifidobacterium* spp. more often metabolize smaller glycans, particularly oligosaccharides, where they act as secondary degraders [38].

Beyond the probiotic properties of bifidobacteria, their niche adaptation is of great interest as these bacteria survive in the harsh conditions of the human gastrointestinal tract. Some species of bifidobacteria have demonstrated various strategies to overcome gastrointestinal stress, including the impact of digestive enzymes, acidic pH, defensins, and antimicrobial peptides. Most studied strains of *Bifidobacterium adolescentis* and all strains of *Bifidobacterium angulatum* lacked a set of active oxygen forms, explaining their high sensitivity to oxygen. Some presumed transcriptional regulators of stress responses differ among different species and strains, indicating various strategies for the transcriptional regulation of stress-related genes [39].

The genus *Bifidobacterium* consists of bacteria that naturally inhabit various ecological niches, including the gastrointestinal tract of humans and animals. Bifidobacteria are widely used as probiotics because they are associated with health benefits. The formation and persistence of *Bifidobacterium* strains in the intestine depend on the species and strain, natural history, genomic adaptation, metabolic interactions of bacteria with the microbiome, and the host's immune properties, all regulated by the diet. For commercial use, bifidobacterial strains are typically selected for fast growth, antibacterial activity, good adhesive properties, and the utilization of prebiotic substrates. Currently, they represent a significant interest in the development of biotechnology, medicine, and agriculture.

Bifidobacterium bifidum

*Bifidobacterium bifidum* is a species within the genus *Bifidobacterium* that is widely distributed in the human gut microbiome [40]. It is one of the earliest bacterial species to colonize the intestinal tract, and its

presence positively correlates with concentrations of aromatic lactic acids in the feces of breastfed infants [7]. *Stewart* also associates higher levels of *bifidobacteria* with breastfeeding, and the cessation of breastfeeding leads to a more rapid maturation of the gut microbiome [8]. *Bifidobacterium bifidum*, present in the intestines of infants, is transmitted from the mother through breast milk [41], and its predominance in the gastrointestinal tract of breastfed infants is due to its ability to release monosaccharides from breast milk oligosaccharides [42].

*Bifidobacterium bifidum* possesses powerful probiotic properties and has significant potential for the prevention and treatment of various human diseases. Currently, it is available as a functional food ingredient and can also be used for therapeutic purposes [43].

*Genome and Glycobiome Features*

In recent years, the GenBank database of the National Center for Biotechnology Information (NCBI) has accumulated over 100 sequenced genomes of *Bifidobacterium bifidum*, particularly those of interest to the probiotic industry. The deposited NCBI reference genome for Bifidobacterium bifidum is derived from the isolate PRL2010, obtained from infant feces and sequenced and published in 2010 [44]. The authors identified a prevalence of chromosomal loci in *Bifidobacterium bifidum* encoding specific enzymes responsible for mucin degradation. The genome size of *Bifidobacterium bifidum* BGN4, isolated from the feces of a breastfed infant, is approximately 2.2 Mb, comprising 1835 sequences [45]. *Ku et al.* assessed the biofunctionality of BGN4 through in vitro studies (anticancer and immunomodulatory effects), in vivo experiments (allergies and inflammatory bowel diseases), as well as clinical investigations (eczema, irritable bowel syndrome) [46]. *Zhurina et al.* annotated the genome sequence of *Bifidobacterium bifidum* S17, a strain firmly adhering to intestinal epithelial cells and exhibiting potent in vitro and in vivo anti-inflammatory activity [47]. *Gueimonde et al.* reported on the genome sequences of the strain *Bifidobacterium bifidum* LMG13195, capable of interacting with human immune cells and generating functional regulatory T-cells [48]. *Andryuschenko et al.* described the genome sequence project of the strain *Bifidobacterium bifidum* ICIS-310, isolated from the feces of a healthy 5-year-old child. The genome size was 2,219,632 base pairs (G+C content 62.4 %), with 1886 identified coding sequences, including 1718 proteins, 6 rRNA genes, and 52 tRNA genes [49]. *Morita et al.* deciphered the complete genome sequence of *Bifidobacterium bifidum* JCM 1255T, isolated from the feces of a breastfed infant [50].

Various strains of Bifidobacterium bifidum have undergone whole-genome sequencing, revealing specific genetic strategies that enable members of this species to attach to and persist in the human intestine. This is achieved through the synthesis of different types of pili [51, 52] or metabolic properties related to glycans obtained from the host [53].

Enzymes that degrade glycans initiate their action from the non-reducing end of the mucin glycan chain. When all glycans are removed, the protein core of mucin degrades, and the entire mucin polymer network dissolves. This contributes to the degradation of MUC2 mucin and mucus. When using glycans as an energy source, carbohydrate-active enzymes (glycoside hydrolases, sulfatases, and proteases) generate acetate and butyrate (short-chain fatty acids), which are absorbed and utilized by intestinal cells to recover some of the energy expended on the synthesis and secretion of MUC2 mucin [54].

The glycobiome of *Bifidobacterium bifidum* comprises over 3000 genes encoding carbohydrate-active enzymes, including glycosyl hydrolases (sialidases, fucosidosis, exo-β-N-acetylglucosaminidase, endo-β-N-acetylglucosaminidase, β-galactosidases, α-N-acetylglucosaminidase, α-N-acetylgalactosaminidase), glycosyltransferases, and carbohydrate esterases. However, research indicates that carbohydrate metabolism is constrained by a relatively small number of carbohydrates [42, 44].

The interaction between the mucosal layer and the intestinal microbiota develops in parallel during early postnatal life, contributing to the host's homeostasis. The mucosal layer serves as a framework and carbon source for gut microorganisms, while intestinal microorganisms influence the expression of mucin genes, glycosylation, and secretion. The integrity of the mucosal barrier is one of the first lines of defense for the gastrointestinal tract [54].

*The interaction of Bifidobacterium bifidum with the host organism and other microorganisms*

Commensal gut bacteria establish direct contact with the host using various structures such as pili, fimbriae, proteins, sialidase, human plasminogen receptor, enolase, capsule, etc. [44, 51, 52].

*Turroni et al.* demonstrated, using the example of *Bifidobacterium bifidum* PRL2010, that pili confer both adhesive properties to intestinal epithelial cells and in vivo immunomodulatory properties to this probiotic [55].

*Andryuschenko et al.* characterized strains of *Bifidobacterium bifidum* ICIS-504, which have a moderate number of sortase-dependent fimbrial determinants (4 genes with the LPxTG domain) and a small number of genes for two-component signal systems: 5 serine-threonine protein kinases, 8 histidine kinases, and 13 response regulators [56].

*Ishikawa et al.* identified multiple sortase-dependent proteins and pili in *Bifidobacterium bifidum* YIT 10347 (BF-1) that work collaboratively for adhesion. The "housekeeping" sortase is responsible for anchoring its substrates to the cell wall to ensure their biological function [52].

The interaction of certain strains of *Bifidobacterium bifidum* with the mucous membrane of the gastrointestinal tract is mediated through sialidases, which act as protein adhesins and process various carbohydrates, including oligosaccharides from breast milk. These carbohydrates are essential for the metabolism and growth stimulation of *Bifidobacteria*. Nishiyama et al. investigated the molecular mechanisms of nutrient uptake and adhesion of *Bifidobacterium bifidum* ATCC 15696, involving the exo-α-sialidase SiaBb2. It was found that the mutant strain exhibited reduced adhesion to human intestinal epithelial cells and pig mucin compared to the wild-type strain, highlighting the crucial role of sialidases as adhesins [57].

Other studies have demonstrated that *Bifidobacterium bifidum* PRL2010 targets host mucin glycans for nutrient assimilation. This catabolic process, conserved across different strains, is a significant factor in the colonization of *Bifidobacterium bifidum* [55].

*Candela et al.* demonstrated that *Bifidobacterium bifidum*, which binds plasminogen, utilizes the key glycolytic enzyme enolase as a surface receptor for human plasminogen [58]. α-enolase is expressed on the surface of various cell types, where it acts as a plasminogen receptor, concentrating plasmin's proteolytic activity on the cell surface. In addition to glycolysis, it possesses other cellular functions and subcellular localizations and is associated with several pathologies such as cancer, Alzheimer's disease, rheumatoid arthritis, and others [59].

Protective mechanisms of bifidobacteria on the intestinal epithelium were studied by *Kainulainen et al.*, showing that three proteins, SERPINB3, PKD1, and PAQR6, are involved in regulating cellular processes related to proliferation, differentiation, apoptosis, as well as inflammation and immunity. Blocking these proteins reduced the adhesion of *Bifidobacterium bifidum* [60].

The surface structure of bifidobacteria involved in the interaction with the host is the surface capsule (a layer of extracellular polysaccharides). It modulates the immune system, enhances bacterial resistance to adverse conditions in the intestine (bile and low pH), and can also serve as a substrate for the growth of other bacteria. Results showed that extracellular polysaccharides significantly increased the growth of lactobacilli and total anaerobic bacteria while inhibiting the growth of enterobacteria, enterococci, and *Bacteroides fragilis* [61].

*Rodríguez et al.'s* study showed that catalase-positive intestinal bacteria are capable of protecting neighboring catalase-negative bifidobacteria from oxidative stress, thereby providing a mechanism of cross-protection among intestinal bacteria that enhances the survival and colonization of bifidobacteria in the intestine [62].

Many strains of *Bifidobacterium bifidum* exhibit favorable effects, such as antibacterial properties against *Helicobacter pylori* [63], *Escherichia coli*, and *Cronobacter sakazakii* [42, 44]. The beneficial impact of *Bifidobacterium bifidum* also includes the restoration of damaged intestinal mucosa and the reduction of apoptosis in intestinal epithelial cells in a model of necrotizing enterocolitis in newborn rats [64], influence on intestinal barrier function and suppression of colitis [65], lowering cholesterol levels [6], reducing the risk of allergy development [66], protection against type 1 diabetes in early development [41], and improvement of cognitive functions when combined with *Lactobacillus plantarum* [67].

Numerous *in vitro* and *in vivo* studies have been conducted, and their results suggest that bifidobacteria when employed as probiotics, may fulfill crucial functions such as reinforcing the mucosal layer of the intestinal epithelium, shaping a balanced microbiota homeostasis, and contributing to immune system support. However, for bifidobacteria to execute these functions, they must survive the conditions of the human gastrointestinal tract, exhibiting viability in this organ system, i.e., demonstrating the capacity for colonization, competition, persistence in the human intestine, and impact on resident microbial communities. Consequently, further research and clinical trials involving *Bifidobacterium bifidum* are warranted.

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## *Bifidobacterium* туысына жататын бактериялардың ішек микробиоценозындағы маңызы

Бифидобактериялар — ана сүтімен тамақтанатын сау балалардың ең кең таралған ішек микроорганизмдері. *Bifidobacterium* туысы денсаулықты нығайтатын және пробиотикалық қасиеттерімен сипатталатын бактериялар, олар иммуномодуляторлардың индукциялау ретінде иесінің денесі ыдыратпайтын субстраттарды сіңіру арқылы тағамның тағамдық құндылығын арттырады, канцерогенге қарсы белсенді, витаминдер синтезін, микробқақарсы препараттарды өндіруде маңызды. Бифидобактериялар ішек эпителийінің адгезиясы, сонымен қатар иесінің ағзасындағы гликандар метаболизмін қамтитын физиологиялық және генетикалық ерекшеліктерге ие. Мультитрофты өзара әрекеттесу қоршаған ортаның субстраттарын танудың және адамның асқазан-ішек жолында өмір сүруге ықпал ететін молекулалық және генетикалық ақпаратты берудің әртүрлі механизмдері негізінде қалыптасады. *Bifidobacterium bifidum* түрінің өкілдері бифидобактериялар арасында басым болып келетін таксондардың бірі, оның пробиотикалық қасиеттері өте жоғары және әртүрлі ауруларды емдеу мен алдын алуда үлкен мүмкіндіктер береді. Қазіргі уақытта медицина, биотехнология және ауыл шаруашылығында қызығушылық тудыратын *Bifidobacterium bifidum* бактериясының көптеген түрлері секвенирленген. Олардың колонизациялануына және адамның ішегінде сақталуына мүмкіндік беретін генетикалық стратегиялары анықталды. *Bifidobacterium bifidum*-дің иесімен және басқа микроорганизмдермен өзара әрекеттесу механизмдері әртүрлі құрылымдарды қолдану арқылы көрсетілді. Мақалада біз *Bifidobacterium* тұқымдасының биологиясына қатысты заманауи деректерді, соның ішінде адамның ішегіне ерекше бейімделуді көрсететін *Bifidobacterium bifidum* түрінің биологиялық ерекшеліктерін талқыладық.

*Кілт сөздер*: бифидобактериялар, *Bifidobacterium bifidum*, пробиотиктер, адамның ішек микробиотасы, микробиом, бифидобактериялардың метаболизмі, филогения, таксономия.

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## Значение бактерий рода *Bifidobacterium* в микробиоценозе кишечника

Бифидобактерии — наиболее распространенные микроорганизмы в кишечнике здоровых детей, находящихся на грудном вскармливании. К роду *Bifidobacterium* относятся бактерии, характеризующиеся пробиотическими свойствами, такими как индукция иммуномодуляторов; повышение пищевой ценности продуктов за счет усвоения субстратов, не расщепляемых хозяином; антиканцерогенная активность; синтез витаминов; производство противомикробных препаратов, которые способствуют укреплению здоровья. Бифидобактерии демонстрируют физиологические и генетические характеристики, включая адгезию к эпителию кишечника, а также метаболизм гликанов в организме хозяина. Мультитрофическое взаимодействие формируется на основе различных механизмов узнавания субстратов в окружающей среде и передачи молекулярно-генетической информации, что способствует выживанию в желудочно-кишечном тракте человека. Представители вида *Bifidobacterium bifidum* составляют доминирующий таксон среди бифидобактерий, демонстрируя значительные пробиотические свойства и обширный потенциал для лечения и профилактики различных заболеваний. В настоящее время секвенировано большое количество видов *Bifidobacterium bifidum*, представляющих интерес для медицины, биотехнологии и сельского хозяйства. Идентифицированы их генетические стратегии колонизации и персистирования в кишечнике человека. Механизмы перекрестного взаимодействия *Bifidobacterium bifidum* с хозяином и другими микроорганизмами были продемонстрированы с использованием различных структур. В этом обзоре мы обсуждаем современные знания о биологии рода *Bifidobacterium*, включая биологические характеристики видов *Bifidobacterium bifidum*, которые демонстрируют специфическую адаптацию к кишечнику человека.

*Ключевые слова:* бифидобактерии, *Bifidobacterium bifidum*, пробиотики, микробиота кишечника человека, микробиом, метаболизм бифидобактерий, филогения, таксономия.

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# *Adenophoraphis*, a new aphid genus from Kazakhstan (Hemiptera: Aphididae: Macrosiphini)

Currently, 889 species of aphids from three families are known in Kazakhstan: Adelgidae (10 species), Phylloxeridae (2), Aphididae (877) [1]. A new to science genus of aphids *Adenophoraphis* gen. n. and a new species *Adenophoraphis burabaica* sp. n. described from Kazakhstan. The specimens of the new taxon were collected in Akmola Region of the northern Kazakhstan in 2002. The new genus belongs to the subtribe Macrosiphina of the tribe Macrosiphini (Aphidinae). It lives on *Adenophora liliifolia* (L.) A. DC, no ant attendance was observed. During the collection period, only apterous viviparous females were found. The specimens were collected in a deciduous forest, in the Kazakh uplands, on the Kokshetau Upland. The new genus belongs to the subtribe Macrosiphina of the tribe Macrosiphini of the subfamily Aphidinae. In addition to the new genus, the other members of Macrosiphina inhabiting Campanulaceae include *Campanulaphis* Kadyrbekov, 2016, *Megouroleucon* Miyazaki, 1971, *Tshernovaia* Holman et Szelegiewicz, 1964 and *Uroleucon* Mordvilko, 1914.

*Keywords:* aphids, new species, Adenophoraphis, A. burabaica, Aphididae, Kazakh uplands, Kokshetau Upland, Kazakhstan.

## *Introduction*

One of the modern main world priorities in biology is the problem of conservation of biological diversity and the inventory of flora and fauna in specially protected areas.

The inventory of insect fauna in specially protected areas is a priority area of entomology in most countries of North and South America, Africa, Europe and Australia. In all these countries, research is underway on the biodiversity of various insect groups [2–5]. In the last 20 years, similar studies have been gaining momentum in the CIS countries, especially in Russia, Belarus and Ukraine [6–11]. In Central Asia, research on the inventory of insect fauna in specially protected areas is being purposefully conducted in Mongolia, China and Kazakhstan.

In 2002, we studied the aphid fauna of the Burabai Nature Park. Unfortunately, those materials have not yet been fully processed, but a new genus of aphids has been discovered in them.

## *Materials and Methods*

Original microscope slides were prepared using coniferous balsam as mounting medium (Kadyrbekov, 2014). The specimens were examined using a Bel Photonics light microscope. Identifications were done with the reference to authoritatively identified material from the collection of the Institute of Zoology of Ministry of Education and Sciences of Kazakhstan (Almaty). Holotypes and paratypes of newly described species are deposited in the collection of the Institute of Zoology (Almaty, Kazakhstan). All measurements are given in millimeters.

Plant taxonomy were verified according to POWO [12]. Descriptions of the related genera were studied too [13–18].

## *Results and Discussion*

*Adenophoraphis* gen. n.

Description. The body is elongate-oval. Cuticle thick, without reticulation, smooth, only slightly wrinkled on antennal tubercles. Small and large median and marginal sclerites are present on pronotum, meso- and metanotum, as well as on abdomen. Pronotum, meso- and metanotum, and in some specimens also tergites 2–4 (on one side) with weak small convex tubercles. The spiracles are small, bean-shaped. Setae on the body, antennae, and legs thick and spatulated. The frontal groove of the median tubercle is shallow (in

one specimen with a barely noticeable median tubercle of a square shape). Antennal tubercles high, divergent. Antennae six-segmented. Third antennal segment (0–1) with secondary rhinaria. The ultimate rostral segment reaches the middle coxae, its last segment is slender, not stocky. Siphunculi semi-cylindrical with a light flange and reticulation in the upper quarter. Cauda, either necessarily conical or co-deserved with a squeeze in the main half, with a pointed apex. First segment of tarsa with 3,3,3 setae.

Etymology. The new genus is named for the generic name of the host plant.

Differential analysis. The new genus belongs to the subtribe Macrosiphina of the tribe Macrosiphini of the subfamily Aphidinae. In addition to the new genus, the other members of Macrosiphina inhabiting Campanulaceae include *Campanulaphis* Kadyrbekov, 2016, *Megouroleucon* Miyazaki, 1971, *Tshernovaia* Holman et Szelegiewicz, 1964 and *Uroleucon* Mordvilko, 1914. The new genus differs from *Megouroleucon* and *Uroleucon* in having a shallow frontal groove and a minimal number of secondary rhinaria on the third antennal segment (0–1). *Adenophoraphis* gen. n. differs well from *Tshernovaia* in the cauda, which is different in shape, the minimum number of secondary rhinaria on the third antennal segment (0–1), and the presence of 3, 3, 3 hairs on tarsal segment 1 (5, 5, 5 in *Tshernovaia*). Differences from other genera with a shallow frontal groove are shown in the next key.

**Key for distinguishing *Adenophoraphis* gen. n. from the Macrosiphina genera with a shallow frontal groove.**

1. First segment of all tarsi with 5, 5, 5 hairs. A single tubercle on the anal plate is clearly expressed. Attended by ants……2

– First segment of all tarsi with 3, 3, 3 hairs. A single tubercle on the anal plate is absent or clearly expressed. Attended or not by ants ……..4

2 Cauda is widened at the base, passing further into a long, thin, sinuous process. On *Adenophora* ……..…....*Tschernovaia adenophorae* Holman, 1964

– Cauda finger-shaped or elongated-triangular……..……..…….……3

3 Frontal groove gently sloping, but distinct, with large median tubercle nearly equal in height to antennal tubercle. Ante- and postsiphuncular semilunar sclerites are absent. The reticulated zone is at least 0.35–0.45 SIPH. Cauda finger-shaped. On *Echinops* and *Cousinia*……..…..*Turanoleucon* Kadyrbekov, 2002

– Frontal groove barely marked, 0.05–0.15 of the distance between apices of antennal tubercles. At least postsiphuncular sclerites are present. The reticulated zone is no more than 0.28–0.35 SIPH. Cauda is elongate triangular. On the root collar and roots of *Campanula*.....……*Campanulaphis* Kadyrbekov, 2016

4 Frontal groove gently sloping, median frontal tubercle well defined…….……5

– Frontal groove without median frontal tubercle…….……..……7

5 The last segment of the ultimate rostral segment is short, almost triangular. On plants of the families Rosaceae and bluegrass (Poaceae)…….…….*Sitobion* Mordvilko, 1914

- The last segment of the ultimate rostral segment is stocky, but not triangular. On Limoniaceae, Amaranthaceae ……..……6

6 Siphunculi are darkened only in the rticular zone. Cauda is short, triangular, with a rounded top. On *Atriplex*……..…….*Metopeuraphis* Narzikulov et Smailova, 1975

– Siphunculi are darkened everywhere except for the basal third. Cauda is finger-shaped or conical, with notched sides. On Limoniaceae.....…...*Staticobium* Mordvilko, 1914

7 A single tubercle on the anal plate is clearly expressed. Attended by ants.……8

– There is no single tubercle on the anal plate. Not attended by ants.....9

8 Ultimate rostral segment almost rod-shaped, with very short setae. Cauda elongated triangular. Dorsal setae of different types: pointed, forked, tridentate, fan-shaped. On *Helichrysum*…… ……...……..*Ramitrichophorus* Hille Ris Lambers, 1947

– Ultimate rostral segment slender, elongated. Dorsal setae pointed. Cauda conical or triangular. On Asteraceae, Urticaceae, Apiaceae…..….....……*Metopeurum* Mordvilko, 1914

9 Body with spatulate setae. Reticulated zone 0.17–0.24 SIPH. On *Adenophora*…… ……..*Adenophoraphis* Kadyrbekov, gen. n.

– Setae of body pointed. Reticulated zone 0.25 SIPH and more. On Asteraceae……. ……..……..…….....….*Macrosiphoniella* (auct.) Del Guercio, 1911

*Adenophoraphis burabaica* sp. n.

**Type material**. Holotype: apterous viviparous female, no 2891, Akmola region, Natural Park "Burabai", lake Zhukey, birch forest, H – 656 m, *Adenophora liliifolia,* 06.06.2002, R.Kh. Kadyrbekov (Institute of Zoology, Almaty, Kazakhstan). Paratypes – 7 apterous viviparous females, same locality and date.

**Etymology.** The new species are named for name of natural park (Fig. 1).

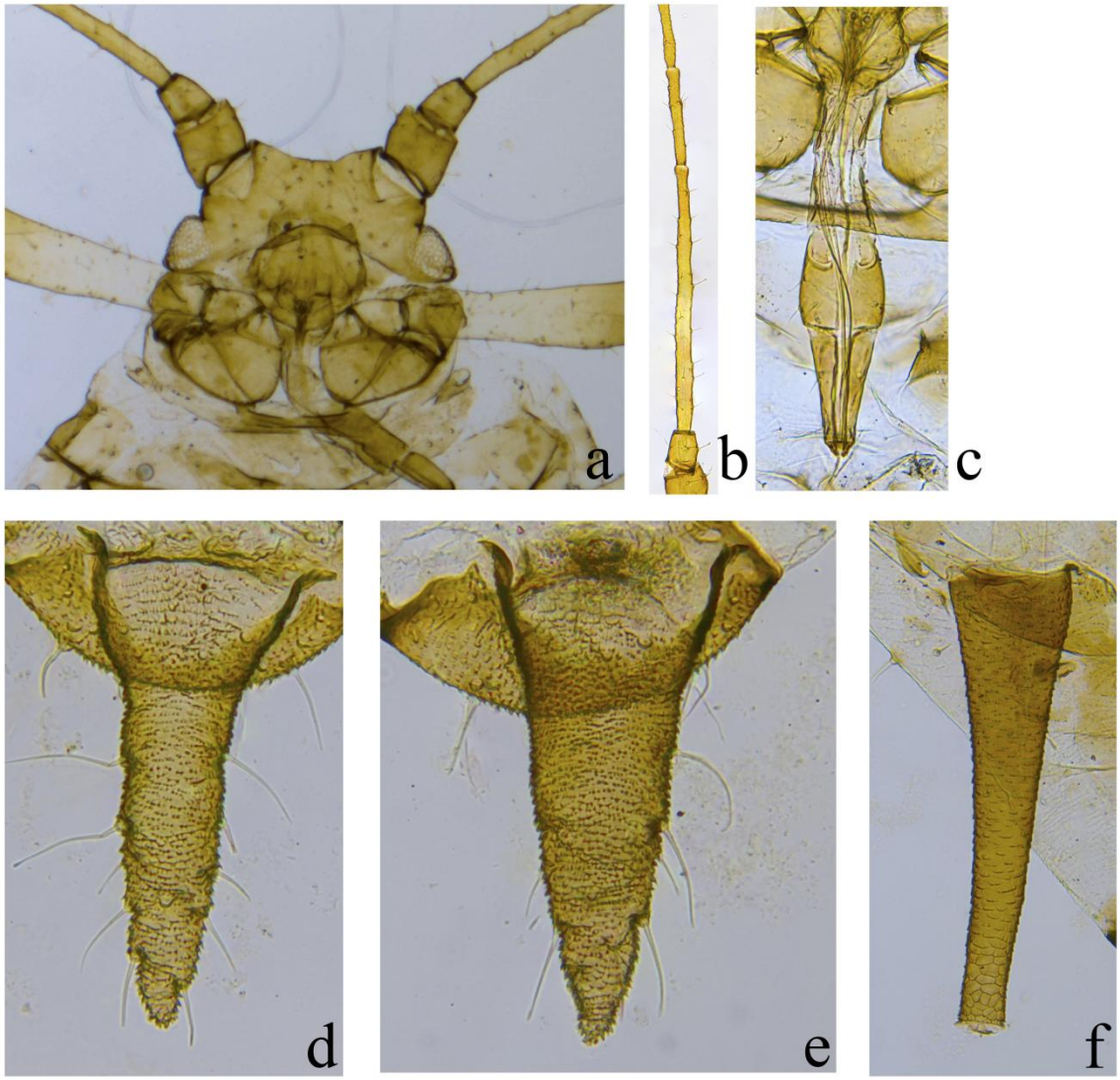


Figure 1**.** *Adenophoraphis burabaica* sp. n.: a – head; b – III–IV antennal segments; c – ultimate rostral segment; d, e – cauda; f – siphunculus.

**Apterous viviparous femal**e (from 8 specimens). Dark brown when alive. Antennae brown, siphunculi, cauda black, legs light with darkened tops of the femora, the very bases and tops of the legs and tarsi brown. On the slide: head, antennae, rostrum, coxae, tops of femora, bases and tops of tibia, tarsi, subgenital and anal plates swarthy. Siphunculi and cauda dark brown. The body elongated-oval. Cuticle thick, without cellularity, smooth, only slightly wrinkled on antennal tubercles. Large marginal sclerites present on pronotum, meso- and metanotum. On the dorsal side of the abdomen, small sclerites are developed at the bases of most hairs. Larger marginal sclerites present on abdominal tergites I–V, each with 2–3 setae, and large massive postsiphuncular sclerite (not semilunar) present on abdominal tergite VI. Abdominal tergites VII–VIII with small sclerites, sometimes combined into longitudinal median bands. Pronotum, meso- and metanotum, and in some specimens also on abdominal tergites II–IV (on one side) with small, weakly convex marginal tubercles. The spiracles small, bean-shaped. Setae on body, antennae, and limbs thickened, spatulate.

Body 2.92–3.67. Frontal groove not deep with low diverged antennal tubercles (Fig. 1a). Frontal hairs (0.058–0.075) long, pointed, 1.12–1.44 of basal diameter of 3rd antennal segment. Antennae normal, six-segmented, 0.68–0.79 of body length. Third segment 2.12–2.93 of 4th one, 1.28–1.36 6th segment, 1.53–1.69 of the processus terminalis. Processus terminalis 2.69–3.58 of the base of 6th segment. Secondary rhinaria in number 0–1 develop on the basal half of the 3rd segment (Fig. 1a). Hairs on the 3rd segment (0.035–0.046) pointed, 0.77–1.00 of its basal diameter. Rostrum reaches before ore behind of the middle coxae. Its ultimate rostral segment (Fig. 1c) 1.14–1.33 of the second segment of hind tarsus, 1.08–1.33 of the base of 6th segment with 4–6 accessory hairs. Siphunculi semi-cylindrical with a light flange and reticulation in the upper quarter, 0.16–0.20 of body length, 1.20–1.57 of cauda (Fig. 1 f). Cauda, either necessarily conical or codeserved with a squeeze in the main half, with a pointed apex, 0.12–0.14 of body with 8–11 setae (Fig. 1 d, e). Second segment of hind tarsus 0.90–1.17 of the base of 6th segment. Dorsal setae 1.15–1.26 of the basal diameter of 3rd antennal segment. There are 12–16 setae on 3rd tergite, 5–6 between siphunculi and 4–6 ones on the 8th tergite. Genital plate broad oval with 2 setae on disk and 8–12 ones along its posterior margin. Legs normal develop. First tarsal segment with 3:3:3 hairs.

Host plant. *Adenophora liliifolia* (L.) A. DC (Campanulaceae).

*Bionomy*. Aphids live on the stems.

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Р.Х. Қадырбеков

## *Adenophoraphis* — Қазақстанда табылған бітенің жаңа тұқымдасы (Hemiptera: Aphididae: Macrosiphini)

Қазіргі кезде Қазақстанда бітелердің фаунасының үш тұқымдасқа жататын, яғни *Adelgidae* (10 түр), *Phylloxeridae* (2 түр), *Aphididae-ның* (877 түр) 889 түрі белгілі [1]. Қазақстаннан табылған *Adenophoraphis* gen. n және *Adenophoraphis burabaica* sp. n. бітенің ғылымға жаңа тұқымдасы мен түрі ретінде сипатталады. Жаңа таксонның үлгілері 2002 жылы Солтүстік Қазақстанның Ақмола облысынан табылды. Жаңа тұқымдас *Macrosiphini* подтрибасының *Macrosiphini* (Aphidinae) триба тармағына жатады. Тұқымдас *Adenophora liliifolia* (L.) A. DC сабақтарында тіршілік етеді және құмырсқалармен қатынасы жоқ. Жазғы кезеңде, дернәсілдерін тірілей туатын тек қана қанатсыз аналықтары жиналды. Коллекциялық үлгілер Қазақтың ұсақ шоқыларындағы аралас орманнан, Көкшетау қыратынан жиналған. Жаңа тұқымдас *Macrosiphina* подтриба тармағындағы басқада тұқымдастарымен бірге қоңыраубаста *(Campanulaceae)* тіршілік етеді және *Campanulaphis* (Kadyrbekov, 2016), *Megouroleucon* (Miyazaki, 1971), *Tshernovaia* (Holman et Szelegiewicz, 1964), *Uroleucon*-пен (Mordvilko, 1914) бірігіп тұқымдастық таксондар тобын құрайды.

*Кілт сөздер:* бітелер, жаңа тұқымдас, жаңа түр, *Adenophoraphis, A. burabaica*, Aphididae, Қазақтың ұсақ шоқылары, Көкшетау қыраты.

Р.Х. Кадырбеков

## *Adenophoraphis* — новый род тлей из Казахстана (Hemiptera: Aphididae: Macrosiphini)

На данный момент фауна тлей Казахстана насчитывает 889 видов из трех семейств: *Adelgidae* (10 видов), *Phylloxeridae* (2), *Aphididae* (877) [1]. Новый для науки род тлей *Adenophoraphis* gen. n. и новый вид *Adenophoraphis burabaica* sp. n. описаны из Казахстана. Экземпляры нового таксона были собраны в Акмолинской области Северного Казахстана в 2002 году. Новый род принадлежит к подтрибе *Macrosiphina* трибы *Macrosiphini* (Aphidinae). Род живет на стеблях *Adenophora liliifolia* (L.) A. DC и не посещается муравьями. В течение летнего периода были собраны только бескрылые живородящие самки. Коллекционные экземпляры были собраны в смешанном лесу, в Казахском мелкосопочнике, на Кокшетауской возвышенности. Новый род вместе с другими родами подтрибы *Macrosiphina*, живущими на колокольчиковых *Campanulaceae*, составляет группу родственных таксонов *Campanulaphis* (Kadyrbekov, 2016), *Megouroleucon* (Miyazaki, 1971), *Tshernovaia* (Holman et Szelegiewicz, 1964) и *Uroleucon* (Mordvilko, 1914).

*Ключевые слова*: тли, новый род, новый вид, *Adenophoraphis, A. burabaica*, Aphididae, Казахский мелкосопочник, Кокшетауская возвышенность, Казахстан.

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# The effect of bubbling on the germination of Sudan grass seeds

In the article the results of experiments to study the effect of bubbling on the germination of Sudan grass seeds before and after cryopreservation were presented. The obtained statistical data were processed using the R-studio program. We calculated the indicators of humidity and germination energy of Sudan grass seeds, and determined the statistically reliable significance between the control and experimental varieties. To conduct the experiment, a bubbler installation was created from a cylindrical container filled with water and a bubbler to supply oxygen. The results of pre-sowing seed treatment were obtained for 4 varieties of Sudan grass: Nika, Tugai, Alina, Novosibirskaya 84. Bubbling increases seed germination compared to the control by 13 % for the Nika variety, by 7 % for the Novosibirskaya 84 variety. While bubbling after cryopreservation significantly reduces the germination of seeds in the Tugai variety by 25 %, in the Alina variety by 32 %, in the Novosibirskaya 84 variety by 33 %, and in the Nika variety by 7 %. Thus, bubbling, in general, had a positive effect on the germination of Sudan grass seeds and may be one of the methods of pre-sowing seed treatment. As a recommendation for improving the germination of Sudan grass seeds, we suggest using bubbling without cryopreservation.

*Keywords:* bubbling, Sudan grass, germination, germination energy, cryopreservation.

## *Introduction*

An increase in livestock production depends primarily on the feed supply. Its quantitative and qualitative indicators can be improved by correctly selecting highly productive forage crops and improving the technology of their cultivation. In the group of annual forage crops, great importance is given to drought-resistant and highly productive sorghum crops, mainly Sudan grass [1, 2]

Sudan grass is a productive crop capable of producing a consistently high yield of biomass of high feed quality. This agricultural crop is widely used to produce both coarse (hay, haylage) and succulent feed (green mass) [3, 4]. The use of physical methods in plant growing makes it possible to increase the intensity of plant growth and development [5].

To increase the germination of seeds and the density of seedlings, it is advisable to use pre-sowing treatment. Some methods of pre-sowing seed preparation are difficult to implement and require the use of pesticides during the growing season. This is associated with high economic costs for seed preparation, and pesticides have a detrimental effect on the environment and human health [6–9].

Among physical methods, pre-sowing treatment of plants with an electromagnetic field, magnetic field, ultraviolet radiation, ozone, ultrasound, electrochemically activated water and many others has become widespread [10–19].

One of the promising methods of pre-sowing treatment is bubbling seeds with compressed air [16–19].

The purpose of the study was to increase the germination of seeds and the density of seedlings using the physical method — bubbling.

## *Materials and methods*

The object of the study was seeds of Sudanese grass of 4 varieties: Alina, Nika, Tugai, Novosibirskaya 84 (Fig. 1). The seeds were provided by the LLP “Research and Production Center for Grain Farming named after Barayev” (Shortandy village, Akmola region). Laboratory studies were carried out in the laboratory of biotechnology and environmental monitoring of Buketov Univesity.

Pre-sowing treatment was carried out using a bubbler for 24 hours.

After bubbling, before sowing, the seeds were kept in a $KMn0_2$ solution for 10 minutes, then washed with distilled water and sown on damp filter paper in Petri dishes in 4 replicates. The growth dynamics of viable seeds

were recorded daily. On 4 day, germination energy was determined, and on 7 day, seed germination was determined. Next, the viable seeds were counted. The results were entered into the log book.

The obtained static data was processed using the R-studio program. We calculated the humidity and germination energy indicators for 4 varieties before and after cryopreservation.

The experimental scheme was as follows:

1. Control
2. Seeds after cryopreservation without cryoprotectants
3. Bubbling without cryopreservation
4. Bubbling after cryopreservation


Figure 1. Seeds of Sudan grass:
I — Tugai variety; II — Nika variety; III — Novosibirskaya 84 variety; IV — Alina variety

*Results and Discussion*

Analysis of the data obtained on germination and germination energy of the Tugai variety showed that bubbling after cryopreservation reduces seed germination by 25 % (Fig. 2). In all other variants, seed germination of the Tugai variety, including the control, is 95 %. Bubbling accelerates the germination of seeds, after which the seeds swell and germinate faster, which allows to check the seeds before sowing and have time to sow the seeds at the right time, which is a very important feature of Sudan grass, a crop that is afraid of low temperatures.

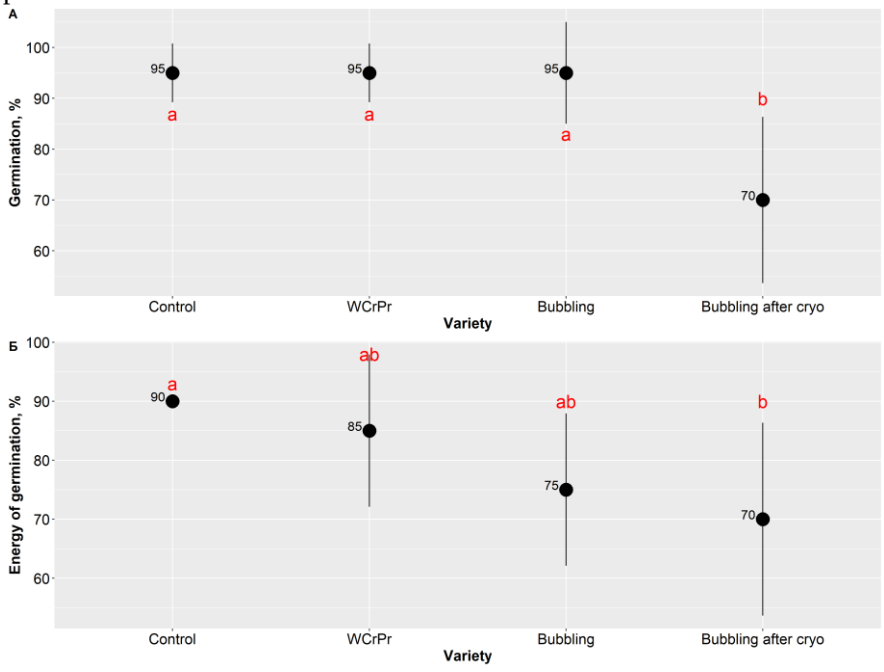


Figure 2. Germination and germination energy of Sudan grass seeds of the Tugai variety

Analysis of the data obtained on germination and germination energy showed that bubbling after cryopreservation reduces seed germination by 25 %. In all other variants, seed germination of the Tugai variety, including the control, is 95 %.

The results of bubbling after cryopreservation are significantly lower than the values in other options.

In terms of germination energy, the maximum values are for the control, the minimum values are for bubbling after cryopreservation. In the variants of cryopreservation without cryoprotectors and bubbling without cryopreservation, the results are statistically insignificantly lower than the control.

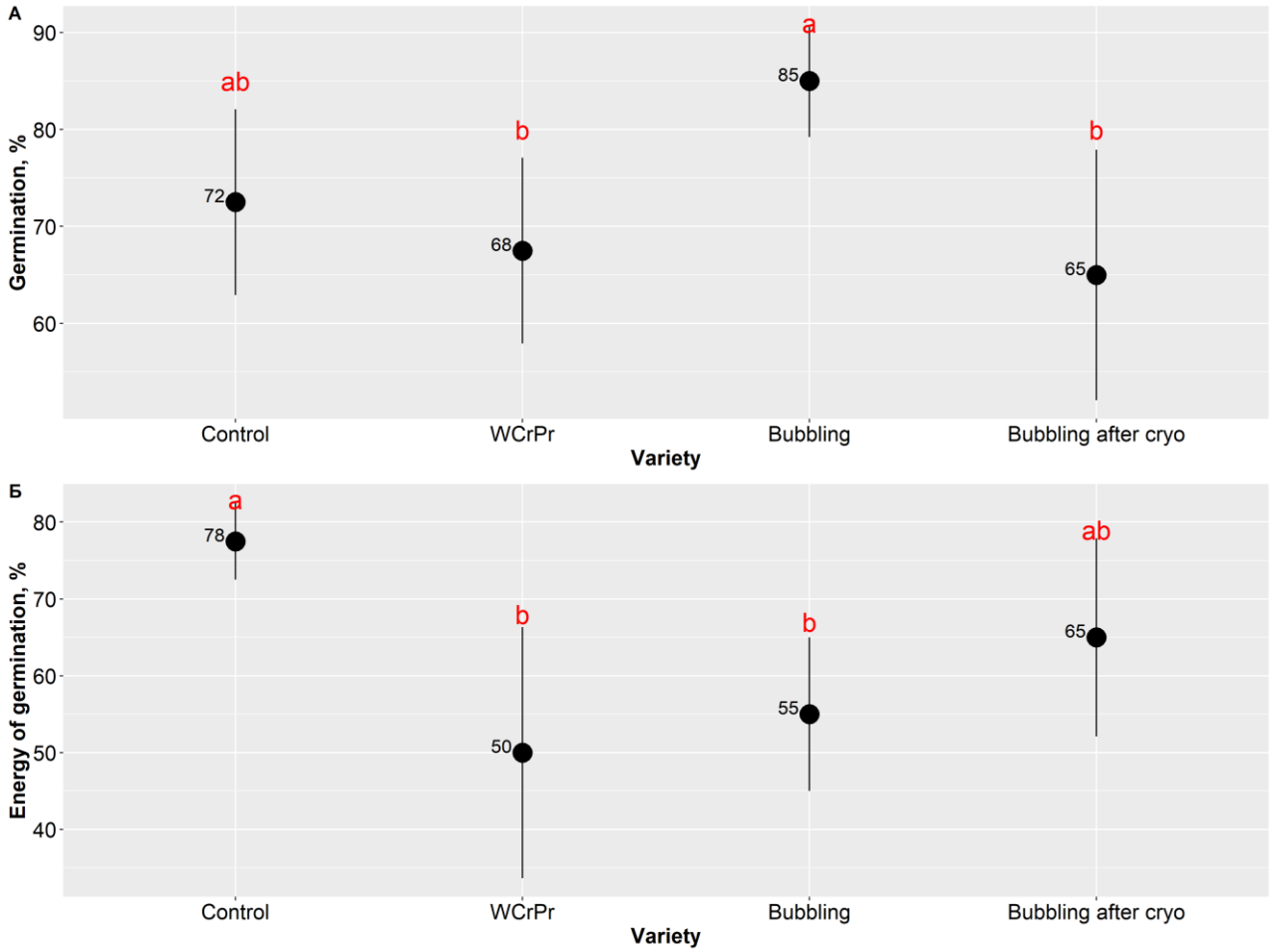


Figure 3. Germination and germination energy of seeds of Sudan grass variety Nika

The Nika variety has a germination rate of 72 % under control. Bubbling increased seed germination by 13 % compared to control. Whereas when bubbling after cryopreservation, germination decreased by 7 %. During cryopreservation without cryoprotectants, a slight decrease in germination was observed (Fig. 3).

Significant statistical differences in comparison with sparging are observed in the variants of cryopreservation without a cryoprotector and sparging after cryopreservation. Compared to control there are only minor static differences.

In terms of germination energy, maximum germination is under control. Reliably significant differences between bubbling and cryopreservation without a cryoprotector. Bubbling after cryopreservation compared with other options shows minor statistical differences.

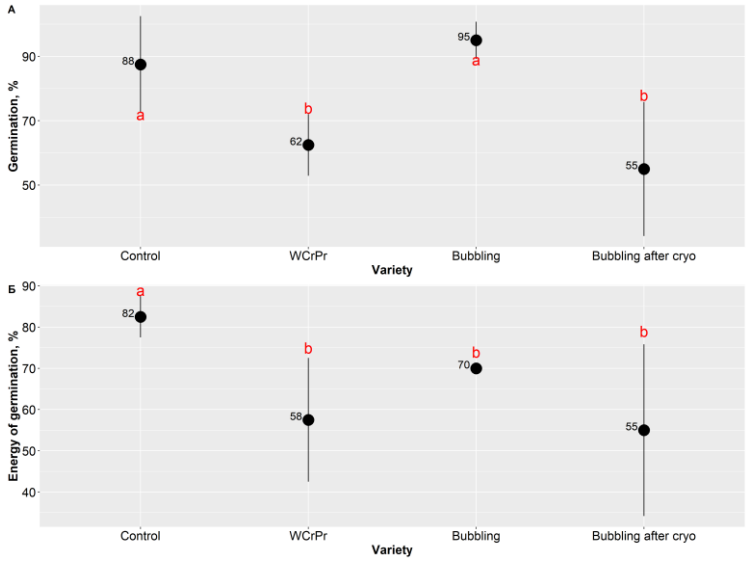


Figure 4. Germination and germination energy of Sudan grass seeds of the Novosibirskaya 84 variety

For the Novosibirskaya 84 variety, germination on the control was 88 %. When bubbling after cryopreservation, seed germination decreased by 33 % compared to the control. When bubbling, germination rate increases by 7 % and amounts to 95 %. Cryopreservation without cryoprotectants reduces germination by 26 % compared to control (Fig. 4).

Thus, statistically significant differences for control and bubbling are the cryopreservation options without cryoprotectants.

When studying the dynamics of germination energy, statistically significant differences are observed between the control and experimental variants.

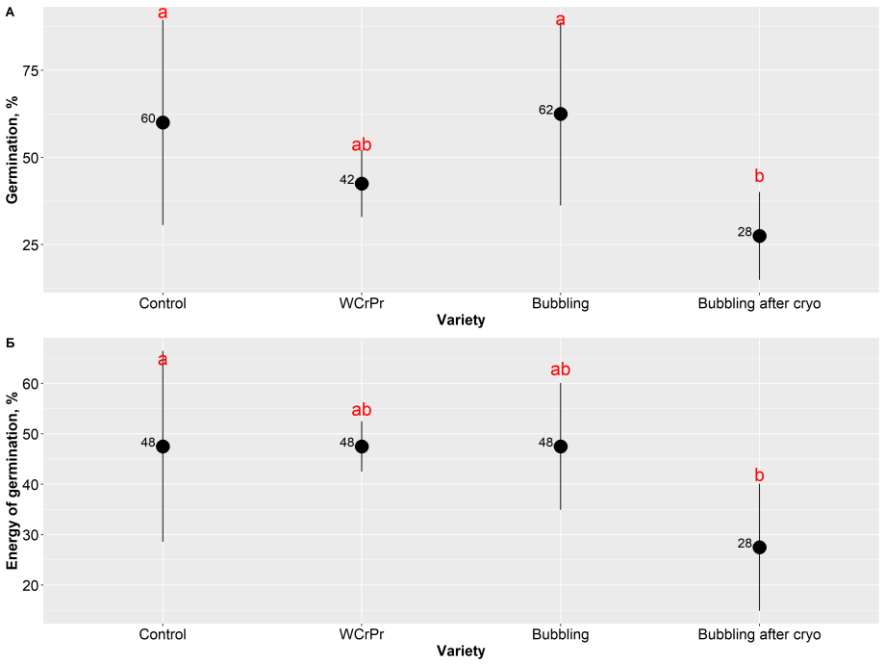


Figure 5. Germination and germination energy of Sudan grass seeds of the Alina variety

The control germination rate of the Alina variety is 60 %. Whereas when bubbling after cryopreservation, germination decreased by 32 %. And during cryopreservation without cryoprotectants, germination decreased by 18 % (Fig. 5).

Statistically significant differences in germination and germination energy between control and bubbling after cryopreservation were noted.

*Conclusion*

As a result of our research, we determined the effect of pre-sowing treatment using the bubbling method for each variety of Sudan grass.

Bubbling increases seed germination compared to the control by 13 % in the Nika variety, by 7 % in the Novosibirskaya 84 variety.

While bubbling after cryopreservation significantly reduces the germination of seeds in the Tugai variety by 25 %, in the Alina variety by 32 %, in the Novosibirskaya 84 variety by 33 %, and in the Nika variety by 7 %.

Thus, bubbling, in general, had a positive effect on the germination of Sudan grass seeds and may be one of the methods of pre-sowing seed treatment.

As a recommendation for improving the germination of Sudan grass seeds, we suggest using bubbling without cryopreservation.

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## Судан шөбі тұқымының өнгіштігіне көпіршіктенудің әсері

Мақалада криоконсервацияға дейін және одан кейін судан шөптерінің тұқымдарының өнуіне көпіршіктердің әсерін зерттеу бойынша эксперименттердің нәтижелері берілген. Алынған статистикалық мәліметтер R-studio бағдарламасының көмегімен өңделді. Судан шөбі тұқымдарының ылғалдылығы мен өну энергиясының көрсеткіштерін есептеп, бақылау және тәжірибелік нұсқалар арасындағы статистикалық маңыздылығы анықталды. Эксперимент жүргізу үшін сумен толтырылған цилиндрлік ыдыстан және оттегімен қамтамасыз ету үшін көпіршікті қондырғы жасалды. Судан шөбінің «Ника», «Тугай», «Алина», «Новосибирская 84» атты 4 сортынан себу алдындағы тұқымдық өңдеудің нәтижесі алынды. Көпіршіктенуде тұқым өнгіштігін бақылаумен салыстырғанда «Ника» сортында 13 %-ға, «Новосибирская 84» сортында 7%-ға артты. Ал криоконсервациядан кейін көпіршіктену «Тугай» сортында 25 %-ға, «Алина» сортында 32 %-ға, «Новосибирская 84» сортында 33 %-ға, «Ника» сортында 7 %-ға, яғни тұқымның өнгіштігі айтарлықтай төмендеді. Осылайша, көпіршіктер негізінен судан шөп тұқымдарының өнуіне оң әсер етті және тұқымды себу алдында өңдеу әдістерінің бірі болуы мүмкін. Судан шөп тұқымдарының өнуін жақсарту бойынша ұсыныс ретінде криоконсервациясыз көпіршікті пайдалануды ұсынамыз.

*Кілт сөздер:* көпіршік, судан шөбі, өнгіштік, өну энергиясы, криоконсервация.

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## Влияние барботирования на всхожесть семян суданской травы

В статье представлены результаты экспериментов по изучению влияния барботирования на всхожесть семян суданской травы до и после криоконсервации. Полученные статистические данные были обработаны с помощью программы R-studio. Просчитали показатели влажности и энергии прорастания семян суданской травы, определили статистически достоверную значимость между контролем и экспериментальным вариантами. Для проведения эксперимента была создана барботажная установка из цилиндрической емкости, заполненной водой, и барботера для подачи кислорода. Получены результаты предпосевной обработки семян для 4 сортов суданской травы: «Ника», «Тугай», «Алина», «Новосибирская 84». Барботирование повышает всхожесть семян по сравнению с контролем на 13 % у сорта «Ника», на 7 % — у сорта «Новосибирская 84». В то время как барботирование после криконсервации значительно снижает всхожесть семян у сорта «Тугай» на 25 %, у сорта «Алина» — на 32 %, у сорта «Новосибирская 84» — на 33 %, у сорта «Ника» — на 7 %. Таким образом, барботирование в целом положительно повлияло на всхожесть семян суданской травы и может являться одним из способов предпосевной обработки семян. В качестве рекомендации по улучшению всхожести семян суданской травы предлагаем использовать барботирование без криоконсервации.

*Ключевые слова:* барботирование, суданская трава, всхожесть, энергия прорастания, криоконсервация.

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# The material relating to the anatomy of *Rhaponticum serratuloides* leaf blades according to age conditions

In the article the features of the morphological and anatomical structure of leaf blades in the process of ontogenesis of *Rhaponticum serratuloides* Georgi (Bobr.) during juvenile, immature, virginal, generative and senile age states were presented. It was noted that as the plant matures, the degree of dissection and linear dimensions of the leaf blades, as well as their vascular bundles and trichomes, increase. It was established that in the juvenile and immature periods of development whole and elliptical leaves predominate. In the virginal state, in addition to the typical entire leaves, leaves with an unpaired pinnate leaf blade appear. The generative state of *Rh. serratuloides* is characterized by having upper leaves as entire, sessile; the lower ones are petiolate, pinnately lobed with a large apical lobe. In the senile state, leaves of immature and virginal types are found. General patterns of leaf internal structure of *Rh. serratuloides* and another representative of the same genus *Rh.carthamoides* Willd (Iljin) were revealed as following: the plants are of dorsal-ventral type of leaf blade structure, with collateral vascular bundles of a closed type with a sclerenchyma covering and leaf pubescence. Along with this, characteristic diagnostic features for leaves of *Rh. serratuloides* were described as the following: the absence of capitate glands and long cord-like hairs during all age states, the presence of air-bearing cavities in the parenchyma of virginal and senile plants, associated with the habitat of the plant under study, because it grows in flooded meadows, along the shores of lakes and swamps.

*Keywords:* age states, anatomical features, types of leaf blades, *Rh. serratuloides*, *Rh.carthamoides.*

## *Introduction*

Among the species of the genus *Rhaponticum, Rh.carthamoides* is perhaps the most economically important one, as its roots, rhizomes and leaves are included in the State Pharmacopoeia of the Russian Federation [1] and the Republic of Belarus [2]. This prompted a detailed study of the anatomical characteristics of various parts of this plant, including the anatomical features and ultrastructure of all vegetative organs and secretory elements *of Rh. carthamoides* [3]. Anatomical and morphological structure of leaves and stems of another species *Rh. karatavicum* was investigated by A.K. Berkenov [4].

Anatomical study *of Rh. serratuloides* was initiated by G.Zh. Sultangazina [5], who first identified the diagnostic characteristics of medicinal raw materials of this species in comparison with *Rh. carthamoides.* Also for the same purposes, A.V. Kotylevskaya and others [6] studied the petiolar characteristics of the petiole of *Rh. serratuloides.*

It should be noted that in Sultangazina's work, the anatomical characteristics of the vegetative (leaves and stems) and generative (flower and involucre leaves) organs of *Rh. serratuloides* were studied during 1, 4 and 5 years of the vegetation year, i.e. virginal and generative individuals.

Our goal is to research *Rhserratuloides* leaf blades throughout the entire ontogeny, with the exception of the seedling stage. Study of the morphological and anatomical structure of *Rh. serratuloides* leaves will allow us to identify general and individual characteristics of the species under study in comparison with other representatives of this genus, determine some patterns of its ontogenesis, and also supplement information about the species diagnostic characters of *Rh. serratuloides*.

## *Materials and Methods*

The object of the study is the leaves of *Rhaponticum serratuloides* of various age states: j — juvenile; im– immature; v — virginal; g — generative; s — senile (except for seedlings), collected in the Akmola and Karaganda regions during the fruiting phase. Sampling (Table 1) was carried out from populations growing in flooded, grass-

wormwood, swampy meadows, roadside hollows in the vicinity of Karaganda city, Karabas, Abay villages in the Karaganda region, in the vicinity of Astana city and the Korgalzhinsky reserve in the Akmola region.

Table 1

**Research points**

| Number | Growing point | Coordinates | | |
|---|---|---|---|---|
| | | N | E | Height above sea level |
| 1. | Karaganda region, Abay reg. | 49°34'48.0» | 72°53'38.1» | 503 |
| 2. | Karaganda region, Abay reg. | 49°38'03.4» | 72°50'38.3» | 500 |
| 3. | Karaganda region, Abay reg. (between Abay and Saran) | 49°40'57.6» | 72°51'37.2», | 485 |
| 4. | Akmola region, Astana. Neighborhood of the village Karazhar, Nura River valley, Astana-Malinovka highway | 51°05´27.9» | 71°11´05.3´´ | 341 |
| 5. | Akmola region, Korgalzhinsky reserve, shore of the lake Yesey | 50°32´08.5» | 69°39´03.4´´ | 305 |

Features of age-related conditions *of Rh. serratuloides* were studied in situ according to the methodological instructions of T.A. Rabotnov [7], A.A. Uranov [8], O.V. Smirnova, et al. [9]. To determine the average values of morphometric parameters of the leaf blade, 10 samples of each shoot were taken. The length and width of the leaf blade were measured using an electronic caliper with digital indexing. To study the anatomic structure, the selected leaves were fixed in a mixture of glycerol: 96 % alcohol: distilled water in a ratio of 1:1:1 (Straus-Fleming mixture) [10, 11]. Transverse sections of the sheet were made by hand. For the leaf, micropreparations were made from the central part of a fragment of the middle fox. Sections were cleared with glycerol. The preparations were photographed on an Altami microscope with a 3.1 megapixel digital camera, with magnification of 16x4 and 16x10. A blue filter was used in some photographs. Photo processing and microscopic measurements were performed in the Altami Studio program using Paint 10.0. When describing the anatomical structure, we used the principles set out in the works of N.A. Aneli [12], L.I. Lotova [13], P.J. Rudall [14]. For each sample, at least 10 micropreparations (microscope slides) were made.

Statistical processing of the results of morphometry and anatomy of leaf blades was carried out using the Statistica 7.0 program.

## *Results and Discussion*

*Morphological features of leaves.* During ontogenesis, the leaf blades *of Rh. serratuloides* undergo a number of changes (Fig. 1.). The first true leaves are narrow-lanceolate. During the juvenile and immature periods of development, the leaves are entire, elliptical, and glabrous with a long petiole. Since the virginal state, in addition to the typical entire leaves, a dissection of the leaf blade appears with the formation of one large and 2-3 small lobes (Table 2). During generative state *Rh. serratuloides* is characterized by various forms of leaves: the upper ones are entire, sessile, the lower ones are petiolate, and its blade is toothed, pinnately divided at the base, with 1–3 pairs of oblong or almost lanceolate lobes. During senile state, the leaves are the same of immature and virginal types.

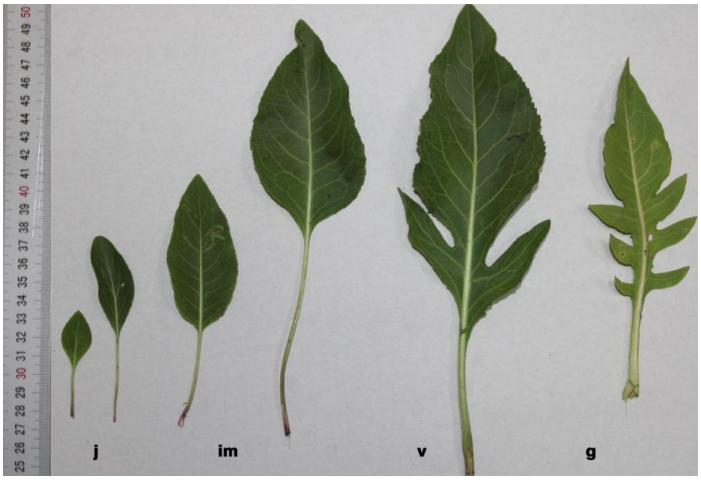


Figure 1. Appearance of *Rhaponticum serratuloides leaves* of different age states

Table 2

**Morphometric parameters of *Rhaponticum serratuloides* leaves during ontogenesis (in cm)**

| Age conditions | Leaf blade length | | Leaf blade width | |
|---|---|---|---|---|
| | Simple | Dissected | Simple | Dissected |
| Juvenile | 3.86±0.52<br>Cv 23.2 | - | 1.47±0.52<br>Cv 61.1 | - |
| Immature | 7.66±0.44<br>Cv 16.2 | - | 1.76±0.19<br>Cv 30.8 | - |
| Virginal | 15.91±0.98<br>Cv 17.5 | | 5.5±0.34<br>Cv 17.7 | |
| Generative | 11.99±0.41<br>C v 21.73 | 15.65 ±0.41<br>Cv 17.8 | 5.91±0.27<br>Cv 29.68 | 6.79±0.25<br>Cv 25.14 |

*Anatomical structure of a leaf*. In a cross section, the leaf is flat, and of dorso-ventral type (Fig. 2, 3). The leaf veins protrude significantly from the underside of the leaf. The leaf is surrounded on both sides by cells of the upper and lower epidermis; the shape is clearly shaped, with thickened outer walls. On the surface of the epidermis on the lower side, mainly in the area of the midrib, only simple multicellular trichomes are located. In a study by G. Sultangazina [5], it is noted that in virginal leaves, on both surfaces of the epidermis, and in generative plants, mainly on the upper epidermis, small capitate hairs with a secretory unicellular head are also found. Columnar mesophyll consists of 2 cell layers, spongy mesophyll is multilayered. The conducting bundle is collateral, of closed type. The central beam is ovoid, the side beams are oval. The xylem strand is oriented towards the upper epidermis, the phloem is towards the lower side. The vascular bundle is intertwined with sclerenchymaon both sides. A section of lamellar collenchyma is localized above the central vascular bundle under the epidermis. During the senile age state, the separation of the lower and upper epidermis from the leaf parenchyma with the formation of air cavities is observed. In Sultangazina's studies [5], this process was observed in leaves of the 1st year of vegetation, i.e. virginile.

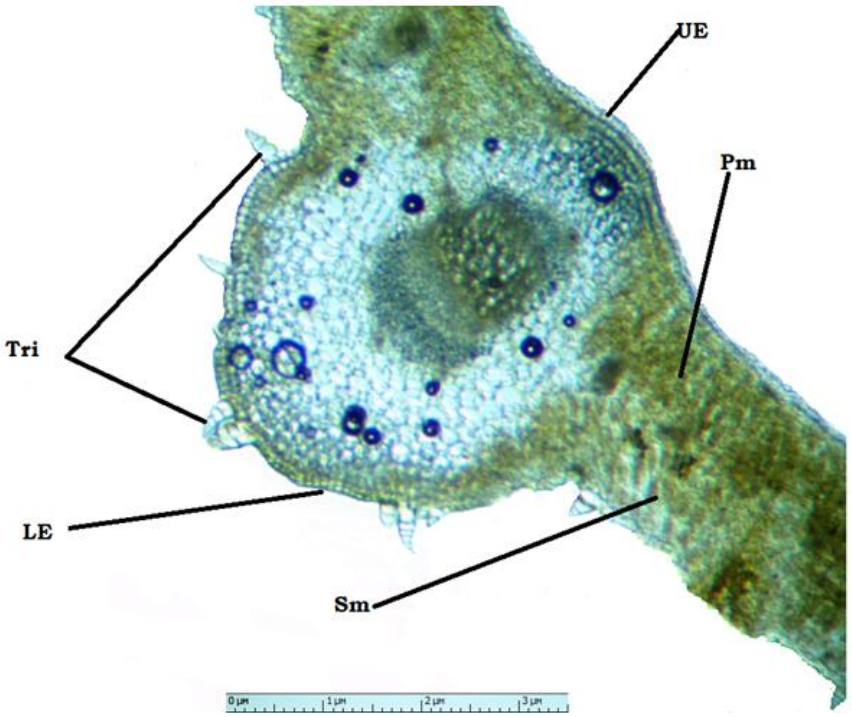


Figure 2. Anatomical structure of a cross section of a *Rh. serratuloides* leaf (the fragment is from the midrib area of the terminal leaflet of the generative state plant, magnified to 16x20): UE — upper epidermis, LE — lower epidermis, Tri — trichomes, PM — columnar mesophyll, SM — spongy mesophyll

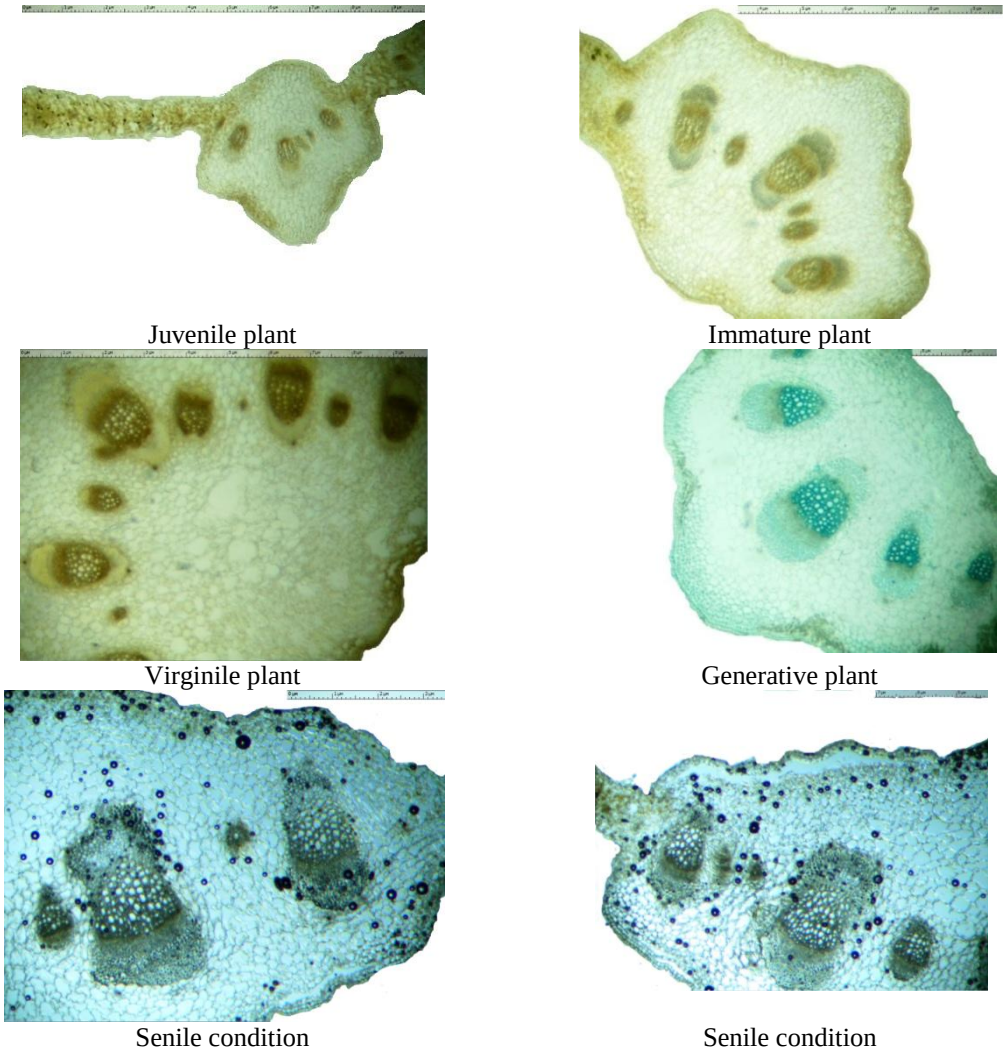


Figure 3. Cross sections of *Rh. serratuloides* leaves in different age states (magnitude 16x20)

Features of the anatomical indicators of leaf blades as ***Rh. serratuloides*** is growing and developing are shown in Table 3.

Table 3

**Quantitative parameters of individual cells and tissues of the *Rh. serratuloides* leaf during ontogeny (in microns)**

| Indicators | Age states *of Rh. serratuloides* | | | | |
|---|---|---|---|---|---|
| | Juvenile | Immature | Virginal | Generative | Senile |
| Leaf thickness at midrib | 4.80±0.02 | 7.64±0.02 | 12.10±0.31 | 7.35±0.18 | 11.18±0.07 |
| Leaf side width | 1.25±0.08 | 2.22±0.02 | 1.73±0.08 | 2.33±0.22 | 1.49±0.09 |
| Conductive beam length | 1.33±0.02 | 2.09±0.04 | 2.74±0.05 | 3.16±0.08 | 4.4±0.08 |
| Conductive beam width | 0.6±0.02 | 0.9±0.09 | 1.41±0.05 | 1.65±0.09 | 2.11±0.03 |
| Thickness of the lower epidermis | 0.06±0.003 | 0.084±0.002 | 0.13±0.001 | 0.098±0.01 | 0.09±0.01 |
| Upper epidermis thickness | 0.07±0.002 | 0.086±0.007 | 0.12±0.002 | 0.12±0.004 | 0.12±0.008 |
| Trichome length | 0.31±0.02 | 0.31±0.02 | 0.74±0.06 | 0.68±0.07 | 0.8±0.01 |

Analysis of the anatomical structure of *Rh. serratuloides* leaf has shown that as the plant is growing and developing, the leaf blades are characterized by an increase in the linear dimensions of vascular bundles and trichomes. In the virginal and senile stages of development, the leaves reach their maximum thickness in the midrib area. The maximum leaf width in the lateral part is observed in *Rh. serratuloides* in immature and

generative age states. No significant differences were found between the cells of the lower and upper epidermis of juvenile and immature individuals. In generative and senile leaves, the cells of the lower epidermis are somewhat smaller than the upper ones.

## *Conclusion*

The study made it possible to identify the features of the anatomical and morphological structure of leaves in the process of ontogenesis. As the plant matures, the degree of dissection and linear dimensions of the leaf blades, as well as their vascular bundles and trichomes, are increasing.

In the juvenile and immature state, the leaves are entire, narrow-lanceolate and elliptical with a long petiole. Since the virginal state, leaflets appear as unpaired and pinnately divided, which consist of one large and 2-3 small lobes. In the generative state, *Rh. serratuloides* is characterized by various forms of leaf blades: the upper ones are simple, sessile, the lower leaves are entire, pinnately divided at the base, with 1–3 pairs of oblong or almost lanceolate lobes. In the senile state, leaves of immature and virginal types are observed.

The anatomical structure of *Rh.serratuloides* leaf blades was compared to *Rh. carthamoides*. The comparative analysis has revealed some characteristics: it is the absence of pubescence on *Rh. carthamoides.* On the lower epidermis only simple multi-cellular hairs (trichomes) are observed in the midrib area. The location of the conductive bundles depends on the age-related condition. In the leaves of virginal and senile individuals, large vascular bundles alternate with small ones. In the juvenile, immature and generative stages there are 3 central large bundles; small bundles may be located between them. Also, for virginal and senile plants, the presence of air-bearing cavities in the leaf parenchyma was noted; this is associated with the habitat, because *Rh. serratuloides* grows in flooded meadows, along the shores of lakes and swamps.

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## *Rhaponticum serratuloides* жастық күйлері бойынша жапырақ тақталарының анатомиясына арналған мәліметтер

Мақалада *Rhaponticum serratuloides* Georgi (Bobr.) онтогенез процесіндегі: ювенильді, имматурлы, виргинильді, генеративтік және сенильді жастық күйлері бойынша жапырақ тақталарының морфологиялық және анатомиялық құрылымының ерекшеліктері берілген. Өсімдік жетілген сайын жапырақ тақталарының, сондай-ақ олардың өткізгіш шоқтарымен трихомаларының бөліну дәрежесімен сызықтық өлшемдері артады. Ювенильді және имматурлы даму кезеңдерінде тұтас, эллипс тәрізді жапырақтардың басым болатыны анықталды. Виргинильді күйде әдеттегі тұтас жапырақтардан басқа, жұпталмаған, яғни қауырсын тәрізді бөлінген жапырақ тақтасы бар жапырақтар пайда болады. *Rh. serratuloides* генеративті күйіндегі жапырақты сипатпасақ: жоғарғысы — тұтас, сағақсыз; төменгілері сағақты, жоғарғы жағы үлкен қауырсын тәрізді бөлінген. Сенильді жағдайында жетілмеген және қызғылт түрдегі жапырақтар кездеседі. *Rh. serratuloides* жапырақтарының ішкі құрылысының жалпы заңдылықтары осы туыстың басқа өкілімен, яғни *Rh. carthamoides* Willd. (Iljin) бірге анықталды: жапырақ тақтасының дорсовентральды құрылымы, склеренхималық жабындысы бар тұйық типті коллатеральды тамыр шоғырлары, жапырақтың түтіктері. Сонымен қатар, тек *Rh. serratuloides* жапырақтарына тән диагностикалық белгілер байқалады: қарастырылған барлық жас жағдайларында бас бездері мен ұзын сым тәрізді түктердің болмауы, сондай-ақ зерттелетін өсімдіктің тіршілік ету ортасымен байланысты виргинильді және сенильді өсімдіктердің паренхимасында ауа қуыстарының болуы, өйткені ол су басқан шалғындарда, көлдер мен батпақтардың жағасында өседі.

*Кілт сөздер:* жастық күйлер, анатомиялық ерекшеліктері, жапырақ тақталарының түрлері, *Rh. serratuloides, Rh. carthamoides.*

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## Материал к анатомии листовых пластинок *Rhaponticum serratuloides* по возрастным состояниям

В статье представлены особенности морфологического и анатомического строения листовых пластинок в процессе онтогенеза *Rhaponticum serratuloides* Georgi (Bobr.): ювенильного, имматурного, виргинильного, генеративного и сенильного возрастных состояниях. Отмечено, что по мере взросления растения увеличиваются степень рассеченности и линейные размеры листовых пластинок, а также их проводящих пучков и трихом. Установлено, что в ювенильном и имматурном периодах развития преобладают цельные, эллиптические листья. В виргинильном состоянии, кроме типичных цельнокрайних листьев, появляются листья с непарно перистораздельной листовой пластинкой. Для генеративного состояния *Rh. serratuloides* характерны верхние — цельные, сидячие; нижние — черешковые, перистолопастные с крупной верхушечной долей. В сенильном состоянии встречаются листья имматурного и виргинильного типов. Выявлены также общие закономерности внутреннего строения листьев *Rh. serratuloides* с другим представителем этого рода, *Rh. carthamoides* Willd. (Iljin): дорзовентральный тип строения листовой пластинки, коллатеральные проводящие пучки закрытого типа со склеренхимной обкладкой и опушение листьев. Наряду с этим отмечены диагностические признаки, характерные только для листьев *Rh. serratuloides*: отсутствие головчатых железок и длинных шнуровидных волосков во всех рассмотренных возрастных состояниях, а также наличие воздухоносных полостей в паренхиме виргинильных и сенильных растений, связанное со средой обитания изучаемого растения, так как оно произрастает на заливных лугах, по берегам озер и болот.

*Ключевые слова*: возрастные состояния, анатомические особенности, типы листовых пластинок, *Rh.serratuloides, Rh.carthamoides.*

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# Soil Microbiota and Particulars of Formation thereof under Traditional and Organic Farming on Chernozem Soils of Northern Kazakhstan

The subject matter of the study is soil microbiota of southern carbonate chernozem and particulars of formation thereof under organic and traditional methods of wheat growing under conditions of Northern Kazakhstan. It has been found that soil microbiota varies with arable farming systems. Application of leguminous and cereal above-ground biomass as organic fertilizers contributed to higher numbers of immobilizers that were twice as high as traditional farming variants. When applied as green manure, sweet clover above-ground biomass increased the number of ammonifying soil organisms (up to 6 million CFU/g a.d.s.), while bromegrass biomass increased the number of immobilizers (83.0 million CFU/g a.d.s.) and fungi (8,0 thousand CFU/g a.d.s.). Cellulose-destroying microorganisms were actively propagating in wheat crops (65.0 CFU/g a.d.s.) where wheatgrass biomass was applied as green manure, while sweet clover biomass, on the contrary, contributed to decrease thereof. Under traditional farming conditions, the introduction of ammonium nitrate into rows when planting crops at a dose of N80 stimulated the development of cellulolytic microorganisms and inhibited the development of ammonifying fungi and bacteria. Ammonifiers and immobilizers were actively propagating with reserve application of ammophos in the fallow at the rate of P40.

*Keywords:* southern carbonate chernozem, soil microbiota, fungi, bacteria, cellulolytic microorganisms, wheat, organic and traditional arable farming.

## *Introduction*

Soil is a heterogeneous environment for the life of most species of microorganisms that is capable to provide for their conservation and survival [1]. Microorganisms act as interlinks in biological cycles and play a significant role in the cycle of matter in Earth ecosystems. Thanks to soil microorganisms, mineralized organic matter turns into available compounds for producers [2, 3]. Besides, microorganisms are essential for soil organic matter mineralization and humification processes, being a key factor of soil formation [4, 5]. They participate in carbon and nitrogen cycles, global trophic web [6, 7]. Each physiological group determines intensity of a certain physiologic and biochemical process performed by taxonomically diversified microorganisms [8], that have various requirements for nutritive conditions and energy sources. Quantitative ratios thereof vary with environmental conditions of formation of a certain microbiota [9]. Microbial pool of microorganisms participating in maintaining homeostatic condition of soil ecosystem also performs significant ecologic functions [10].

Maintenance of diversified revivable and functioning microbial populations in the soil is critical for sustainable farming, since soil fertility depends not only on its chemical composition, but also on quantitative and qualitative character of soil-inhabiting ecologic and trophic microorganism groups [11, 12].

Soil microorganisms perform various systemically important functions. They participate in processes of soil formation, destruction of organic substances and mineralization, stimulation of plant growth and development, and plant protection from phytopathogens [13, 14].

Increased technogenic load on agricultural ecosystems results in a change of soil biota composition. In its turn, it affects microbiological processes influencing soil fertility. Changes in microbiota structure result in increase of the share of some soil microorganisms and decrease of the share of the others. Quite often, such microbiota is dominated by phytopathogens that cause farm crop diseases resulting in partial loss of yield or deteriorated quality thereof. Under modern arable farming conditions, increase of technology intensification contributes to increased farm production, which requires application of large volumes of mineral fertilizers and pesticides [15]. The latter results in changes of soil microbial flora due to modification of quantitative and qualitative composition [16, 17]. When the soil is highly saturated with agricultural chemicals, some bacterial species die, while others, being adapted to nitrogen consumption, develop faster. As the undesirable trends become more obvious, the interest to conservational agricultural practices [18]. In view of

the above, it should be noted that it is necessary to study soil microbiota as a whole, as well as taking into account farming systems in order to reduce unfavorable factors when cultivating crops.

Insufficiency of studies related to soil microbiota in chernozem soils and particulars of formation thereof in traditional and organic farming under conditions of Northern Kazakhstan predetermines comprehensive investigation of the issues in question that are critical for farm production.

The objective of this research is to study environmental trophic groups of soil microbial communities under spring soft wheat grown under conditions of traditional and organic farming.

*Materials and Methods*

Soil microbiota was studied from 2018 through 2020 at established experimental plots of "A.I. Barayev Research and Production Center for Grain Farming" LLP (N51°36'44,47»; E71°02'40,27») in the grain and fallow three-course rotations (fallow-wheat-wheat). Soil phase is low-humous southern carbonated chernozem of heavy clay-loam texture. In the upper soil level (0–20 cm), humus content is 3.1 %, gross nitrogen and phosphorus content is 0.20 % and 0.11 %, carbonate content, around 5 %. Arable soil layer active acidity is mildly alkaline (pH=7.2). Nitrate nitrogen content is 5.5–30.1 mg per 1 kg of soil, P2O5 (per Machigin): 20.3–35.6 mg per 1 kg of soil, mobile potassium: 550–570 mg per 1 kg of soil.

Soil microbiocenosis was studied in the variants of organic and traditional arable farming on wheat (Shortandinskaya 95 improved), the preceding crop being fallow after sweet clover.

In traditional farming, ammophos (11–46–0) was used, which was added to the fallow at a depth of 12–14 cm at the rate of P40 (control — background); on the same background, ammonium saltpeter (34–0-0) was applied in the rows during planting at various rates (N20, N40, N60, N80).

Organic farming: fertilizers in the form of dry above-ground biomass of various perennial grasses were applied in fallow: sainfoin (*Onobrychis arenaria*) — 4.71 t/ha, alfalfa (*Medicago varia Mart.*) — 4.32 t/ha, sweet clover (*Melilotus officinalis (L.) Pall.)* — 4.71 t/ha, bromegrass (*Bromus inermis Leyss.)* — 5.71 t/ha, wheatgrass (*Agropyron pectiniforme Roem. et Schult)* — 4.85 t/ha.

Organic and mineral fertilizer rates are calculated with due account primarily for soil phosphorus deficit-free balance. The experiments are established in 4 randomized replications on plots of 4.3x30 m (129 $m^2$).

The timing, norms and depth of sowing spring soft wheat are in accordance with the recommendations for the research area.

Seeding and fertilizer application were performed with the SZS-2.1 duck-foot seed drill. With traditional farming, various herbicides, fungicides and insecticides were applied. At wheat tillering stage, tank mixture of herbicides was used: Esthete (0.6 l/ha) combined with Granstar (15 g/ha) and Trend (120 g/ha); at the booting stage, a combination of Falcon fungicide (0.5 l/ha) + Puma Super 7.5 graminicide (1.0 l/ha) + Angio insecticide (0.1 l/ha) was applied; Falcon fungicide at the rate of 0.6 l/ha was applied at the grain filling stage. No pesticides were applied under organic farming.

Soil samples were taken before wheat seeding and at complete ripeness in various soil profile horizons (0–10, 10–20. 20–3- cm) into sterile envelopes [19]. Microbiological analyses for identification and investigation of environmental trophic groups were performed in fresh soil samples per established practices [20].

Soil weighted portion (10 g) was placed into a sample flask with 100 ml of sterile water and then was stirred for 10 minutes with OS-20 shaker at 120 rpm.

Soil suspension was plated per limited dilution technique on agar media with two replications: ammonifying bacteria on meat-and-peptone agar (MPA); immobilizer bacteria and actinomycetes on starch-and-ammonia agar (SAA); fungi on Czapek medium; cellulose-destroying aerobic bacteria, including micromycetes, on Hutchinson medium (with blotting paper as a source of carbon).

The incubation was performed in a temperature-controlled cabinet at 25–27°C. Soil microorganisms were registered on various dates: on the $3^{rd}$ day — bacteria; on the $5^{th}$–$7^{th}$ day — fungi; on the $30^{th}$ day — cellulolytic bacteria. The number of microorganisms was expressed as the number of colony-forming units (CFU) per 1 gram of absolutely dry soil (a.d.s.) [21].

To identify microorganisms, classic (based on microorganism microscopy and use of determinants) and biomolecular methods were used.

*Classic method.* 3–10 days after incubation, soil micromycete colonies that developed on the culture medium were visually inspected with due attention paid to the following: form and margin of the colony, texture of aerial mycelium, color and reversal thereof; with bacteria, form and margin of the colony, as well as pigmentation. To conduct the microscopy, preserved and live microorganism preparations (slide test) were prepared in accordance with the method described in [22].

Soil microorganism microscopy was carried out with *Altami Bio 1* digital binocular microscope with the use of magnifying eyepieces (x15) providing magnification power from 600 to 1500 (for fungi and bacteria, respectively) as depended on the eyepiece magnification power (40x and 100x).

When bacteria were microscoped, morphological characters were taken into account (form and size of cells and relative positions thereof, type of flagellation, existence of capsules, capability of sporulation, particular characteristics of internal constitution), as well as Gram staining related to cell wall configuration, with the use of determinants [23–25].

When identifying soil fungi, major attention was paid to cell morphology and structure. With *Deuteromycetes* (*Fungi imperfecti*), major attention was focused on ways of conidial sporulation. Conidia formed directly on vegetative mycelium or on conidiophore, the so-called specialized offshoots of vegetative mycelium hyphae that differ morphologically from vegetative mycelial paraphyses. Conidia formation is one-step and takes a form of catenulae or heads. Conidiophore development was on hyphae or on a stroma (tight plexus of vegetative hyphae) with formation of various types of conidiophore aggregations: sporodochia, pionnotes or papilliform sporodochia, etc.

The investigation rated conidia form, color and envelope, existence of dissepiments, type of conidia formation, particularly phialospores with *Fusarium, Phyalophora, Cylindrocarpon* fungi. Determinators were used for fungi identifications [26–29].

*Biomolecular method.* Additionally, to elaborate the specific name of some fungal isolates, a biomolecular method was used that included definition analysis of direct nucleotide sequence of the ITS region (intergenic transcribed spacer region) and subsequent identification of nucleotide identity with sequences deposited in the Gene Bank international database. The PCR reaction was performed with primers ITS 5 5’ — ggaagtaaaagtcgtaacaagg -3’ and ITS 4 5’- tcctccgcttattgatatgc -3’ in the total volume of 30 mcl. The PCR program was implemented with the use of DNA Engine Tetrad 2 Cycler PTC-0240 (Bio-Rad) thermocycler.

Genetic identification of bacterial isolates was conducted on the basis of *16S rRNA* nucleotide sequence analysis. DNA was isolated by the method described by Kate Wilson that allows to effectively isolate DNA from gram-negative and gram-positive bacteria. The PCR reaction was performed with multipurpose primers [30] 8f 5’ — AgAgTTTgATCCTggCTCAg-3 and 806R- 5’ ggACTACCAgggTATCTAAT in the total volume of 30 mcl. The PCR program was implemented with the use of GeneAmp PCR System 9700 (Applied Biosystems) thermocycler.

For statistical data processing, the SNEDECOR software package [31] and Excel (for dispersion and correlation analysis) were used. The results were presented graphically using Microsoft Excel.

*Meteorological conditions.* During the research period, meteorological conditions were favorable in general, however changeable temperature profile and uneven rainfall distribution across months and weeks were registered during growing seasons.

In May 2018, the temperature profile was 3,7°C lower than the long-term annual average (12.4°C). Rainfall amount in June was 29.0 mm higher than the long-term annual average (Fig. 1).

In July, weather conditions were around the long-term annual averages. In August, the amount of rainfall was substantial, being, in fact, twice higher than the long-term annual averages (40.0 mm), while the temperature profile was 4.8°C lower than normal. Precipitation level in October was within the norm, while the temperature was lower than the long-term annual averages, amounting to 1.2°C.

May 2019 was characterized by actually triple shortfall of rainfall. The monthly precipitation amount was as low as 10.1 mm, while the long-term annual average norm is 32.4 mm. In June, the amount of rainfall was 39.5 mm, i.e. within the long-term annual average norm, which contributed to wheat development. During the first and second ten-day periods of July there was no rainfall, which to a considerable extent inhibited wheat growth. Insufficient rainfall amount was also registered in August (first and second ten-day periods), however, in the third ten-day period the amount of rain shower precipitation was 21.7 mm. Climatic conditions of early spring and summer of 2020 were characterized by higher temperatures. Spring was dryer, there was practically no rainfall in March and in May. However, in April the amount of precipitation was substantial, exceeding the norm 1.9 times. Ambient air temperature over all the months was over 3,0°C higher than normal. Then, severe atmospheric drought was registered for around 50 days (up to 26 June) followed by a heavy rainfall of 39.5 mm (a monthly norm) within two days. Precipitation in July was 46.6 mm, which was actually at the level of the long-term average (57.0 mm). Precipitation that fell at the beginning of the month contributed to sufficient moisture in the root layer. The temperature profile was 2.2°C below the long-term average. The first and third ten days of August were characterized by dry weather.

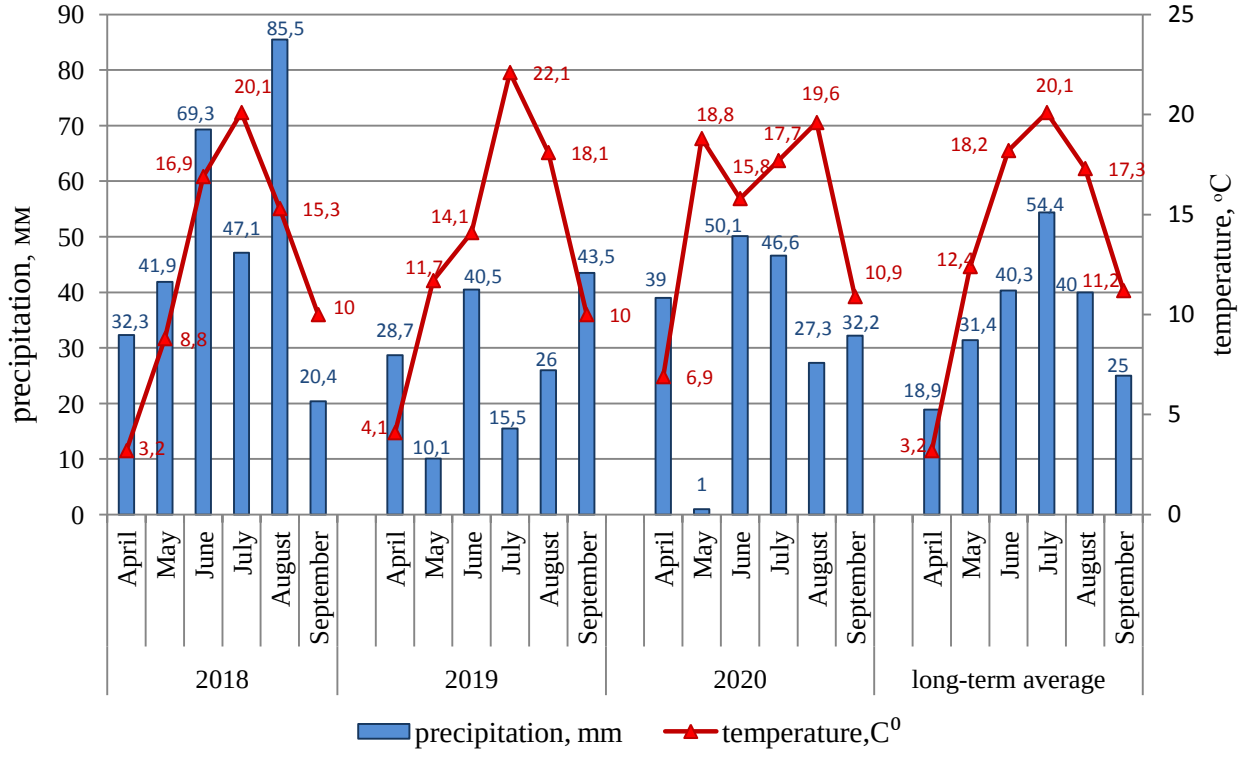


Figure 1. Climatic chart for wheat growing periods

*Results and Discussion*

Under traditional and organic farming, soil microbiota under spring soft wheat crops was represented by various microorganism groups, population thereof varying with soil horizons and experiment variants.

On average over the three year of the research, under conditions of traditional farming, the population of ammonifiers in the layer of 0–30 cm varied from 1.8 to 6.6 million CFU/g a.d.s. (Fig. 2).

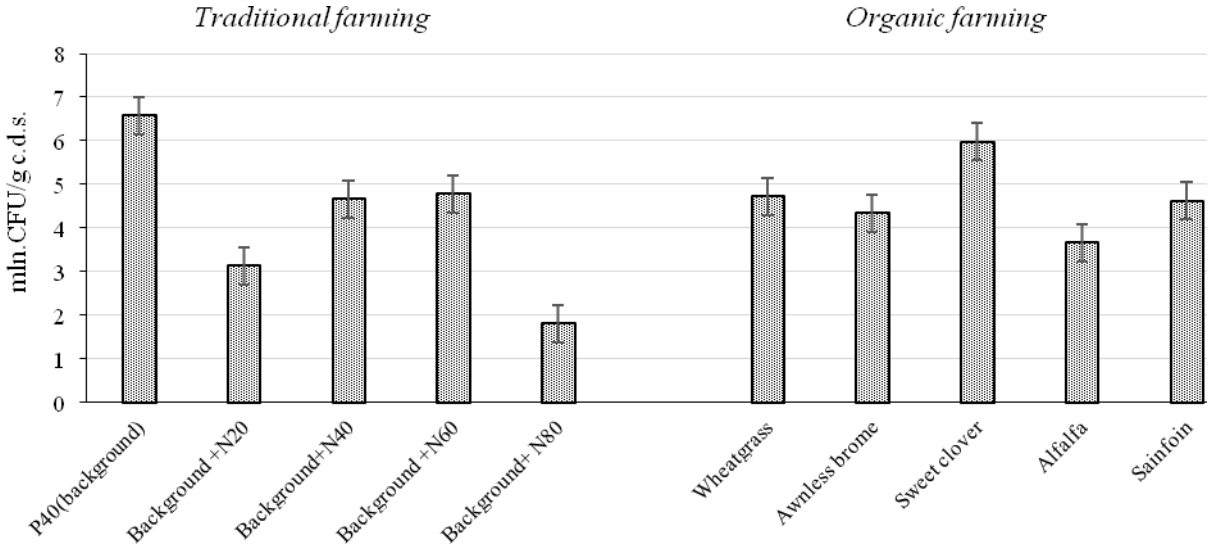


Figure 2. The number of ammonifying bacteria under wheat crops in the soil layer of 0–30 cm (average for 2018–2020)

The active growth of ammonifiers was contributed by application of ammophos into fallows at the rate of P40, when the population thereof grew up to 7.0 million CFU/g a.d.s. The same situation occurred with

the application of sweet clover biomass, which contributed to the growth of ammonifying bacteria up (to 6.0 million CFU/g a.d.s.). Ammonifying microorganisms in the soil, due to emission of enzymes that enrich the soil with nitrogen and other compounds. At the same time, a sanitary role is performed: cleaning the soil of decomposable organic substrate.

All the variants studied were characterized by regular reduction of the number of ammonifiers in the lower layers of the soil plowing horizon. The given group of microorganisms developed actively in soil layers of 0–10 cm and 10–20 cm (Fig. 3). Under traditional farming, the number of ammonifiers was maximal in the layer of 0–10 cm in the variant with sole amorphous and amounted to 6.39 million CFU/g a.d.s., while additional application of ammonium saltpeter ate rate of N40 increased that number to 7.44 million CFU/g a.d.s. In the soil level of 10–20 cm, the maximal number of ammonifying bacteria: 8.71 million CFU/g a.d.s., was registered in variants with ammonium saltpeter application at the rate of N60. In the soil level of 20–30 cm, the maximal number of ammonifying bacteria was registered in the sole phosphorus variant (P40): 7.79 million CFU/g a.d.s.

Under organic farming, the highest number of ammonifying bacteria was detected in the 0–10 cm layer in the variants with the biomass of sweet clover, sainfoin and bromegrass (9.08, 7.45 and 6.29 million CFU/g a.d.s. respectively).

The following ammonifying microorganisms were isolated: sporogenous aerobic bacteria *Bac.mesentericus*, *Bac.subtilis*, *Bac.megatherium*, and non-sporogenous aerobic ammonifiers: *Ps. fluorescens, Proteus vulgaris.*

Therefore, application of perennial grass above-surface biomass as green manure contributes to active development of ammonifiers.

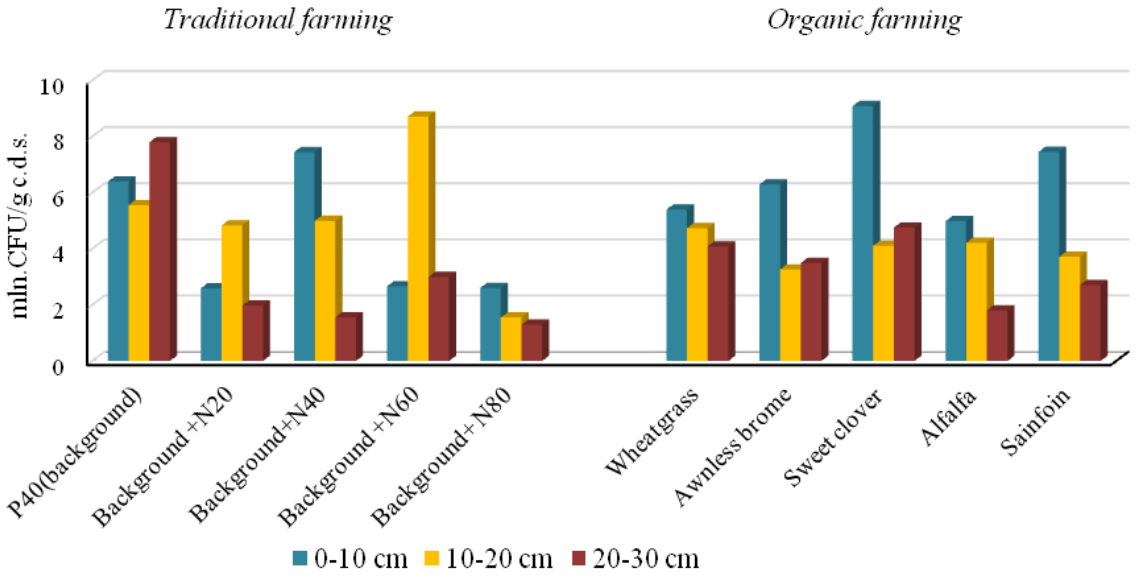


Figure 3. Distribution of ammonifying bacteria in the soil layer of 0–30 cm (on average for 2018–2020)

The bacterial complex was dominated by immobilizers, the population thereof was actually 3 to 19 times higher than that of ammonifying bacteria. On the average, over the years of the research, in the variants with traditional farming their population varied with variants from 7.11 to 36.1 million CFU/g a.d.s., while with organic farming it varied from 16.8 to 82.6 million CFU/g a.d.s. (Fig. 4).

A large population of microorganisms that assimilate inorganic nitrogen was identified in the variant with phosphorus application under traditional farming (32.4 million CFU/g a.d.s.) and in the variant with the application of bromegrass biomass as a fertilizer under organic farming (83.0 million CFU/g a.d.s.).

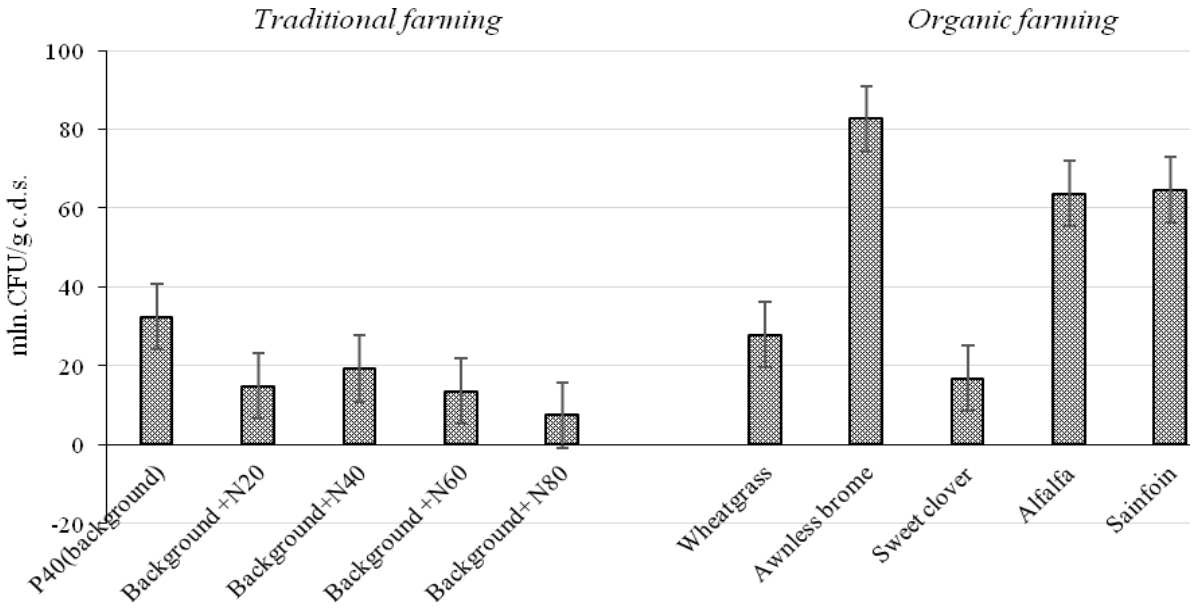


Figure 4. The number of immobilizing bacteria under wheat crops in the soil layer 0–30 cm (average for 2018–2020)

As a whole, it can be noted that both immobilizers and ammonifiers developed most actively in the variants with application of organic fertilizers. Distribution of immobilizers over soil layers was uneven, the development was more active in the layers of 0–10 and 10–20 cm, while in the layer of 20–30 cm the number of immobilizers was low (Fig. 5). That group of microorganisms was represented by various species of bacteria and actinomycetes. Micromycetes were also present, however in singular quantities.

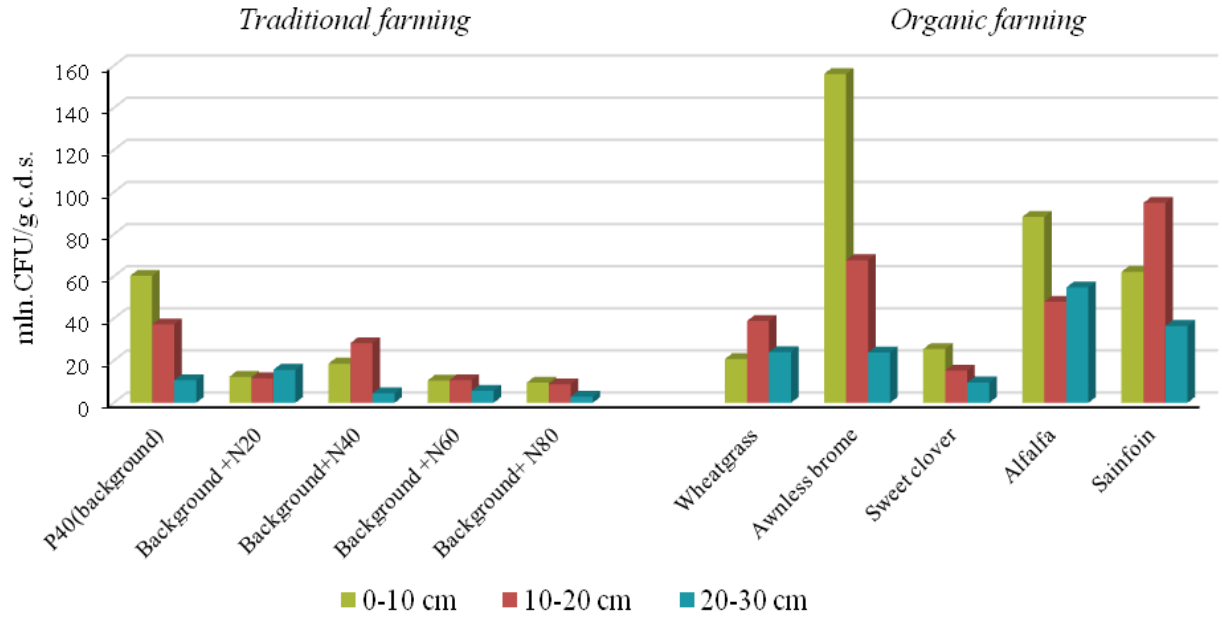


Figure 5. Distribution of immobilizer bacteria over soil layers (average for 2018–2020)

Under traditional farming, the number of immobilizers in the soil layer of 0–30 cm varied from 7.46 million CFU/g a.d.s. (in the variant with nitrogen rate N80) to 32.44 million CFU/g a.d.s. (in the variant with phosphorus). Application of moderate rates of mineral fertilizers contributed to increment of soil bacterial

microflora, which contributed to enhancement of mineralization processes. Similar data were obtained in another research [32].

Under organic farming conditions, the smallest population of immobilizing bacteria in the 0–30 cm soil layer was found in the variant with sweet clover biomass — about 17.0 million CFU/g a.d.s, while with application of bromegrass biomass, the population thereof substantially increased to 82.6 million CFU/g a.d.s., especially in the soil layer of 0–10 cm, where the population of immobilizers was especially large: 156.0 million CFU/g a.d.s. It should also be noted that with application of sainfoin biomass, the population thereof in the soil layer of 10–20 cm increased to 95.0 million CFU/g a.d.s., while with application of alfalfa biomass, the population in the soil layer of 2–30 cm amounted to 54.8 million CFU/g a.d.s.

Application of bromegrass biomass contributed to active development of immobilizer microorganisms.

The fungal complex was represented by various types of soil micromycetes (Penicillium spp., Aspergillus spp., Trichoderma spp., Fusarium spp., Mucor spp., etc.)

On the average for the period of 2018–2020, the number of fungi varied with variants from 4,0 to 6.0 thousand CFU/g a.d.s. The maximal quantity of fungi was registered in the variant with ammonium saltpeter at the rate of N40 (Fig. 6).

It is well known that soil fungi participate in the processes of fermentation of organic compounds and are sensitive to high rates of mineral fertilizers [33], however, with application of ammonium saltpeter at the rate of N80, their population was very low: 3.8 thousand CFU/g a.d.s.

Under organic farming, the total number of fungi varied from 5.6 thousand CFU/g a.d.s. (the variant with alfalfa biomass) to 7.8 thousand CFU/g a.d.s. (variant with bromegrass biomass).

Fungi distribution over soil layers varied significantly, however the fungus pool prominently tended to reduce with depth. That was a consistent pattern on variants with the use of phosphorus (P40) and nitrogen-phosphorus (N60 and N80) fertilizers in traditional farming, as well as with the use of sweet clover, wheatgrass and sainfoin biomass in organic farming (Fig. 7).

In the remaining variants active accumulation occurred in the soil layer of 10–20 cm.

Population dynamics of soil fungi varied with years and variants of the experiment, while the number thereof tended to grow by the third year of the research, especially in the soil layers of 0–10 and 10–20 cm, which is due to soil saturation with fresh plant residues and sufficient soil moisture content during the vegetation period. Under organic farming, bromegrass and sainfoin biomasses used in the capacity of fertilizers contributed to substantial increase of micromycete population.

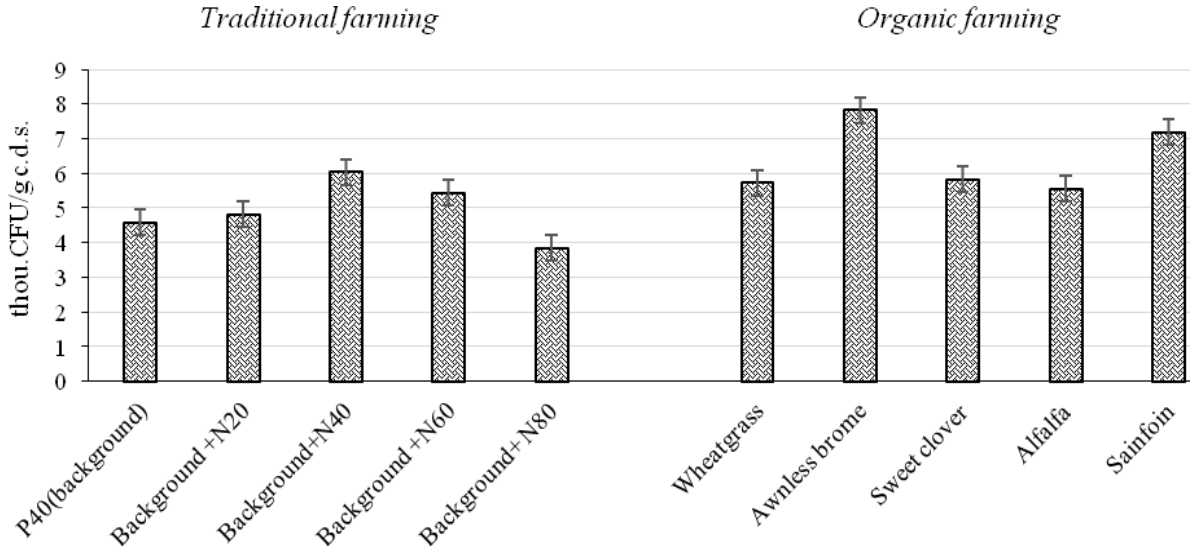


Figure 6. Populations of fungi under wheat crops in the soil layer of 0–30 cm (average for 2018–2020)

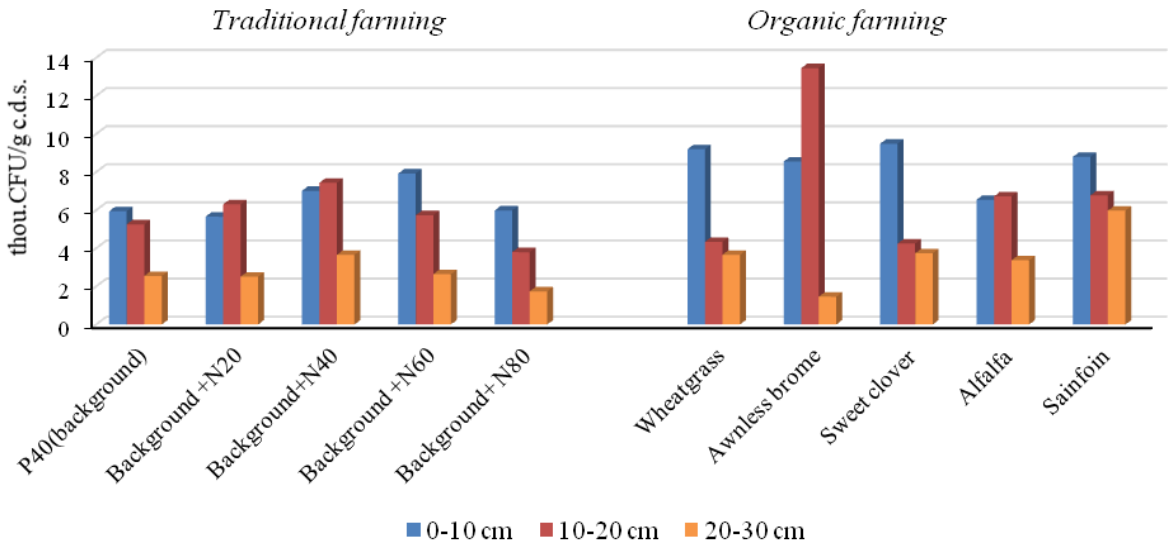


Figure 7. Distribution of fungi over the soil layers (average for 2018–2020)

The number of cellulolytic microorganisms was on the same level irrespective of the farming system. On average, over the three years of research it varied from 39.3 to 63.7 thousand CFU/g a.d.s. under traditional farming and from 32.4 to 64.5 thousand CFU/g a.d.s. under organic farming (Fig. 8).

Under traditional faming, the maximal quantity of cellulolytic organisms was registered in the variant with ammonium saltpeter row application at the rate of N80 (63.7 thousand CFU/g a.d.s.) while the minimal quantity was registered with nitrogen fertilizer application at the rate of N40 (39.3 thousand CFU/g a.d.s.).

Under organic farming, the maximal quantity of cellulolytic bacteria was registered with the application of wheatgrass biomass (64.5 thousand CFU/g a.d.s.), while the application of sweet clover and bromegrass biomass reduced the population thereof by half (32.4 and 32.6 thousand CFU/g a.d.s., respectively).

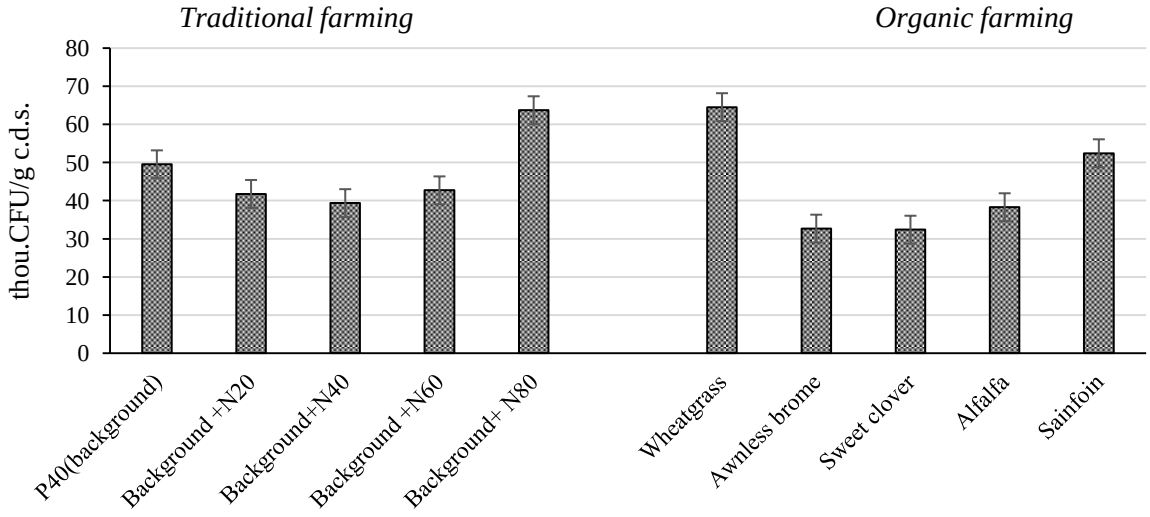


Figure 8. Numerical composition of cellulose-destroying microorganisms under wheat crops in the soil layer of 0–30 cm (2018–2020)

Distribution of cellulose-destroying microorganisms over arable soil layers was uneven. Depending on the experimental options, the largest number of cellulolytic bacteria was identified in the layer of 0–10 cm and 10–20 cm, the smallest — at a depth of 20–30 cm (Fig. 9). This can be explained by the slight accumulation of plant residues on a given soil horizon and their use in cultivating the land. In particular, the use of flat-cutting implements only loosens the soil, but does not cultivate it.

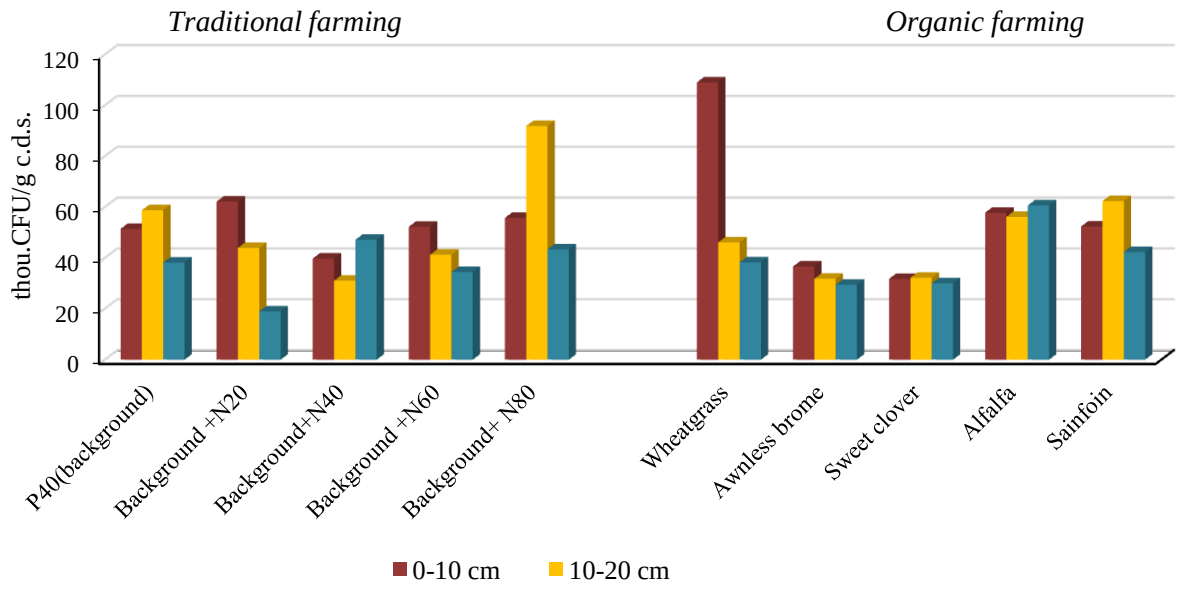


Figure 9. Distribution of cellulolytic microorganisms over soil layers (average for 2018–2020)

Among representatives of cellulolytic microorganisms there were isolated actinomycetes, bacteria and fungi, including *Trichoderma spp., Chaetomium sp., Fusarium spp., Mucor.*

Figure 10 shows major environmental trophic groups of microorganisms isolated from the soil (0–30 cm) under wheat crops grown under traditional and organic farming. Species composition thereof was practically identical with the exception of quantitative ratio.


Figure 10. Soil microorganisms isolated from soil under traditional (A) and organic (B) farming systems

## *Conclusion*

The study of the soil microbiota under wheat crops cultivated under traditional and organic farming allowed made it to identify that make it possible to identify microorganisms belonging to various ecological and trophic groups that participate in various soil biochemical processes.

Regular application of dry biomass of perennial grasses, even more so of bromegrass, in the capacity of organic fertilizers, resulted in increase of population and biodiversity of soil microorganisms, specifically ammonifiers and immobilizers.

Fungi actively propagated with soil application of bromegrass and sainfoin biomass. Application of sainfoin and wheatgrass biomass contributed to the increase of cellulolytic bacteria quantity up to 64.5 thousand CFU/g a.d.s., while application of sweet clover biomass reduced the quantity thereof (down to 32.6 thousand CFU/g a.d.s.).

Distribution of microorganisms over soil layers was uneven. They mostly prevailed in the upper layer (0–10 cm) and the number thereof significantly decreased with depth, especially in the layer of 20–30 cm. No major differences were identified in the species composition.

Under traditional faming, application of ammonium saltpeter at the rate N80 contributed to active development of cellulolytic microorganisms, but retarded development of fungi and ammonifiers. Reserve application of ammophos in the fallow field at the rate P40 contributed to active propagation of bacteria (ammonifiers and immobilizers).

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## Топырақ микробценозы және оның қалыптасу ерекшеліктері Солтүстік Қазақстанның қара жер топырақтарында дәстүрлі және органикалық егіншілік

Оңтүстік карбонатты қара топырақтың топырақ микробценозы және Солтүстік Қазақстан жағдайында бидай өсірудің органикалық және дәстүрлі технологиясы кезінде оның қалыптасу ерекшеліктері зерттелді. Топырақ микробценозасы егіншілік жүйесіне байланысты өзгеретіні анықталды. Топыраққа органикалық тыңайтқыш ретінде бұршақ және дәнді шөптердің жерүсті биомассасын енгізу дәстүрлі егіншілік нұсқаларынан екі есе көп иммобилизаторлардың сандық құрамының артуына ықпал етті. Тыңайтқыш ретінде қолданылатын түйежоңышқаның жерүсті биомассасы топырақтағы аммонификациялаушы микроорганизмдердің (6,0 млн. ҚҚБ/г м.қ.т. дейін), ал қылтықсыз арпабас биомассасы — иммобилизаторлар (83,0 млн. ҚҚБ/г м.қ.т.) және саңырауқұлақтардың (8,0 мың ҚҚБ/г м.қ.т.) санын арттырды. Целлюлоза түзетін микроорганизмдер бидай дақылдарының егістігінде белсенді дамыды, онда тыңайтқыш ретінде еркешөп биомассасы енгізілді (65,0 мың ҚҚБ/г м.қ.т.), керісінше, түйежоңышқа мен қылтықсыз арпабастың биомассасы олардың төмендеуіне ықпал етті. Дәстүрлі егіншілікте N 80 дозасында себу кезінде қатарға аммиак селитрасын енгізу целлюлозолитикалық микроорганизмдердің дамуын ынталандырды, бірақ саңырауқұлақтар мен аммонификатор бактерияларының дамуын тежеді. Аммонификаторлар мен иммобилизаторлар Р40 дозасында сүрі танабына енгізу кезінде белсенді дамыды.

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# Почвенный микробоценоз и особенности его формирования при традиционном и органическом земледелии на черноземных почвах Северного Казахстана

Изучен почвенный микробоценоз чернозема южного карбонатного и особенности его формирования при органической и традиционной технологии возделывания пшеницы в условиях Северного Казахстана. Установлено, что почвенный микробоценоз изменяется в зависимости от системы земледелия. Внесение надземной биомассы бобовых и злаковых трав в качестве органических удобрений в почву способствовало увеличению численного состава иммобилизаторов, которые в два раза превышали варианты традиционного земледелия. Вносимая в качестве удобрения надземная биомасса донника увеличивала количество аммонифицирующих микроорганизмов в почве (до 6,0 млн КОЕ/г а.с.п.), а биомасса костреца — иммобилизаторов (83,0 млн КОЕ/г а.с.п.) и грибов (8,0 тыс. КОЕ/г а.с.п.). Целлюлозоразрущающие микроорганизмы активно развивались под посевами пшеницы, где в качестве удобрения вносили биомассу житняка (65,0 тыс. КОЕ/г а.с.п.), и, наоборот, биомасса донника и костреца способствовала их снижению. В традиционном земледелии внесение аммиачной селитры в рядки при посеве в дозе N80 стимулировало развитие целлюлозолитических микроорганизмов, но сдерживало развитие грибов и бактерий аммонификаторов. Аммонификаторы и иммобилизаторы активно развивались при внесении аммофоса в запас в паровое поле в дозе P40.

*Ключевые слова:* чернозем южный карбонатный, почвенный микробоценоз, грибы, бактерии, целлюлозолитические микроорганизмы, пшеница, органическое и традиционное земледелие.

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# Impact of abiotic stressors on oleic acid accumulation in the leaves of young quinoa plants

Investigating the impact of not only individual stress factors but also their combined effect on plants becomes imperative in the context of natural and climatic fluctuations. 18-carbon unsaturated fatty acids such as oleic (18:1), linoleic (18:2) and α-linolenic (18:3) serve as vital non-enzymatic antioxidants, making significant contributions to plant defense. Moreover, they are indispensable in assessing the nutritional and biological value of plant lipids. Currently, *Chenopodium quinoa* L., a member of the Amaranth family, is increasingly recognized as a valuable source of antioxidant metabolites. Current study examined the fluctuation patterns in oleic acid ester content, serving as a non-enzymatic antioxidant, when plant exposed to varying intensities of osmotic, saline, and combined stress. A constant concentration of oleic acid esters was shown under different levels of saline stress. Osmotic stress did not affect the oleic acid content. Under salt stress, the oleic acid content increased compared to the control, varying at different NaCl concentrations. However, under combined stress, there was a significant increase in ester content, peaking at a stress level of 200NaCl/L+PEG, followed by a decrease as stress increased. It was noted that signs of stress for the photochemical quenching index of YII and ETR in photosystem II of young quinoa plants also occur with a combination of exposure to 300 mM/L NaCl + PEG. It was suggested that the level of combined stress at 200NaCl/P is transitional from eustress to distress. The results obtained could potentially become the basis for the targeted synthesis of valuable plant antioxidants for food and pharmaceutical purposes in the future.

*Keywords:* oleic acid, salt stress, abiotic, quinoa, eustress.

## *Introduction*

In the context of global climate change, extensive desertification, and land salinization, plants are exposed to various abiotic stressors. Generally, abiotic stressors exert their impact concurrently by altering osmotic pressure, disrupting nutrient supply, inducing ion toxicity, and causing oxidative damage to cells and tissues [1–3]. Comprehension of above stressors is complicated due to their complexity, including source, intensity, duration, and effects [4].

Nature has evolved diverse mechanisms to prevent or alleviate abiotic stress, which encompasses a powerful antioxidant defense system consisting of both enzymatic and non-enzymatic components. In addition, 18-carbon unsaturated fatty acids (UFAs), including oleic (18:1), linoleic (18:2), and α-linolenic (18:3) acids, serve as vital non-enzymatic antioxidants, contributing significantly to plant protection [5, 6].

Furthermore, UFAs serve multiple roles within plant tissues, specifically they: a) function as constituents and regulators of cell membranes in glycolipids; b) serve as carbon and energy reserves within triacylglycerol; c) govern the storage of extracellular barrier components like cutin and suberin; d) act as precursors to various biologically active molecules, including jasmonates and nitroalkenes; e) function as regulators in stress signaling pathways, while also having the potential to induce oxidative stress [5, 7].

The alterations in lipid composition that occur during a plant's adaptation to adverse environmental conditions can determine the types of radical-free reactions induced by stress [8]. Fatty acids in plants exist not only in their free form but also as esters [9].

Throughout history, humans have utilized plants for nutrition and medicinal purposes since plant antioxidants possess the ability to regulate not only the physiological processes within plants but also various functions within the human body, reducing the risk of chronic diseases caused by free radical oxidation [10, 11]. Consequently, understanding the antioxidant systems of food and medicinal plants holds great significance. The primary reference point for assessing the nutritional and biological value of plant lipids is UFAs content [12].

Epidemiological research suggests that a diet with a higher proportion of UFAs, particularly oleic acid, may offer protection against cardiovascular disease. Oleic acid is acknowledged for its exceptional resistance to oxidation and its capacity to enhance the activity of other antioxidants, such as tocopherol [13].

Nowadays, plants from the *Amaranthaceae* family, particularly quinoa (*Chenopodium quinoa* L.), have been gaining heightened recognition as valuable sources of antioxidant metabolites [14, 15]. Additionally, amaranth species are stress-resistant and well adapted for cultivation in marginal regions [16–18].

Therefore, current research aimed at investigating the accumulation of oleic acid in quinoa plants when subjected to osmotic, saline, and combined stress conditions.

## *Materials and Methods*

*Plant material*

The study utilized the Tajik quinoa variety "Vandat" obtained from the Centre for Genetic Resources of the Tajik Academy of Agricultural Sciences. The experiment involved plants with no cotyledons and four rows of unfolded leaves. Two top unfolded leaves and the intervening stem section were examined.

*Growth conditions*

Research plants were grown in a climatic chamber with fluorescent lamps providing 200 μmol $m^{-2}$ $s^{-1}$ PAR, a 16-h photoperiod, and a temperature of +25 °C. Seeds were germinated for 5 days, and then transplanted into plastic pots (20 seedlings $pot^{-1}$). Seedlings were exposed to circadian illumination for 10/14 h. The seedlings were cultivated for 26 days using 50 % Hoagland nutrient solution, and for the next 14 days with added stress agents, resulting in a total of 8 experimental conditions (Table 1).

Table 1

**Experimental conditions**

| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|
| | Control | P | 100NaCl | 200NaCl | 300NaCl | 100 NaCl/P | 200NaCl/P | 300NaCl/P |
| Days | 14 | 10 + 4 | 14 | 14 | 14 | 10 + 4 | 10 + 4 | 10 + 4 |
| 50 % Hoagland solution | + | + | + | + | + | + | + | + |
| PEG-6000 | - | 12.5 % (m/v) | - | - | - | 12.5 % (m/v) | 12.5 % (m/v) | 12.5 % (m/v) |
| NaCl | - | - | 100 mM | 200 mM | 300 mM | 100 mM | 200 mM | 300 mM |

*Determination of organic compounds in extracts*

Gas chromatography with mass spectrometric detection (Agilent 6890 N/5973 N, Santa Clara, CA, USA) was employed to analyze organic compounds. Plant samples were fixed in 96 % ethanol at a ratio of 100 g of tissue to 500 mL of ethanol. Extraction occurred in an orbital shaker across two stages until a clear and colorless solvent was obtained. A 1.0 μL sample was injected into the GC-MS system at 260 °C without flow division. The separation utilized a DB-35 MS chromatographic capillary column with a constant carrier gas velocity of 1 mL $min^{-1}$. The chromatographic temperature rose by 10 °C $min^{-1}$ from initial 40 to 150 °C, followed by 5 °C $min^{-1}$ rate from 150 to 300 °C. Detection was performed using SCAN m/z 34–850 mode. GC system regulation and results processing was carried out by Agilent MSD ChemStation software (Santa Clara, CA, USA).

*Photosynthetic Activity Determination*

Photosynthetic activity parameters were estimated by determination of fluorescence levels. Rapid light curves (RLCs) were recorded using Junior-PAM ("Heinz WalzGmbH", Effeltrich, Germany) under actinic illumination of 450 nm. The RLC for each sample was recorded after quasi-darkness to assess the effect of actinic light absence, while complete darkness is difficult to achieve under field conditions [19]. For each measurement the fluorometer provided eight saturation light pulses of 10,000 μmol/$m^2$ s every 20 s, while actinic light increased from 0 to 625 μmol/$m^2$ s gradually. For comparison, the data obtained from the last pulse of the light curve were taken [20]. The following parameters were calculated using WinControl-3.29 (Walz, Effeltrich, Germany) software: Y(II): effective photochemical quantum yield of PSII; ETR: PSII relative electron transport. In the experiment, each time the region of the middle third of the active leaf was selected. All measurements were performed on a sunny day from 09:00 to 11:00 a.m.

All experiments were done in three replicates. The processing of data and graphing was performed using Microsoft Excel (Microsoft Corp., Redmond, Washington, DC, USA). Atypical values were excluded from the data based on t-tests, the standard error of the average sample was calculated. Differences were considered significant at $p < 0.05$.

*Results and Discussion*

Oleic acid, a monounsaturated carboxylic acid, is characterized by a single double bond. The systematic name of oleic acid is 9-octadecenoic acid with chemical formula of $CH_3–(CH_2)_7–CH=CH–(CH_2)_7–COOH$. Oleic acid is an oily, colorless, and odorless liquid, with a density lower than that of water. It is insoluble in water but exhibits solubility in organic solvents. The melting point of oleic acid is +13.4 °C, and its empirical formula is $C_{18}H_{34}O_2$ **(**Fig. 1**)**.

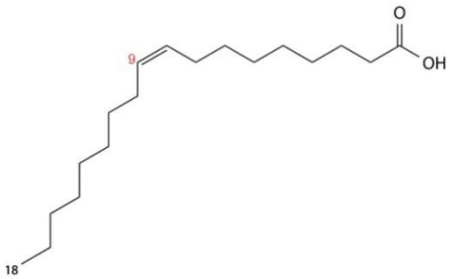


Figure 1. Oleic acid chemical structure

The examination of oleic acid ester content in the leaves of experimental quinoa plants revealed significant quantitative variations as stress levels of osmotic, saline, and combined nature increased (Table 2).

Table 2

**The influence of stress conditions on oleic acid ester content in photosynthetic organs of young *Chenopodium quinoa*.**

| Condition | Control | +100 mM NaCl | +200 mM NaCl | +300 mM NaCl |
|---|---|---|---|---|
| Saline stress | 3.13 ± 0.06 | 5.02 ± 0.03* | 5.00 ± 0.02* | 5.01 ± 0.03* |
| Combined stress (+12.5 % PEG) | 3.03 ± 0.05 | 5.55 ± 0.06* | 11.3 ± 0.08* | 6.67 ± 0.06* |
| *Note* – * indicates a significant difference between the control and the stress at $p \leq 0.05$ | | | | |

Thus, individual osmotic stress did not induce alterations in the oleic acid ester content. Conversely, under individual saline stress, the oleic acid ester content increased compared to the control but remained consistent with increasing NaCl concentration.

The picture became more complicated under combined stress conditions. The tendency for oleic acid ester content to increase compared to control persisted, with the highest levels observed at combined stress of 200NaCl/P. However, at a combined stress level of 300NaCl/P, there was a reduction in oleic acid ester content, even though remaining higher than the control values.

Consequently, stress reactions can significantly alter the UFAs content and shape the lipid composition of plant cells and tissues during the adaptation process [21, 22].

Since fatty acids can only undergo *de novo* synthesis within plastids, specifically in chloroplasts [4, 23], the increased content of UFAs, including in various ester forms, within the lipids of internal chloroplast and mitochondria membranes can serve as natural antioxidants, thereby potentially contributing to the attenuation of PSII photoinhibition under stress conditions [24, 25].

Our analysis of YII, a key indicator of photochemical quenching that evaluates the effective photochemical quantum yield of PSII, did not reveal any statistically significant variations under stress conditions. However, it revealed a trend of increasing values with the rise in NaCl concentration in the nutrient solution up to 200 mM/L, followed by a marked decrease at a concentration of 300 mM/L NaCl under combined stress. Literature suggests that consistent photochemical quantum yield values indicate PSII's resilience to saline conditions [26], whereas a decrease signifies photodamage caused by stress [27, 28]. Consequently, it appears that stress indicators related to photochemical quenching in PSII of young quinoa plants become ev-

ident under the combined effects of 300 mM/L NaCl and PEG6000. This phenomenon has been similarly documented in quinoa and various other plant species [29–31] (Fig. 2).

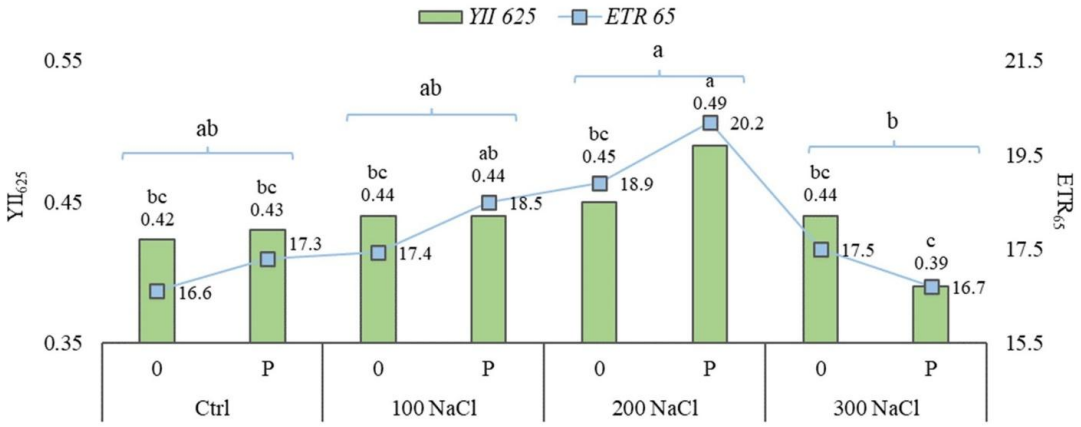


Figure 2. Activity alterations of photosynthetic parameters under stress conditions. Different letters above the bars represent significant differences at $p \leq 0.05$

The negative effects of combined stress on the PSII quantum efficiency index likely arise from the inhibition of electron transport, disruption of reaction centers, and the initial stages of damage to the oxygen-evolving complex [30, 32, 33]. In our study, we observed an uptick in the electron transport rate (ETR) as the concentration of NaCl in the nutrient solution increased to 200 mM/L, under both salt and combined stress conditions. This increase correlated with the leaf's water content, whereas a significant decrease in ETR was seen at a NaCl concentration of 300 mM/L. Under salt stress alone, ETR values returned to baseline (control) levels, but they were markedly lower under combined stress. These observations are in line with research suggesting that PSII-mediated electron transport can improve under mild salinity [34] but is adversely affected under intense stress [35], leading to diminished electron transport capacity during photosynthesis and reduced efficiency in energy utilization from PSII [35, 36]. The disruption of intersystem electron transport and damage to PSII's terminal electron acceptors play significant roles in generating reactive oxygen species [37]. This indicates that young quinoa plants facing severe combined stress experience greater oxidative stress compared to those under normal conditions or dealing with only osmotic or salt stress. A strong correlation (r = 0.9) between YII625 and ETR values further supports the conclusion that genuine stress symptoms in young quinoa plants manifest under the combined influence of osmotic and salt stress at a 300 mM/L NaCl +PEG concentration.

The disruption of photosynthesis is one of the earliest responses to stress [38–40] and consistent high levels of oleic acid esters across different saline stress levels may suggest a noteworthy degree of salt tolerance for photosynthetic organs in young quinoa plants. This aligns with previously published findings on the morphological and anatomical responses of quinoa's photosynthetic tissues [41].

The significant elevation in oleic acid ester content observed at 200NaCl/P, followed by a decline as stress levels increase to 300NaCl/P, may potentially indicate that the stress level of 200NaCl/P signifies a transition from eustress to distress for young quinoa plants. During eustress, all physiological processes are geared towards growth and development. Contrarily, during distress, all plant adaptive mechanisms turn off [26].

## *Conclusion*

Thus, the study findings represent a new step towards a better understanding of adaptation mechanisms in quinoa plants exposed to individual and combined stress. This could potentially pave the way for future advancements in the targeted synthesis of valuable plant antioxidants for pharmaceutical purposes by focusing on specific stressor concentrations on plants possessing significant nutritional and medicinal attributes at distinct developmental stages.

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## Абиоттық стрессорлардың жас киноа өсімдерінің жапырақтарында олеин қышқылдарының жиналуына әсері

Табиғи-климаттық өзгерістер құбылысында өсімдіктерге жалғыз ғана емес, сонымен қатар біріктірілген күйзеліс факторларының әсерін зерттеу маңызды. Олеин (18:1), линол (18:2) және α-линолен (18:3) сияқты 18 көміртекті қанықпаған май қышқылдары өсімдік қорғанысына маңызды үлес қосатын ферментативті емес өмірлік маңызды антиоксиданттар ретінде қызмет етеді. Сонымен қатар, олар өсімдік липидтерінің тағамдық және биологиялық құндылығын бағалауда өте қажет. Қазіргі таңда Амарант тұқымдасына жататын *Chenopodium quinoa* L. өсімдігі антиоксиданттық метаболиттердің құнды көзі ретінде жақсы танылуда. Мақалада жас киноа өсімдіктерінің фотосинтезге қабілетті мүшелерінің осмостық, тұзды және әртүрлі қарқындылықтағы аралас күйзелістер кезінде ферментативті емес антиоксидант ретінде олеин қышқылы күрделі эфирлерінің құрамының өзгеру динамикасы зерттелген. Әртүрлі деңгейдегі тұзды стрестің әсерінен олеин қышқылы тәрізді күрделі эфирлерінің тұрақты концентрациясының көтерілгені көрсетілді. Тұзды стресс жағдайында олеин қышқылының мөлшері әртүрлі NaCl концентрацияларында өзгеріп, бақылаумен салыстырғанда жоғарылады. Дегенмен, біріктірілген стресс кезінде күрделі эфир құрамының айтарлықтай артуы байқалды, ол 200NaCl/L+PEG стресс деңгейінде максимумға жетіп, содан кейін стресс жоғарылаған сайын азаяды. Жас киноа өсімдіктерінің II фотожүйесінде YII және ETR фотохимиялық сөндіру индексі үшін стресс белгілері 300 мМ/л NaCl + ПЭГ әсерінің комбинациясы кезінде де артатыны атап өтілді. 200NaCl/P кезінде біріктірілген стресс деңгейі

эустрестен күйзеліске ауысады деген болжам бар. Алынған нәтижелер болашақта тағамдық және фармацевтикалық мақсаттарға арналған құнды өсімдік антиоксиданттарының мақсатты синтезіне негіз бола алады.

*Кілт сөздер:* олеин қышқылы, тұзды стресс, абиотикалық, киноа, эустресс.

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## Влияние абиотических стрессоров на накопление олеиновой кислоты в листьях молодых растений киноа

На фоне природно-климатических изменений актуально изучение влияния на растения не только одиночных, но и комбинированных стрессоров. 18-углеродные ненасыщенные жирные кислоты, такие как олеиновая (18:1), линолевая (18:2) и α-линоленовая (18:3), служат жизненно важными неферментативными антиоксидантами, внося значительный вклад в защиту растений. При этом они являются незаменимыми при оценке пищевой и биологической ценности растительных липидов. В настоящее время представитель семества Амарантовых *Chenopodium quinoa* L. получает все большее признание как ценный источник антиоксидантных метаболитов. В статье рассмотрена динамика изменений содержания эфиров олеиновой кислоты как неферментативного антиоксиданта при осмотическом, солевом и комбинированном стрессах различной интенсивности в фотосинтетических органах молодых растений киноа. Показаны увеличение и неизменная концентрация содержания эфиров олеиновой кислоты при различных уровнях солевого стресса. В условиях солевого стресса содержание олеиновой кислоты увеличивалось по сравнению с контролем, варьируя при разных концентрациях NaCl. Однако при комбинированном стрессе наблюдалось существенное увеличение содержания эфиров, достигающее максимума при уровне стресса 200NaCl/L+ПЭГ, за которым следовало снижение по мере усиления стрессового воздействия. Отмечено, что признаки стресса для показателя фотохимического тушения YII и ETR в фотосистеме II молодых растений киноа также наступают при сочетании воздействия 300 mM/L NaCl+ПЭГ. Сделано предположение о том, что уровень комбинированного стресса в 200NaCl/P является переходным от эустресса к дистрессу. Полученные результаты потенциально могут стать основой для направленного синтеза ценных растительных антиоксидантов для пищевых и фармацевтических целей в будущем.

*Ключевые слова:* олеиновая кислота, солевой стресс, абиотический, киноа, эустресс.

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# Evaluation of the *Dracocephalum ruyschiana* L. and *Salvia sclarea* seed material cryopreservation effectiveness.

Cryopreservation of plant material of valuable plants is an effective way to preserve biological diversity in conditions of active and widespread anthropogenic pressure on natural ecosystems. Introduction to cryocollections is justified not only for food agricultural plants, but also for medicinal plants that have valuable secondary metabolites and essential oils. These include *Dracocephalum ruyschian* and *Salvia sclarea*. To effectively restore the viability of seeds after freezing in liquid nitrogen, we examined the influence of various cryoprotectants: glycerin, dimethyl sulfoxide and polyvinypyrrolidone, as well as various methods of their application — at room temperature and in the cold. It was found that for effective cryopreservation of *Dracocephalum ruyschiana* seed material, the use of cryoprotectors is justified; however, the method of their application does not matter. When cryopreserving *Salvia sclarea* seed material, it is important to use cryoprotectors and introduce them into the cooling system, preferably at the crystallization temperature of water; in this case, the energy of seed germination increases significantly.

*Keywords: Dracocephalum ruyschiana*, *Salvia sclarea*, cryoprotectors, cryopreservation, seed material, germination, germination energy.

## *Introduction*

Human economic activities, especially the mining industry, have a significant degrading impact on ecosystems. Biological diversity is constantly declining, populations, and then species, may disappear. The loss of any species has a negative impact, however, the loss of a species that is of practical importance for the national economy leaves an indelible imprint. *Dracocephalum ruyschiana* and *Salvia sclarea* — essential oil and medicinal plants of the Lamiaceae family [1–3], are valuable representatives of the flora of Kazakhstan and their conservation is an urgent task.

Preservation of the gene pool of plants can currently be carried out in a variety of ways. Depending on the chosen method, storage times will vary. Cryopreservation is an innovative, popular, effective and inexpensive way to preserve biological material for a long time without loss of genetic stability [4–9]. The stages of freezing and thawing of the material are critical, therefore optimization of the conditions for freezing seed material of the studied species in liquid nitrogen is the subject of discussion in this publication. Among the factors influencing the degree of preservation of the viability of biological material during cryopreservation are endocellular and exocellular cryoprotectants, which have different mechanisms of action on the cell and therefore contribute to different degrees of survival, the method of introducing the cryoprotectant — at room temperature and in the cold, which leads to a decrease in the negative impact of cryoprotectants substances on cell metabolism. The addition of cryoprotectants in the cold can be considered as a two-stage freezing, since the biological material is cooled to the crystallization temperature of water before cryopreservation.

## *Materials and Methods*

The object of the study was the seed material of *Dracocephalum ruyschiana* and *Salvia sclarea*. The studied species are valuable representatives of the Lamiaceae family, are included in the list of medicinal plants of Kazakhstan, are essential oil plants, and contain a large number of secondary metabolites with biological activity. They are widely used, for example, clary sage essential oil is used in medicine, cooking, winemaking, it has a pleasant aroma, and it is often used in the composition of expensive perfumes [10–14].

Seed material was frozen in plastic tubes in liquid nitrogen using the direct immersion method. Cryoprotectors were used in various concentrations, endocellular — glycerin and dimethyl sulfoxide (DMSO), exocellular — polyvinylpyrrolidone (PVP). Two methods of introducing cryoprotectants into the

freezing system were used: at room temperature and in the cold. For the second application method, the seed material was pre-cooled in an ice bath.

After cryopreservation, cryoprotectants were washed three times with distilled water, then placed in Petri dishes on two layers of filter paper to assess viability.

The viability of seed material was determined by germination and germination energy [15–17]. All experiments were performed in triplicate.

*Results and Discussion*

The initial growth characteristics of *Dracocephalum ruyschiana* seeds were determined; germination was 84.33±7.72 %, germination energy was 42.33±3.09 %. Dry seeds were frozen in liquid nitrogen without cryoprotectants, germination in this experiment was 67±11.22 %, germination energy was 12±4.24 %. Note that after cryopreservation the energy of germination of seed material decreased significantly. Damage to the embryo occurs, which slows down the process of exiting the dormant state. These initial data were used in the comparative analysis as Control 1 and Control 2.

We conducted an experiment in which seeds were frozen in different types of cryoprotectants: endocellular (glycerol and dimethyl sulfoxide) and exocellular (polyvinylpyrrolidone) in different concentrations. In this case, two methods of introducing the cryoprotector were used — at room temperature and in the cold (0 °C).

The results obtained are presented in Table 1. When considering the germination rate, we do not see significant differences in the effect of cryoprotectors of different types. And the germination energy indicator turned out to be more labile and informative. For clarity of the analysis, we calculated the proportion of surviving seeds and their germination energy from the initial indicators (control 1). These calculations are presented in the form of diagrams in Figure 1.

Analysis of the presented diagram shows that the seed material of *Dracocephalum ruyschiana* does not lose its viability after freezing; the germination rate from the original practically does not fall below 0.8. It is worth noting that the use of high concentrations of cryoprotectors, for example, 50 % glycerol and its cold introduction into the system even leads to a stratification effect and an increase in the number of sprouted seeds. The energy of germination in almost all variants of the experiment was greater than one, that is, after cryopreservation, the seed material sprouted more efficiently than the original seeds. We cannot see a definite trend in the effectiveness of adding cryoprotectants at 0 °C. However, we see the best options for preserving, even increasing the growth performance of *Dracocephalum ruyschiana* seed material in the variant of cold application of glycerol.

Table 1

**Growth parameters of *Dracocephalum ruyschiana* seed material after cryopreservation in various cryoprotectants**

| Cryoprotector (mass fraction in %) | Germination energy (%) | Germination (%) | Proportion of the initial germination energy | Proportion of initial germination | Share of the germination energy of frozen seeds without cryoprotectors | Share of the germination rate of frozen seeds without cryoprotectors |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Glycerol 50 | 43,33±12,47 | 70±8,16 | 1,02 | 0,83 | 3,6 | 1,04 |
| Glycerol 25 | 43,33±4,71 | 71,67±2,36 | 1,02 | 0,84 | 3,6 | 1,07 |
| Glycerol 12 | 53,33±9,43 | 73,33±17 | 1,25 | 0,86 | 4,4 | 1,09 |
| Glycerol 50 (cold application) | 76,67±12,47 | 93,33±4,71 | 1,81 | 1,1 | 6,3 | 1,39 |
| Glycerol 25 (cold application) | 56,67±12,47 | 83,33±9,43 | 1,33 | 0,98 | 4,7 | 1,24 |
| Glycerol 12 (cold application) | 60±8,15 | 70±0 | 1,41 | 0,83 | 5 | 1,04 |
| DMSO 15 | 70±16,33 | 70±16,33 | 1,65 | 0,83 | 5,8 | 1,04 |
| DMSO 10 | 60±24,49 | 73,33±12,47 | 1,41 | 0,87 | 5 | 1,09 |
| DMSO 5 | 60±14,4 | 80±0 | 1,41 | 0,95 | 5 | 1,19 |
| DMSO 15 (cold application) | 53,33±4,71 | 73,33±4,71 | 1,26 | 0,86 | 4,4 | 1,09 |

Continuation of Table 1

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| DMSO 10 (cold application) | 56,67±20,55 | 66,67±12,47 | 1,34 | 0,79 | 4,7 | 0,99 |
| DMSO 5 (cold application) | 60±8,16 | 73,33±9,43 | 1,42 | 0,87 | 5 | 1,09 |
| PVP 5 | 47,33±0,47 | 72,67±9,10 | 1,12 | 0,86 | 3,9 | 1,08 |
| PVP 3 | 35,67±6,8 | 65,33±2,49 | 0,84 | 0,77 | 2,9 | 0,98 |
| PVP 1 | 67,67±3,3 | 80,67±0,94 | 1,6 | 0,96 | 5,6 | 1,2 |
| PVP 5 (cold application) | 38,67±3,86 | 70,67±6,13 | 0,91 | 0,84 | 3,2 | 1,05 |
| PVP 3 (cold application) | 47,33±3,77 | 75±4,08 | 1,12 | 0,89 | 3,9 | 1,12 |
| PVP 1 (cold application) | 47,33±0,47 | 84,67±4,71 | 1,12 | 1,0 | 3,9 | 1,26 |
| Control 1 (initial indicators) | 42,33±3,09 | 84,33±7,72 | | | | |
| Control 2 (freezing without cryoprotectants) | 12±4,24 | 67±11,22 | 0,28 | 0,79 | | |

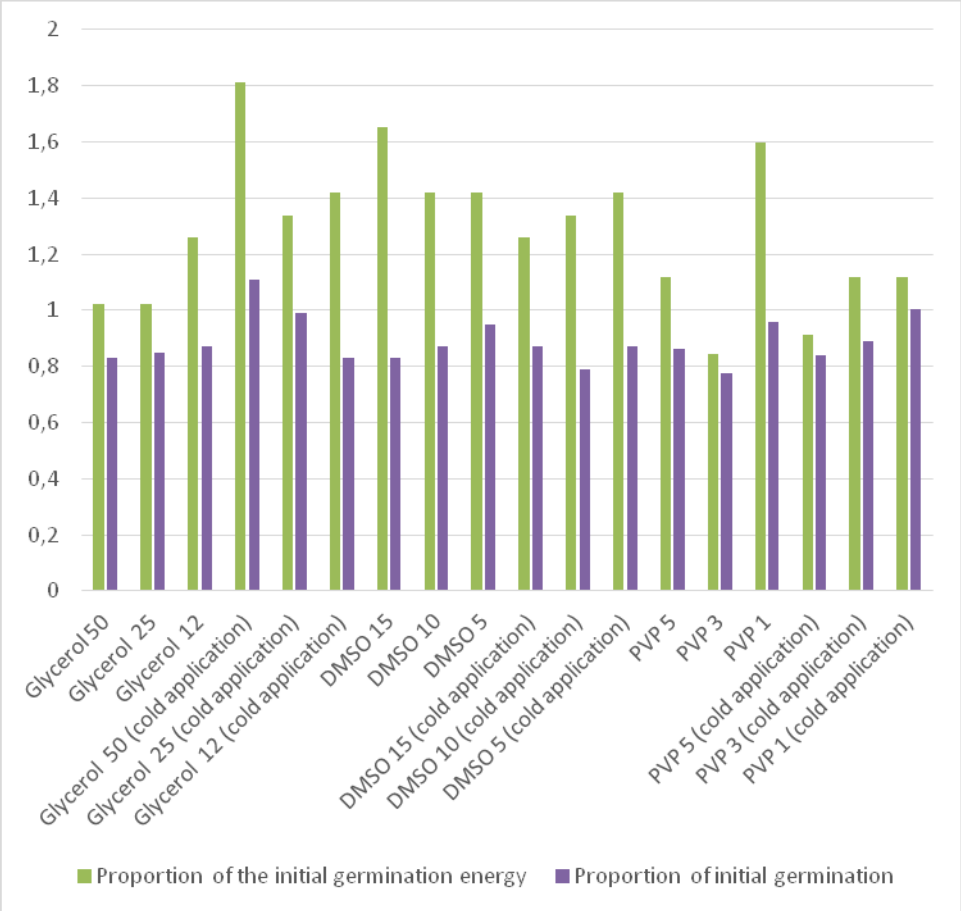


Figure 1. Proportion of growth characteristics of *Dracocephalum ruyschiana* seeds after cryopreservation from the initial indicators

To compare the effectiveness of using cryoprotectants compared to freezing biological material without using them, we calculated the proportion of surviving seeds compared to similar indicators for seeds frozen without cryoprotective solutions. The obtained data are presented in Figure 2.

We see that the germination rate has not changed significantly; in almost all variants of the experiment it is slightly more than one.

However, the germination energy increased several times, in some variants of the experiment by 5–6 times. Germination energy is an important factor that demonstrates the vigor of seedlings and the activation of the state of the entire biochemical arsenal of the embryo, its exit from the dormant state. High rates of germination energy demonstrate the good adaptive qualities of the seed material and its ability to withstand extreme environmental factors.

It is interesting to note that the maximum increase in germination energy was achieved with cold addition of glycerol. Probably, this method of administration reduces its pseudotoxic effect and its inhibition of biochemical processes. In experiments with DMSO and PVP, the maximum performance was achieved in the variants of adding cryoprotectants at room temperature, i.e. the reaction to the method of administration depends not only on the type of seed material, but also on the type of cryoprotector.

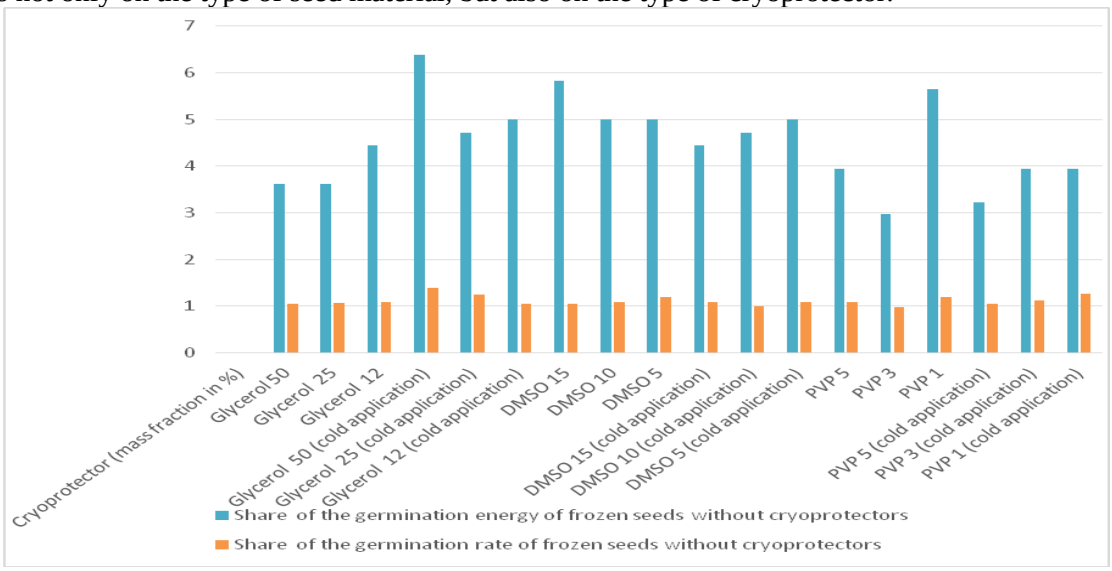


Figure 2. Ratio of growth characteristics of Dracocephalum ruyschiana seed material after freezing in liquid nitrogen to similar indicators of seeds frozen without cryoprotectants

Based on the analysis of the data obtained, we can conclude that the use of cryoprotectants for cryopreservation of *Dracocephalum ruyschiana* seed material is justified, while the method of applying the cryoprotectant is not particularly important.

At the next stage, a similar experiment was conducted to study the influence of various cryoprotectors and methods of their introduction on the preservation of the viability of *Salvia sclarea* seed material during cryopreservation. The obtained data are presented in Table 2. The initial growth characteristics of *Salvia sclarea* seeds were determined, germination was 83.33±17 %, germination energy was 16.67±4.71 %. Dry seeds were frozen in liquid nitrogen without cryoprotectants, germination in this experiment was 73.67±3.4 %, germination energy was 6.67±4.71 %. It can be seen that when frozen in liquid nitrogen, seeds lose 10 % in terms of germination and germination energy, which can be assessed as a slight decrease. However, if we look at it in absolute numbers, then the germination energy of 7 % means very slowly and unharmonious germinating seeds.

Table 2

**Growth parameters of Salvia sclarea seed material after cryopreservation in various cryoprotectants**

| Cryoprotector (mass fraction in %) | Germination energy (%) | Germination (%) | Proportion of the initial germination energy | Proportion of initial germination | Share of the germination energy of frozen seeds without cryoprotectors | Share of the germination rate of frozen seeds without cryoprotectors |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Glycerol 50 | 16,67±4,71 | 46,67±12,47 | 1,02 | 0,83 | 3,61 | 1,04 |
| Glycerol 25 | 9,83±11,11 | 25,5±11,4 | 1,02 | 0,84 | 3,61 | 1,06 |
| Glycerol 12 | 13,33±4,71 | 73,33±7,45 | 1,25 | 0,86 | 4,44 | 1,09 |
| Glycerol 50 (cold application) | 0 | 43,33±20,55 | 1,33 | 0,98 | 4,72 | 1,24 |
| Glycerol 25 (cold application) | 31±0,82 | 65,67±4,92 | 1,33 | 0,98 | 4,7 | 1,24 |
| Glycerol 12 (cold application) | 10±8,16 | 56,67±4,71 | 1,47 | 0,83 | 5 | 1,04 |

Continuation of Table 2

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| DMSO 15 | 10±0 | 46,67±12,47 | 1,65 | 0,83 | 5,89 | 1,04 |
| DMSO 10 | 13,33±4,71 | 40±0 | 1,41 | 0,86 | 5 | 1,09 |
| DMSO 5 | 10±0 | 43,33±4,71 | 1,42 | 0,94 | 5 | 1,19 |
| DMSO 15 (cold application) | 20±0 | 36,67±4,71 | 1,25 | 0,87 | 4,44 | 1,09 |
| DMSO 10 (cold application) | 33,33±9,43 | 63,33±4,71 | 1,34 | 0,79 | 4,72 | 0,99 |
| DMSO 5 (cold application) | 6,67±0,93 | 56,67±17 | 1,42 | 0,86 | 5 | 1,09 |
| PVP 5 | 12,33±5,56 | 25,67±13,82 | 1,11 | 0,86 | 3,94 | 1,08 |
| PVP 3 | 9,33±0,94 | 34,33±4,19 | 0,84 | 0,77 | 2,97 | 0,97 |
| PVP 1 | 29,33±8,99 | 45±4,08 | 1,59 | 0,95 | 5,64 | 1,2 |
| PVP 5 (cold application) | 0 | 44±17,48 | 0,91 | 0,83 | 3,22 | 1,05 |
| PVP 3 (cold application) | 33,33±12,47 | 64,33±24,3 | 1,11 | 0,89 | 3,94 | 1,11 |
| PVP 1 (cold application) | 22±2,16 | 49±5,89 | 1,11 | 1,01 | 3,94 | 1,26 |
| Control 1 (initial indicators) | 16,67±4,71 | 83,33±17 | | | | |
| Control 2 (freezing without cryoprotectants) | 6,67±4,71 | 73,67±3,4 | | | | |

Analysis of the growth performance of Salvia sclarea seed material after cryopreservation showed that exposure to extreme temperatures leads to a decrease in germination rate (Fig. 3). In all variants of the experiment, we observe the value of the indicator under consideration at a level less than one. This indicates that low temperatures lead to, albeit minor, damage to the seed embryo in the species Salvia sclarea.

However, when considering the share of germination energy from a similar indicator in intact seeds, we see in some variants of the experiment an increase in this characteristic in seeds subjected to cryopreservation by almost 2 times: when using glycerol 12 %, DMSO 10 % and PVP 3 % introduced into the system in the cold.

This indicates the activation of metabolic processes in the tissues of the seed embryo and the stratification effect, which lead to more uniform seed germination.

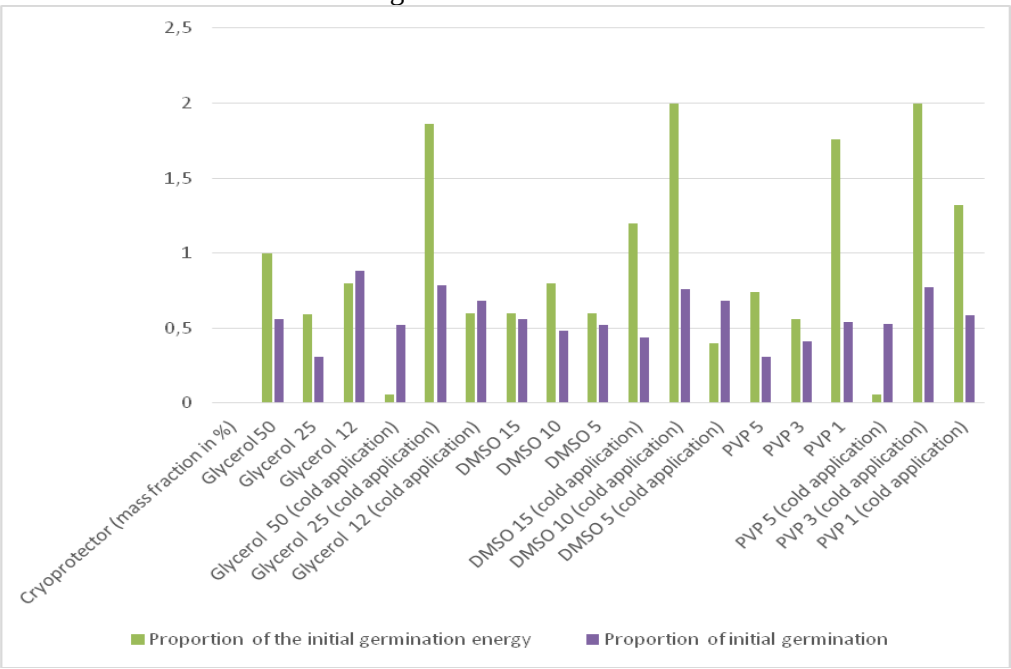


Figure 3. Proportion of growth characteristics frozen in liquid nitrogen Salvia sclarea seeds from the original

When comparing the obtained data with the indicators of germination and germination energy of *Salvia sclarea* seed material, which was frozen without the use of cryoprotectants, we see that the germination indicators did not change or became less than one (Fig. 4).

That is, the use of cryoprotectors does not lead to better preservation of seeds when frozen in liquid nitrogen.

But if we turn to the germination energy indicator, we see that the use of cryoprotectants contributes to more friendly seed germination; the germination energy exceeds that of seeds frozen without cryoprotectors several times, in some experimental variants — 5 times — when using 12 % glycerol, DMSO 10 % and PVP 3 % with the addition of cryoprotective substances in the cold.

Thus, we believe that the use of cryoprotectants and their cold application is justified during cryopreservation of *Salvia sclarea* seed material.

## *Conclusion*

Application of cryoprotectants in the cold is often more effective due to several factors. This is a slowdown in cell metabolism, a decrease in the toxicity of the cryoprotector, and a decrease in osmotic stress caused by cryoprotectants [18]. In addition, at low physiological temperatures, membranes are stabilized, which reduces the penetration of the cryoprotector into the cell and additionally protects against the toxic effects of these substances.

The study determined that seed material of different species, even within the same family, reacts differently to extremely low temperatures, the type and concentration of the cryoprotectant, and the method of its introduction into the cooling system.

We recommend freezing the seed material of *Dracocephalum ruyschiana* using cryoprotectants, and the type and concentration do not seriously matter; the growth performance of the seeds will be higher than in the case of freezing without cryoprotectants. When cryopreserving *Salvia sclarea* seeds, we recommend using low concentrations of cryoprotectants and introducing it into the cooling system at the crystallization temperature of water.

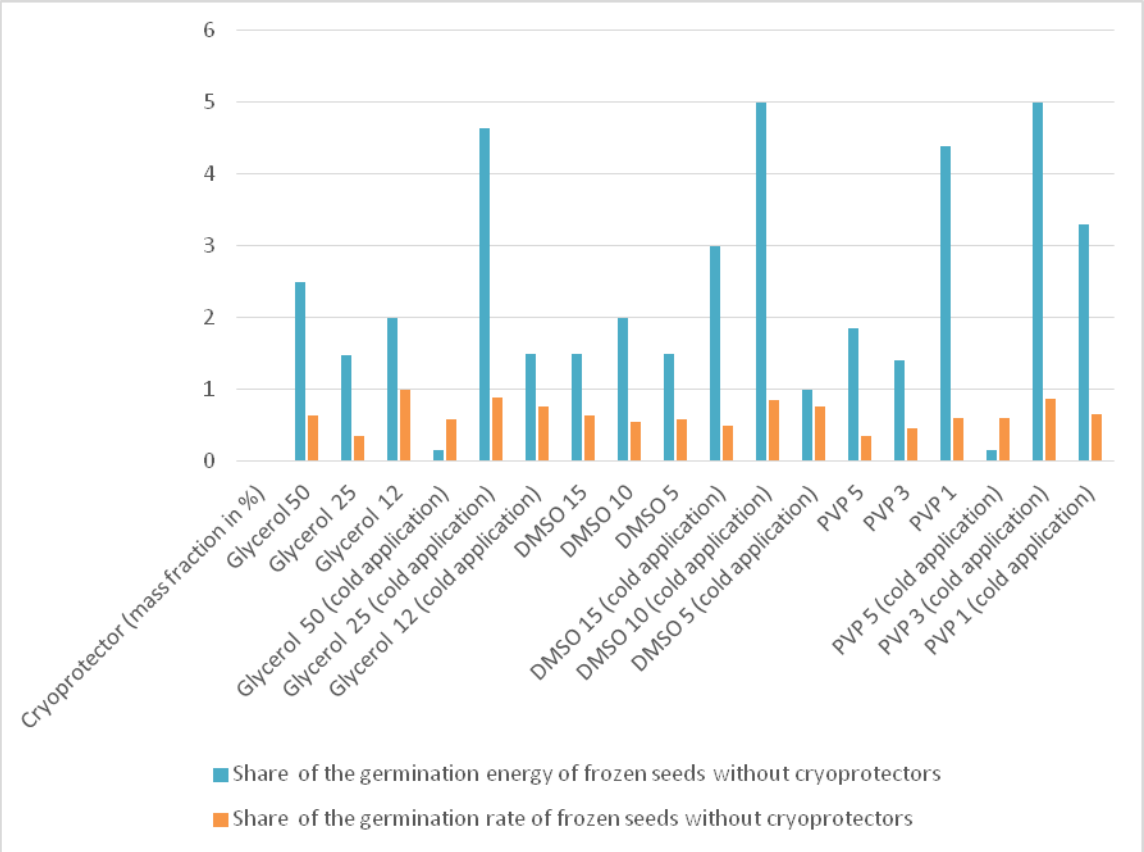


Figure 4. Ratio of growth parameters of Salvia sclarea seeds after cryopreservation with the use of cryoprotectants to those after freezing without cryoprotectors

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## *Dracocephalum ruyschiana* L. және *Salvia sclarea* тұқымдық материалдарын криоконсервациялау тиімділігін бағалау

Бағалы өсімдіктердің өсімдік шикізатын криоконсервациялау табиғи экожүйелерге белсенді және кең таралған антропогендік қысым жағдайында биологиялық әртүрлілікті сақтаудың тиімді әдісі болып табылады. Криоколлекцияларға кіріспе азық-түлік ауылшаруашылық өсімдіктеріне ғана емес, сонымен қатар бағалы екіншілік метаболиттері мен эфир майлары бар дәрілік өсімдіктерге де негізделген. Оларға *Dracocephalum ruyschian* және *Salvia sclarea* жатады. Сұйық азотта мұздатылғаннан кейін тұқымның өміршеңдігін тиімді қалпына келтіру үшін әртүрлі криопротекторлардың әсері зерттелген: яғни, глицерин, диметилсульфоксид және поливинипирролидон, сондай-ақ оларды қолданудың әртүрлі әдістері — бөлме температурасында және суықта. *Dracocephalum ruyschiana* тұқымдық материалды тиімді криопросервациялау үшін криопротекторларды қолдану негізделген, алайда оларды қолдану әдісі маңызды емес. *Salvia sclarea* тұқымдық материалды криоконсервациялау кезінде криопротекторларды қолдану және оларды салқындату жүйесіне енгізу маңызды, бұл жағдайда тұқымның өну энергиясы айтарлықтай артады.

*Кілт сөздер*: *Dracocephalum ruyschiana, Salvia sclarea*, криопротекторлар, криоконсервация, тұқым материалы, өну, өну энергиясы.

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# Оценка эффективности криоконсервации семенного материала *Dracocephalum ruyschiana* L. и *Salvia sclarea*

Криоконсервация растительного материала ценных растений — эффективный способ сохранения биологического разнообразия в условиях активного и повсеместного антропогенного давления на природные экосистемы. Введение в криоколлекции оправдано не только для пищевых сельскохозяйственных растений, но и лекарственных, обладающих ценными вторичными метаболитами и эфирными маслами. К таковым можно отнести *Dracocephalum ruyschian* и *Salvia sclarea*. Для эффективного восстановления показателей жизнеспособности семян после замораживания в жидком азоте рассмотрели влияние различных криопротекторов: глицерина, диметилсульфоксида и поливинипирролидона, а также различные способы их внесения — при комнатной температуре и на холоде. Обнаружено, что для эффективного криосохранения семенного материала *Dracocephalum ruyschiana* применение криопротетокров оправдано, однако способ их внесения не имеет значения. При криоконсервации семенного материала *Salvia sclarea* важно использовать криопротекторы и вводить их в систему охлаждения лучше при температуре кристаллизации воды, в этом случае значительно вырастает энергия прорастания семян.

*Ключевые слова: Dracocephalum ruyschiana, Salvia sclarea,* криопротекторы, криоконсервация, семенной материал, всхожесть, энергия прорастания.

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# The morphological features of above-ground parts of *Juniperus sabina* in Central Kazakhstan

In the article the results of the study of morphological parameters of vegetative organs of *Juniperus sabina* growing in the vicinity of Karaganda city, Karkaraly and Ulytau Mountains, hills of Zhanaarka district were presented. The results of research are based on complexly conducted field and experimental materials, scientifically substantiated methods and modern statistical analyses evaluating the reliability criterion. It is noted that for the leaf length indicator the maximum values were for individuals from Zhanaarka district, the minimum values were for the vicinity of Karaganda city. For leaf width and annual growth value, no reliable difference was observed between individuals from different growing points. The maximum size of plants was observed in the vicinity of Karaganda city, the minimum size was observed for individuals from Zhanaarka and Ulytau districts. The obtained data are conditioned by different degree of environmental pollution and climatic conditions.

*Keywords*: *Juniperus sabina*, morphology, plant height and diameter, leaf length and width, annual growth size.

## *Introduction*

Cossack juniper (*Juniperus sabina* L., family Cupressaceae) is a coniferous shrub, a dioecious creeping shrub 1–1.5 meters high. Bushes grow rapidly in width, forming dense thickets. The bark is red-brown, flaky. The shoots contain essential oil and are poisonous [1]. The needles are of two types: in young plants and on shady branches, needle-shaped, straight, pointed, 4–6 mm long, bluish-green above, soft, with a pronounced middle root; in adult plants, the needles are scaly, lamellar. A characteristic feature of the species is a pungent odor. It is drought-resistant, phytophilous, unpretentious to soils, resistant to smoke and gas, has protective properties in relation to soils. Shoots are rich in glycosides, saponins and flavonoids [2].

In Central Kazakhstan, the species grows on hillsides, stony screes, on granite outcrops, under the canopy of coniferous forests [3]. On the surface of the soil layer, the roots grow rapidly in horizontal conditions (Fig. 1).

Figure 1. *Juniperus sabina* in natural conditions of Central Kazakhstan

*J. sabina* is used in the traditional Chinese medicine system to prevent or treat various diseases as anticholinesterase, antidiabete, and anti-drug resistant bacteria activity [4]. In particular, J. sabina is rich in podophyllotoxin, a synthetic precursor of the first-line anticancer drug etoposide [5]. Aqueous suspension of dried needles of *J. sabina* causes hemorrhagic and necrotic changes in malignant tumors and also has signifi-

cant antimicrobial activity against Gram-positive bacteria [6]. The leaves of *J. Sabina* are used in traditional Uygur medicine for the treatment of rheumatism and arthritic pain [7].

*J. sabina*, despite its wide distribution in the forests of Kazakhstan, remains one of the least studied conifers. Detailed studies on the study of form diversity, biometric and morphometric variability of the Cossack juniper, the features of their renewal in the Karaganda region were not carried out. Therefore, it is necessary to consider the issue of factors leading to changes in the environmental conditions of its growth over the past decades. *J. sabina* has a healing effect in the forest environment, produces more phytoncides than other conifers, forms the microclimate of the surface layer of the atmosphere and promotes the natural renewal of coniferous woody plants [8].

The purpose of this study is to study the features of the morphological structure of the vegetative organs of *J. sabina*, growing in the territory of Karaganda (surrounding of Karaganda city, Karkaraly and Zhanaarkinsky district) and Ulytau (Ulytau district) regions. All selected areas have different levels of pollution. So, Karaganda is an industrial city, and Ulutau and Karkaraly Mountains are an environmentally friendly area.

## *Materials and Methods*

The object of the study is samples of *J. sabina* growing in the Karaganda and Ulytau regions. They differ from each other in the level of air pollution. In field research, samples of *J. sabina* were collected from four research plots: i) surrounding of Karaganda city, ii) Zhanaarkinsky district, iii) Karkaraly Mountains, iv) Ulytau Mountains (Fig. 2).

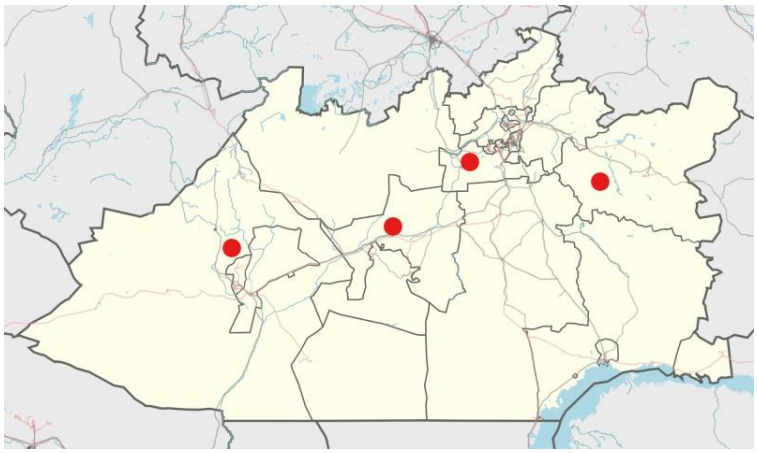

Figure 2. Map of sampling point for *Juniperus sabina* in Karaganda and Ulytau regions

At least five objects were obtained from each study area. For each point, 10-fold measurements of 10-year-old plants were taken. In the course of the research work, a comparative morphological study of *J. sabina* was carried out for the following indicators: shrub width and height; the length of the annual shoots and needles. All data were processed statistically, and the reliability criterion was calculated according to Mann-Whitney. Statistical processing of the material was carried out according to the generally accepted method of G.N. Zaitsev [9], as well as using the computer program Microsoft Office Excel.

## *Results and Discussion*

Some researchers [2] pay considerable attention to the flexibility of the morphological features of the Cossack juniper. This is due to the fact that the juniper stalk is one of the most sensitive organs, it instantly reacts to any environmental conditions. The study of its variability makes it possible to understand the direction of the forthcoming micro-evolution.

In most cases, the level of variational characters plays an important role in solving taxonomic problems. When describing the juniper family, such features as the length, width and shape of the needles are necessarily used. Needle length is one of the most variable traits. It usually continues to change regardless of the place of growth, regions. The needles are scaly, 0.7–1.5 cm long, 0.5–1.7 mm wide. According to the research, the following data were obtained: the length of coniferous specimens collected from the Zhanaarka region ranged from 4.9 mm to 5.01 mm (Fig. 3–6). Of the studied objects, the shortest conifers are found in the city

of Karaganda. However, the populations in this region are ahead of other regions in their distribution in width of needles.

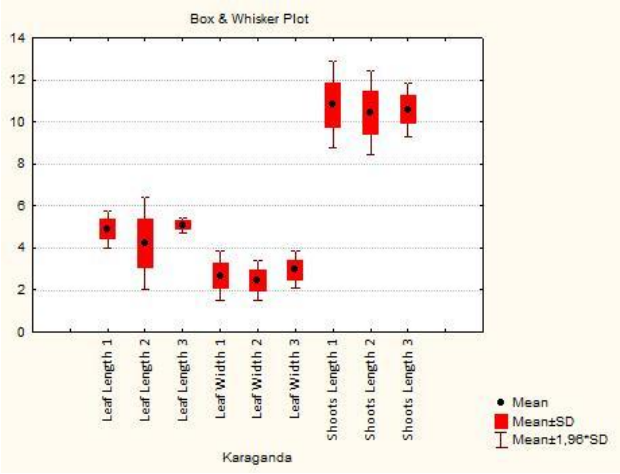


Figure 3. Morphological parameters of *Juniperus sabina* in surrounding of Karaganda city

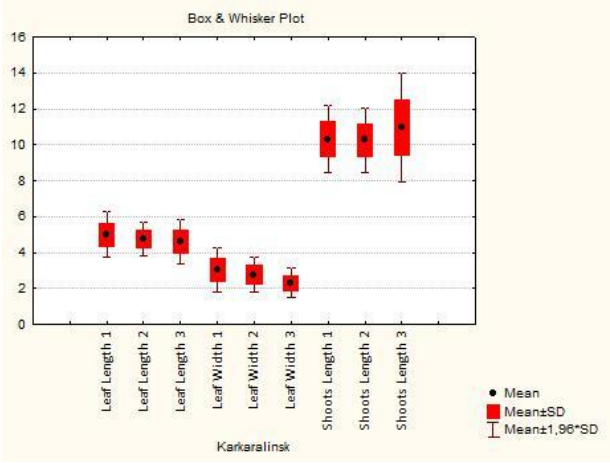


Figure 4. Morphological parameters of *Juniperus sabina* in Karkaraly Mountains

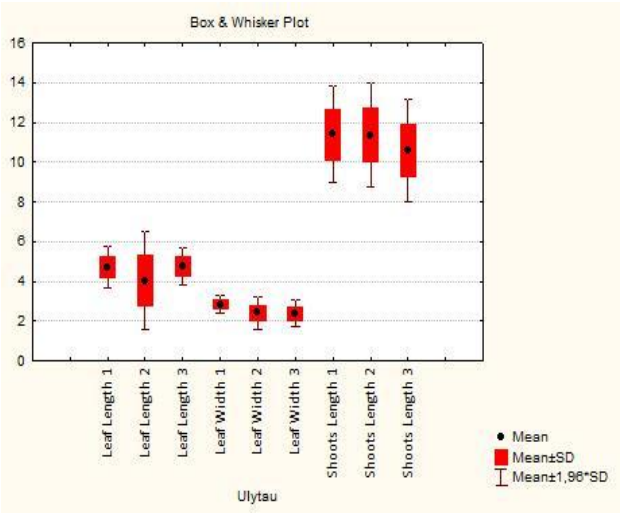


Figure 5. Morphological parameters of *Juniperus sabina* in Ulytau Mountains

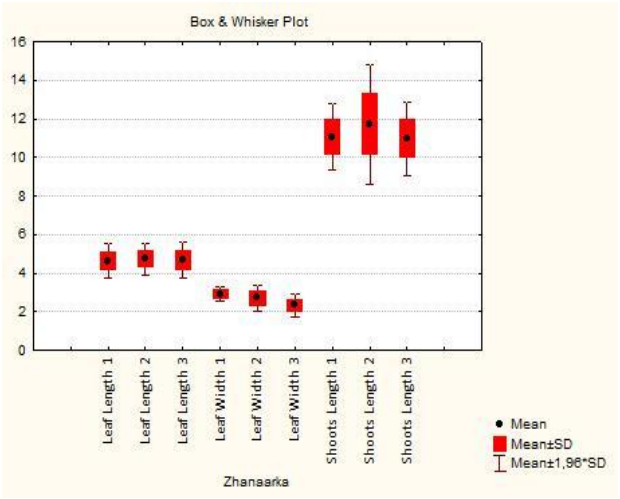


Figure 6. Morphological parameters of *Juniperus sabina* in Zhanaarka district

In the Ulytau Mountains, needle length varied from 4.56 to 4.79 mm, leaf width — from 0.9 to 0.98 mm, shoot growth ranged from 11.02 to 12.55 cm. In the vicinity of Karaganda city, the minimum sizes of leaf length and width were noted: 4.09–4.42 mm and 0.89–0.95 mm, respectively. The shoots growth ranged from 9.74 to 12.61 cm.

Comparison of indices allowed distinguishing that the greatest length of juniper leaf was noted for individuals from Zhanaarka district, on the second place — individuals from Karkaraly Mountains, on the third place — from Ulytau Mountains. The minimum values of this trait were recorded for the vicinity of Karaganda city.

The leaf width index showed no significant differences between individuals growing in different habitats. Maximum values of annual growth were observed for individuals from the Ulytau Mountains; no reliable differences in annual growth were found between the other habitats.

However, the maximum metric sizes of juniper individuals were observed in the vicinity of the Karkaraly Mountains (Fig. 7), and the minimum ones — in the Zhanaarka district. In terms of plant height, no reliable differences were found in the height of individuals, and in terms of the diameter of individuals, plants from the Ulytau Mountains were reliably smaller than individuals from the Karkaraly Mountains.

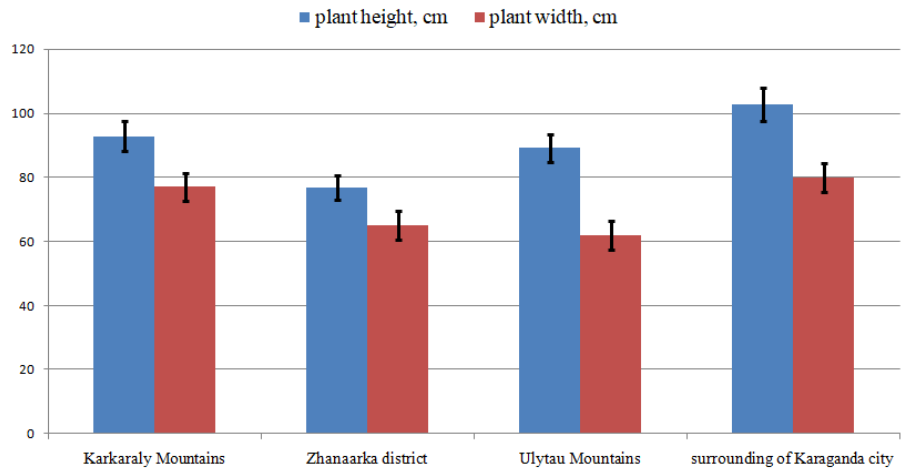


Figure 7. Indices of *Juniperus sabina* shrubs length and width at different growing points

## *Conclusion*

Since *J. sabina* is influenced by the general anthropogenic factor, but the level of phenotypic variability of morphological traits as an indicator of intraspecific differentiation, one can see that the signs of the vegetative organs of objects collected from Karaganda are significantly less compared to species growing in forests. It should be noted that common juniper is more resistant to technogenic impact than other plant representatives. Also, the results of the work are based on comprehensively conducted field and experimental materials, scientifically based methods and modern statistical analyzes that evaluate the reliability criterion.

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## Орталық Қазақстандағы *Juniperus sabina* жерүсті бөліктерінің морфологиялық ерекшеліктері

Мақалада Қарағанды қаласының маңында, Қаркаралы және Ұлытау тауларында, Жаңаарқа ауданының шоқыларында өсетін *Juniperus sabina* вегетативтік органдарының морфологиялық параметрлерін зерттеу нәтижелері келтірілген. Зерттеу нәтижелері кешенді жүргізілген далалық және эксперименттік материалдарға, ғылыми негізделген әдістемелерге және сенімділік критерийін бағалайтын заманауи статистикалық талдауларға негізделген. «Жапырақ ұзындығы» көрсеткіші бойынша ең жоғары мәндер Жаңаарқа ауданының дарақтары үшін, ең аз мәндер — Қарағанды қаласының маңы үшін болғандығы атап өтілді. «Жапырақ ені» және «жылдық өсу мөлшері» көрсеткіштері бойынша әр түрлі өсу нүктелеріндегі дарақтар арасында сенімді айырмашылық байқалмайды. Өсімдіктердің ең үлкен мөлшері Қарағанды қаласының маңы үшін, ең аз мөлшері — Жаңаарқа және Ұлытау аудандарының дарақтары үшін белгіленді. Алынған мәліметтер қоршаған ортаның ластануының әртүрлі дәрежесіне және климаттық жағдайларға байланысты.

*Кілт сөздер*: *Juniperus sabina*, морфология, өсімдіктің биіктігі мен диаметрі, жапырақтың ұзындығы мен ені, жылдық өсу мөлшері.

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## Морфологические особенности надземных частей *Juniperus sabina* в Центральном Казахстане

В статье представлены результаты исследования морфологических параметров вегетативных органов *Juniperus sabina*, произрастающих в окрестностях города Караганды, горах Каркаралы и Улытау, сопках Жанааркинского района. Результаты исследований базируются на комплексно проведенных полевых и экспериментальных материалах, научно обоснованных методиках и современных статистических анализах, оценивающих критерий надежности. Отмечено, что по показателю «длина листа» максимальные значения были для особей из Жанааркинского района, минимальные — для окрестностей города Караганды. По показателям «ширина листа» и «величина годичного прироста» не отмечено достоверной разницы между особями из разных точек произрастания. Максимальные размеры растений отмечены для окрестностей города Караганды, минимальные — особей из Жанааркинского и Улытауского районов. Полученные данные обусловлены разной степенью загрязнения окружающей среды и климатическими условиями.

*Ключевые слова*: *Juniperus sabina*, морфология, высота и диаметр растения, длина и ширина листа, величина годичного прироста.

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## The influence of melatonin on the functional state of the human body during desynchronosis

In the article the mechanisms of melatonin action in the human body, exploring its impact on circadian rhythms, sleep, the immune system, and overall physiological function were considered. A focal point is the use of melatonin as a pharmacological tool to address dyssynchrony, particularly in students facing new time zones or geographic latitude changes. The study aims to understand melatonin's potential influence on regulating biological rhythms and the general physiological state in such scenarios. It scrutinizes how melatonin affects circadian rhythms, sleep, activity, and overall physiological balance during disruptions in biorhythmic synchronization. Recent studies were analyzed, revealing promising prospects for melatonin in regulating desynchronization and maintaining human health amid altered biological rhythms. Findings indicated that students in the experimental group, who took melatonin, experienced enhanced academic performance, increased work capacity, and improved mood. That underscored melatonin's positive impact on the functional state of the human body, even in the presence of desynchronosis. A study involving 100 students identified changes in circadian rhythms contributing to seasonal depression, with daily melatonin tablets proving effective in alleviating desynchronization symptoms. The article furnishes vital scientific data and practical recommendations, catering to professionals in biomedicine, biology, and pharmacology, as well as individuals keen on understanding human health and biological rhythms.

*Keywords:* desynchronosis, melatonin, biorhythm, chronotype, dyssomnia.

### *Introduction*

The development of desynchrony in the lives of modern individuals is influenced by both exogenous and endogenous factors. Mostly, desynchrony arises from the use of artificial light sources during the dark phase of the circadian rhythm, leading to the emergence of circadian disruptions and alterations in physiological processes [1, 2].

The functioning of the immune system is closely intertwined with the regulation of homeostasis by various neuroendocrine systems. Therefore, changes in ethological status and immune status in desynchrony can mutually reinforce or weaken allostatic adjustments [3–5]. Many studies on desynchrony focus on nocturnal animals, such as rodents, birds, and hamsters, which differ from humans in their response to light [6].

Desynchrony significantly affects the homeostatic adaptation mechanisms, primarily through the reduction of melatonin production. Melatonin influences the sleep-wake cycle, immune processes, aging, blood circulation, mental state, and thermoregulation [7, 8]. Melatonin receptors, found in various tissues, including neurons in the suprachiasmatic nucleus, and immune-competent cells, demonstrate its direct neurotropic and immunotropic effects [9]. Additionally, melatonin may exert autocrine or paracrine effects.

Melatonin production in the pineal gland follows a circadian rhythm, influenced by the alternation of light and darkness. The synthesis of melatonin begins with the hydroxylation of L-tryptophan to 5-hydroxytryptophan, which is then converted to serotonin before finally forming melatonin [10–13]. The regulation of melatonin synthesis involves the release of norepinephrine during the night, which stimulates adrenergic receptors in the pineal gland, leading to increased melatonin secretion [14]. The metabolism of melatonin in the saliva occurs through three main pathways: classical, alternative, and the kynurenine pathway.

Melatonin acts through two main types of receptors, named MT1 and MT2, also referred to as Mel1a and Mel1b. MT1 receptors are expressed in various tissues, including immune cells, blood vessels, aorta, heart, immune system, adrenal glands, skin, sweat glands, kidneys, renal pelvis, placenta, breast milk, pineal gland, and brain areas such as the hypothalamus, amygdala, hippocampus, and substantia nigra. MT2 receptors are mainly found in the hypothalamus, suprachiasmatic nucleus, eye retina, pituitary gland, blood vessels, adrenal glands, gastrointestinal tract, sweat glands, skin, and immune-competent cells [15].

## *Materials and Methods*

1st-year foreign students aged 19–24 years from the Faculty of Medicine at the International Business University (IBU), registered with the state utility enterprise “City Student Clinic” in Almaty, were selected as the subjects of the research. The total number of volunteers was 100 students, comprising 75 men and 25 women.

In the research, students were divided into three groups depending on the level of health. According to health level I, 23 students had slight changes in the temporal structure of their physiological states. According to health level II, 32 students had physiological desynchronosis. According to health level III, 55 students experienced severe changes in the physiological state of the body in the temporal structures, and this group itself was further divided into two subgroups (group III A and subgroup III B). Additionally, with the permission of the ethical committee, various doses of antioxidants were used in the state utility enterprise with the right of economic management of the “City Student Clinic” to normalize group III suffering from pathological desynchronosis.

The study employed the following methods:

1. Chronobiological Assessment: First of all, students were briefed about the chronobiological assessment and instructed to comply with certain guidelines to ensure accurate measurements. They were advised to avoid strenuous physical activity, caffeine consumption, and alcohol intake during the assessment period. Each student participated in the measurement sessions conducted over three consecutive days. At predetermined time points (7:00, 10:00, 13:00, 16:00, 19:00, 22:00, 1:00), students were brought to the assessment area where trained personnel measured their systolic and diastolic pressure, as well as pulse rate.

Calibrated instruments were used to obtain accurate readings of cardiovascular parameters. Measurements were taken in a controlled environment to minimize external influences on the results.

Data collected from each student's measurements were meticulously recorded, including the time of measurement and corresponding cardiovascular parameters. This information served as the basis for subsequent analysis using the “Rhythm” computer program.

2. Chronotype Assessment: Questionnaire Administration: The Ostberg and Horn questionnaire was distributed to each student along with clear instructions on how to complete it. Students were encouraged to respond honestly and accurately to the questions based on their personal preferences and habits regarding sleep and daily activities. Students completed the questionnaire individually in a quiet and private setting to ensure confidentiality and minimize external distractions.

Assessment of patients' chronotype by O. Ostberg and D. Horn questionnaire. The Ostberg questionnaire consists of 19 questions. The questions were mainly based on the preferences of the person who participated in the survey (which time to choose for waking up, going to bed, doing physical activity, etc.). After filling out the questionnaire, it is analyzed and the chronotype of the subject is determined based on the sum of the points. According to the results of the survey, the subjects are divided into five chronotypes: clearly indicated morning, weakly indicated morning, indifferent (individual) type, weakly indicated evening, clearly indicated evening chronotype is determined. Upon completion, researchers analyzed the responses to determine each student's chronotype. This involved summing the points assigned to each question according to the questionnaire's scoring system.

3. “WAM” (well-being, activity, mood) questionnaire. Each student received the “WAM” questionnaire along with instructions for completion. They were asked to evaluate their well-being, activity levels, and mood based on the provided pairs of opposite characteristics.

The questionnaire consists of 30 pairs of opposite characteristics, according to which the subject is asked to evaluate his situation. Each pair represents a scale in which the subject notes the degree to which one or another description of his situation is relevant. Subjects are asked to associate their condition with a number of symptoms on a multi-point scale. The scale consists of indices (3 2 1 0 1 2 3). Students rated each pair of characteristics on a multi-point scale ranging from -3 to +3, indicating the degree to which each description reflected their current situation. Students completed the questionnaire independently, ensuring that their responses accurately reflected their subjective experiences. Responses from all students were compiled and analyzed to identify patterns and trends in well-being, activity levels, and mood among the study participants.

*Results and Discussion*

The possibility of melatonin correction for pathological desynchronosis developing in students studying in the Republic of Kazakhstan from abroad during educational activities was investigated.

Using the Ostberg questionnaire, five different chronotypes were identified in the study participants. Differences were found between groups with clearly expressed morning chronotype (12.7 %), weakly expressed morning chronotype (16.9 %), indifferent chronotype (43.4 %), weakly expressed evening chronotype (11.4 %), and clearly expressed evening chronotype (15.5 %) (Fig. 1).

By determining the chronotype, the diurnal typology of foreign students, or individual differences in activity and alertness in the morning and evening, was established. Knowing their chronotypes helps them understand how their internal body clock works during their learning process, adapting to a new place, and how to synchronize it with their daily activities and tasks to make the most of their time. Identifying and understanding how your chronotype affects your sleep and wake times can help you to improve your productivity, gain insight into your health, and learn new ways to improve your sleep quality.

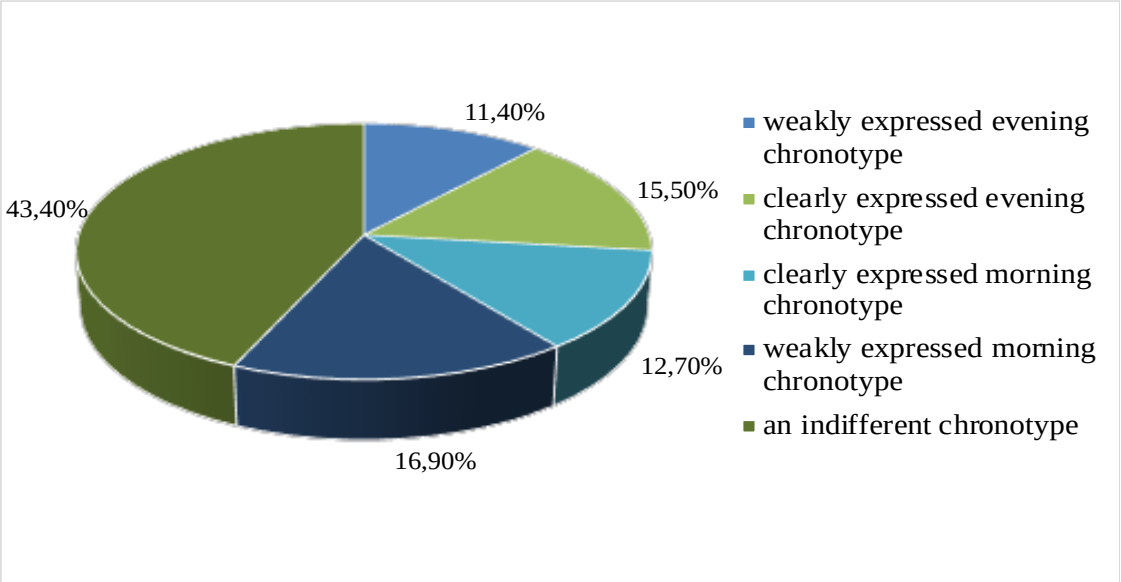


Figure 1. Classification of foreign students by chronotype

Based on the results of autorhythmometry, students of the Faculty of Medicine were divided into 3 groups depending on their health status. The first group included 23 people with a consistent intertemporal structure of physiological functions: most rhythms (65–75 %) are reliable, among them (60–70 %) circadian frequencies prevail; the rhythms of conjugate systems are in phase, mesors, amplitude and characteristics of acrophases are within normal oscillation limits, acrophases correspond to the chronotype of the subjects, and it was determined that their movement zone along the time axis is within 2–4 hours. The results of the analysis in this group show a successful adaptation (health level I). The second group included 32 people with physiological desynchronosis. A decrease in the share of reliable rhythms by up to 50 %, mainly due to a decrease in circadian frequencies, an increase in the share of ultradian rhythms by 5–10 %, a violation of synphasic rhythms, depending on the organism, an increase in the amplitudes and areas of the cyclic acrophases of rhythms from 4 to 6 hours is shown. It was determined that the described rhythm shifts allow

to maintain adaptation and rhythm mesors within normal limits (II level of health). The third group included 55 people with obvious disturbances in the intertemporal organization of physiological functions, in which the share of unreliable rhythms was high (>50 %), the share of daily frequencies in the spectrum of reliable rhythms decreased. 38.5 %, the share of ultradian rhythms increased to 45.2 %, amplitudes of rhythms decreased, acrophases of rhythms did not correspond to the chronotype of the subjects, their walking area. Students complain of decreased work capacity, decreased memory, attention, sleep disorders, decreased appetite, increased fatigue, and headaches. These symptoms indicate unsatisfactory adaptation, excessive stress of adaptation mechanisms, and preclinical health disorders were assessed as a state of pathological desynchronization (health level III).

In the group of students with pathological desynchronosis, 30 % of students had a well-defined evening chronotype, 27.4 % had a clear morning chronotype, and 12.3 % had a weak morning chronotype, 24.1 % were indifferent, and 6.2 % had a weakly defined evening chronotype (Fig. 2). A high percentage of pathological desynchronosis in medical students with an evening chronotype may be associated with the early start of classes and mental loads during the first half of the day, that is, they showed a low level of work ability.

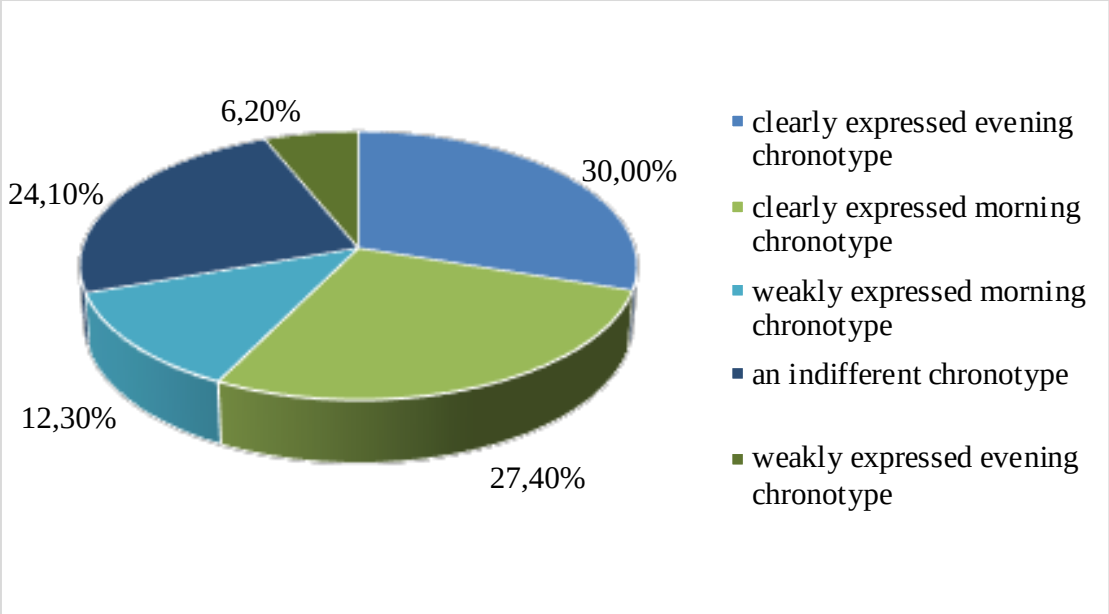


Figure 2. Classification of students with pathological desynchronosis by chronotype

As mentioned above, we classified the experimental group with pathological desynchronosis into two subgroups (group III A, subgroup III B) according to the degree of desynchronosis. Students with obvious disturbances in the architecture of biological rhythms in subgroup III A — 24 students received 0.75 mg of melatonin for 10 days, 30 minutes to 1 hour before bedtime. Students with complaints of obvious disturbances of indicators of biological rhythms in group III B, experiencing dyssomnia, increased fatigue, reduced work capacity, headache, loss of appetite — 31 students, took 3 mg of melatonin for 10 days, 30 minutes to 1 hour before bedtime. After the chronocorrection course, medical students with pathological desynchronosis were examined again.

After chronocorrection of 0.75 mg of melatonin in students with pathological desynchronosis, in the group analysis of the general spectrum of biological rhythms of physiological functions, due to the increase in circadian frequency, the proportion of reliable rhythms increased by 57 % (1.4 times), and by 55.5 % (1.4 times), the share of ultradian rhythms decreased to 26 % (1.7 times).

In the group of students receiving 3 mg melatonin, the percentage of reliable rhythms increased to 57 % (1.4 times), the percentage of diurnal frequency in the spectrum of reliable rhythms increased to 55 % (1.3 times), the percentage of ultradian rhythms decreased to 28.5 % (1.6 times) (Table 1). It is known in scientific literature reviews that melatonin interacts with receptors localized in the suprachiasmatic nuclei of the hypothalamus, synchronizes free-flowing circadian rhythms, corrects endogenous rhythms in relation to exogenous rhythms of the environment, thus increasing the body's adaptation capabilities.

Table 1

**Biorhythm spectrum of physiological functions in foreign students with pathological dyssynchrony before and after correction with melatonin**

| Sinusoidal rhythms: SAP, DAP on the right and left hand, pulse, body temperature, "individual minute", "individual decimeter" with open and closed eyes | Reliable rhythms % (abs.) | | | | Unreliable rhythms % (abs.) |
|---|---|---|---|---|---|
| | Total | Ultradian | Circadian | Infradian | |
| III A group before chronocorrection n=143 | 42 (60) | 44 (26) | 40,5 (24) | 16 (8) | 59 (85) |
| III A group before taking 0,75 mg melatonin n=143 | 57 (85) | 26 (22) | 55,5 (47) | 18,2 (14) | 43 (60) |
| III B group before chronocorrection n=200 | 40,2 (82) | 46,4 (35) | 40,5 (32) | 13,1 (10) | 60 (123) |
| III B group after taking 3 mg melatonin n=200 | 57 (115) | 28,5 (34) | 55 (63) | 16,5 (18) | 43 (85) |
| *Note – n-the number of analyzed sinusoids; SAP-systolic arterial pressure; DAP-diastolic arterial pressure* | | | | | |

After chronocorrection, the acrophases of most of the biorhythms in both subgroups shifted according to the chronotype of the subjects, their walking zones were shortened by 1.5–2 hours, there was a tendency to decrease in mesors of integral indicators (arterial pressure, heart rate, and axillary temperature), and the amplitude of rhythms increased. The change of these indicators shows that the adaptability of foreign students studying at the examined medical faculty has increased.

The duration of "personal minute" and "personal decimeter" in medical students increased in both subgroups after taking melatonin and approached the normal values (Table 2). This showed that spatio-temporal perception improved, adaptation mechanisms and emotional stress decreased.

Table 2

**Individual minutes and individual decimeters with open and closed eyes in medical students with pathological dyssynchrony before and after correction with melatonin**

| A group of students | Indicators | | | |
|---|---|---|---|---|
| | "individual minute" when the eyes open | "individual minute" when the eyes closed | "individual decimeter" when the eyes open | "individual decimeter" when the eyes closed |
| Before correction III A group | 52±5,4 | 50,5±2,3 | 9,1±0,5 | 7,8±0,5 |
| III A group after taking 0,75 mg melatonin | 58,1±3,3 | 55,5±3,9 | 8,9±0,4 | 8,9±0,2 |
| After correction III B group | 54±4,1 | 51,3±3,2 | 8,2±0,5 | 8,2±0,5 |
| III B group after taking 3 mg melatonin | 54,7±3,2 | 55±2,8 | 9,7±0,1 | 9,0±0,7 |

Correction of pathological desynchronosis with 0.75 mg of melatonin resulted in an increase in "well-being, activity, mood" test indicators. After taking 0.75 mg melatonin, there was an improvement of 3.5 % in well-being indicators, 5.5 % in activity, and 10 % in mood. After taking 3 mg of melatonin, there was an improvement of 4.0 % in well-being indicators, 5.8 % in activity, and mood improved by 15.5 % (Table 3). Melatonin had a greater effect on mood indicators and a slower effect on well-being.

It was determined that the effect of melatonin on the mood indicators of the subjects is related to the activity of the psychotropic hormone carried out through serotoninergic mechanisms, the modulation of dopaminergic transmission, and the change in the activity of motivational and cognitive (striatal) mechanisms in people due to the effect on gamma-aminobutyric acid (GABA) neurons.

Melatonin weakens the excitability of the hippocampus and other emotional structures, stabilizes the psycho-emotional sphere by limiting anxiety, anti-stress properties and restoring disorganized vibration pro-

cesses in the body. It also has a positive effect on seasonal depression. This type of depression is associated with the changing of the seasons and occurs at the same time each year, with symptoms usually appearing in the fall or winter. Because melatonin plays a role in regulating circadian rhythms, melatonin depression is often used at low doses to reduce symptoms. According to a study of 100 people, changes in circadian rhythms contribute to seasonal depression, and taking a daily melatonin pill was effective in reducing symptoms.

Table 3

**"WAM" (well-being, activity, mood) test indicators in foreign students with pathological dyssynchrony before and after correction with melatonin**

| A group of students | Indicators | | |
|---|---|---|---|
| | well-being | activity | mood |
| Before correction III A group | 4,95±1,3 | 4,90±1,3 | 4,75±1,3 |
| III A group after taking 0,75 mg melatonin | 5,15±1,4 | 5,20±1,4 | 5,22±1,4 |
| After correction III B group | 4,85±1,1 | 4,80±1,1 | 4,50±1,0 |
| III B group after taking 3 mg melatonin | 5,0±1,2 | 5,10±1,2 | 5,15±1,2 |

After chronocorrection, subjects noted improved sleep. A decrease in the time spent falling asleep and an improvement in well-being upon awakening were observed. The sedative properties of melatonin have been described by many researchers for sleep disorders associated with various pathologies.

## *Conclusion*

The study of medical students who took melatonin reveals positive effects on physiological and psychophysiological functions. Chronoanalysis of individual and group patterns indicates an improvement in the organization and efficiency of the circadian system, overall health levels, and quality. Moreover, melatonin supplementation led to an increase in the sleep quality of students affected by desynchronosis, while those with pathological desynchronosis showed a decrease in their well-being.

The acquired results suggest that melatonin can be effectively used to regulate and correct physiological functions in students, offering a potential solution for addressing health-related challenges. This research supports the notion that melatonin, administered in suitable doses, could positively influence the academic and exam performance of students, making it a viable option for enhancing their overall well-being.

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## Десинхроноз кезінде адам ағзасының функционалдық күйіне мелатонинің әсері

Мақалада адам ағзасындағы мелатониннің әсер ету механизмдері, соның ішінде оның тәуліктік ырғаққа, ұйқыға, иммундық жүйеге және физиологиялық функционалдық күйге әсері қарастырылды. Зерттеулер мен клиникалық бақылаулар негізінде десинхронозды түзету үшін мелатонинді фармакологиялық агент ретінде қолдануға ерекше назар аударылды. Жұмыстың мақсаты — жаңа уақыт белдеуінде орналасқан немесе географиялық ендіктің өзгеруіне байланысты десинхроноздан зардап шегетін студенттердің биологиялық ырғақтарын және жалпы физиологиялық жағдайын реттеуге мелатониннің ықтимал әсерін анықтау. Мелатониннің тәуліктік ырғаққа әсер ету механизмдері, сондай-ақ бұзылған биоритмиялық синхрондау жағдайында оның ұйқыға, белсенділікке және жалпы физиологиялық тепе-теңдікке әсері қарастырылады. Мелатонинді десинхронозды реттеуде және өзгерген биологиялық ырғақтар жағдайында адам денсаулығын сақтауда қолдану перспективаларын ұсына отырып, өзекті зерттеулер талданды. Зерттеу нәтижелері мелатонинді қабылдаған тәжірибелік топтағы студенттердің оқу үлгерімі жақсарып, еңбек қабілеттері артып, көңіл күйлерінде сергектік пайда болғаны анықталды. Яғни десинхроноз кезінде де, адам ағзасында функционалдық күйінің өзгерістеріне мелатониннің оң әсер еткені белгілі болды. 100 адамға жүргізілген зерттеуге сәйкес, тәуліктік ырғақтағы өзгерістер маусымдық депрессияға ықпал ететіні және мелатонин таблеткасын күнделікті қабылдау десинхроноз симптомдарын азайтуда тиімді болды. Мақала авторлары биомедицина, биология және фармакология саласындағы, сондай-ақ адам денсаулығы мен биологиялық ырғақтарға қызығушылық танытатын мамандарға маңызды ғылыми деректер мен практикалық ұсыныстар ұсынады.

*Кілт сөздер:* десинхроноз, мелатонин, биоырғақ, хронотип, диссомния.

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## Влияние мелатонина на функциональное состояние организма человека при десинхронозе

В статье рассмотрены механизмы действия мелатонина в организме человека, в том числе его влияние на циркадные ритмы, сон, иммунную систему и физиологическое функциональное состояние. На основании исследований и клинических наблюдений особое внимание уделено использованию мелатонина в качестве фармакологического средства для коррекции диссинхронии. Цель работы — определить возможное влияние мелатонина на регуляцию биологических ритмов и общее физиологическое состояние студентов, находящихся в новом часовом поясе или страдающих десинхронозом вследствие изменения географической широты. Рассмотрены механизмы влияния мелатонина на циркадные ритмы, а также его влияние на сон, активность и общее физиологическое равновесие при нарушении биоритмической синхронизации. Проанализированы современные исследования, открывающие перспективы использования мелатонина в регуляции десинхронизации и поддержании здоровья человека в условиях измененных биологических ритмов. Результаты исследования показали, что студенты экспериментальной группы, принимавшие мелатонин, улучшили свою успеваемость, повысили трудоспособность и имели более бодрое настроение. То есть было известно, что мелатонин оказывает положительное влияние на изменение функционального состояния организма человека даже при десинхронозе. Согласно исследованию, у 100 студентов были изменения циркадных ритмов, которые спо-

собствуют сезонной депрессии, а ежедневные таблетки мелатонина были эффективны в уменьшении симптомов десинхроноза. Авторами статьи представлены важные научные данные и практические рекомендации для специалистов в области биомедицины, биологии и фармакологии, а также для тех, кто интересуется здоровьем человека и биологическими ритмами.

*Ключевые слова:* десинхроноз, мелатонин, биоритм, хронотип, диссомния.

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# Спектральные характеристики эфирных масел распространенных пряных пищевых растений

В настоящее время пряности широко используются для коррекции питания и фитооздоровления. Целью данного исследования явилось выявление спектральных характеристик эфирных масел пряно-ароматических растений, которые могут быть использованы для стандартизации препаратов на их основе. Объектами исследования служили листья лавра благородного, заготовленные в период цветения в городе Сочи; гвоздики бутоны промышленного производства; кора корицы сорта «Alba», поставляемая по импорту из Республики Шри-Ланка, и корневища имбиря свежие, реализуемые в торговой сети. Эфирное масло получали методом гидродистилляции и проводили исследование его УФ-спектра в диапазоне 200–400 нм. Полученные спектры сравнивали со спектрами стандартных образцов эвгенола, коричного альдегида и цингиберена. Было установлено, что мажорным компонентом эфирных масел гвоздики и лавра является эвгенол, в эфирном масле корицы очевидно присутствуют два компонента — коричный альдегид и эвгенол, а в эфирном масле корневищ имбиря эвгенола не обнаружено, его основным компонентом является сесквитерпеноид цингиберен. В целом можно сделать вывод о формировании бактерицидных и фунгистатических свойств исследуемых эфирных масел различными группами биологически активных соединений: эвгенола у лавра и гвоздики, суммы эвгенола и коричного альдегида у коры корицы и цингеберена в имбире лекарственном. Важным является возможность использования УФ-спектров эвгенола, цингиберена и коричного альдегида в качестве стандартов, определяющих доброкачественность масла, обеспечивающих воспроизводимость фармакологического действия препаратов лавра, гвоздики, имбиря и корицы.

*Ключевые слова:* лавр, корица, гвоздика, имбирь, спектрофотометрия, эфирное масло, мажорные компоненты, стандартизация сырья.

## *Введение*

Пряности использовались людьми с древнейших времен в качестве пищевых, ароматических, косметических средств [1]. Примеры использования специй в качестве лекарственных средств в ранних цивилизациях можно найти в папирусе Эберса, который представляет собой египетский свиток с перечнем растений, применявшихся в качестве лекарств, датируемый примерно 1550 годом до нашей эры [2]. Корица применялась как антисептическое средство, гвоздика — против диареи, а также как местное обезболивающее, имбирь — при простудных заболеваниях, как противорвотное, противоревматическое средство. Процедура сжигания лавровых листьев способствовала очищению дыхательных путей, укреплению иммунитета, снятию стресса и головных болей. Кроме этого, дымом окуривали помещения для дезинфекции воздуха и очищения от неприятных запахов [3].

История применения пряностей тесно связана с великими географическими открытиями и техническим прогрессом, что было обусловлено их редкой распространенностью и высокой стоимостью. С активным развитием транспорта в XX веке доступность пряностей значительно возросла, так как сократились сроки доставки и их стоимость, кроме того, пряно-ароматические растения стали широко выращиваться во многих странах Юго-Восточной Азии, Африки, Америки [4, 5]. В настоящее время пряности продолжают активно применяться как для улучшения органолептических свойств пищи, так и для фитооздоровления.

Наиболее популярны в настоящее время имбирь, корица, лавровый лист, гвоздика, различные виды перца, бадьян, розмарин, куркума, базилик и многие другие [6, 7].

Источником получения корицы является кора коричника цейлонского (*Cinnamomum ceylanicum* Blume) семейства лавровые (*Lauraceae*). Лавровый лист заготавливают от растения лавр благородный (*Laurus nobilis* L.) семейства лавровые (*Lauraceae*). Гвоздика представляет собой высушенные бутоны гвоздичного дерева (*Syzygium aromaticum* (L.) Merrill et. Perry) семейства миртовые (*Myrtaceae*). Им-

бирь — это пряность, представляющая собой свежие или переработанные корневища имбиря лекарственного (*Zingiber officinale* Roscoe) семейства имбирные (*Zingiberaceae*).

За исключением листьев лавра благородного, перечисленные растения входят в состав комплексных лекарственных растительных препаратов, применяющихся при лечении различных заболеваний. Так, в Государственный реестр лекарственных средств Российской Федерации [8] включены различные формы выпуска бальзама «Золотая звезда», «Содекор», «Кармолис», «Доктор Мом», «Трависил», содержащие эфирные масла или экстракты имбиря, корицы и гвоздики. Большую популярность в последнее время приобрели чаи с добавлением имбиря, гвоздики и корицы, которые обладают не только выраженным вкусом, но и иммуномодулирующим, противомикробным, противогрибковым и противовирусным действием [9–18]. Чаще всего их употребляют для профилактики и при лечении острых респираторно-вирусных инфекций.

Кроме того, большую популярность приобрело использование эфирных масел в ароматерапии. Ассортимент эфирных масел чрезвычайно разнообразен: масла можно приобрести не только в аптеке, но и в косметических и парфюмерных магазинах, а также на торговых площадках маркетплейсов, ценовой диапазон варьирует в широких пределах и может различаться в десятки раз.

Основными действующими веществами корицы, имбиря и лавра являются эфирные масла, однако компонентный состав масел различен. Для корицы основными компонентами являются коричный альдегид и эвгенол, для гвоздики — эвгенол, для лавра — эвгенол и 1,8-цинеол; для имбиря — цингиберен [19–24].

Вместе с тем востребованность корицы, имбиря, лавра и гвоздики порождают проблему фальсификации данного растительного сырья. В связи с этим необходима процедура стандартизации и контроля качества продукции, содержащей эти пряности, с использованием экспресс-методов, которые будут малозатратными по времени исследования и ресурсам. Одним из таких традиционных и эффективных методов может служить спектрофотометрия. Для реализации такого подхода необходимо установление УФ-спектров с реперными экстремумами, характерными для мажорных компонентов эфирных масел, определяющих ту или иную фармакологическую активность.

Целью данного исследования явилось выявление спектральных характеристик эфирных масел пряно-ароматических растений.

### *Материалы и методы*

Объекты исследования: листья лавра благородного, заготовленные в период цветения в г. Сочи; гвоздики бутоны промышленного производства; кора корицы сорта «Alba», поставляемой по экспорту из Республики Шри-Ланка, и корневища имбиря свежие, реализуемые в торговой сети.

Эфирное масло получали методом гидродистилляции с использованием аппарата Гинзберга и Клевенджера из доведенного до воздушно сухого состояния сырья. Время дистилляции составляло 4 часа после закипания воды в перегонной колбе. Эфирное масло количественно отбиралось из приемника и растворялось в 5 мл спирта этилового 95 %. Спектры поглощения снимались в диапазоне 200–400 нм на спектрофотометре СФ–56. Количественное содержание эфирного масла в исследуемом сырье определяли как отношение объема полученного масла (по шкале приемника эфирных масел) к массе загруженного в перегонную колбу сырья в пересчете на абсолютно-сухое сырье. Содержание преобладающего оптически активного компонента определяли по измеренному показателю поглощения на характерной длине волны и известному коэффициенту молярной экстинкции.

Кроме того, для последующего сравнения были сняты в аналогичных условиях спектры стандартных образцов эвгенола и коричного альдегида.

### *Результаты и их обсуждение*

В результате проведенной гидродистилляции были получены эфирные масла, представляющие собой прозрачные маслянистые жидкости, желтоватого цвета с характерным запахом.

Сравнивая полученные УФ-спектры эфирных масел гвоздики (рис. 1), лавра (рис. 2) и корицы (рис. 3) с УФ-спектрами стандартных образцов эвгенола и коричного альдегида (рис. 4) можно сделать выводы о преобладающих компонентах в эфирных маслах исследуемых растений.

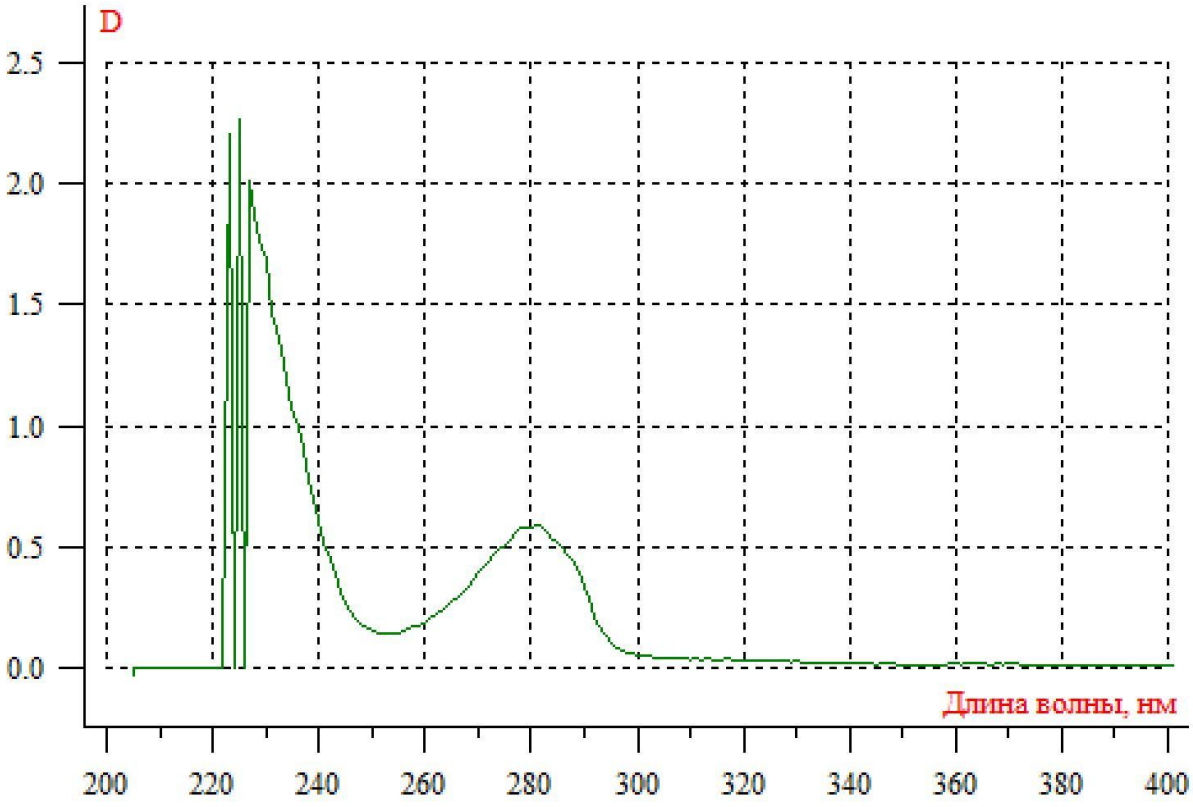


Рисунок 1. УФ-спектр эфирного масла, полученного методом гидродистилляции из бутонов гвоздики

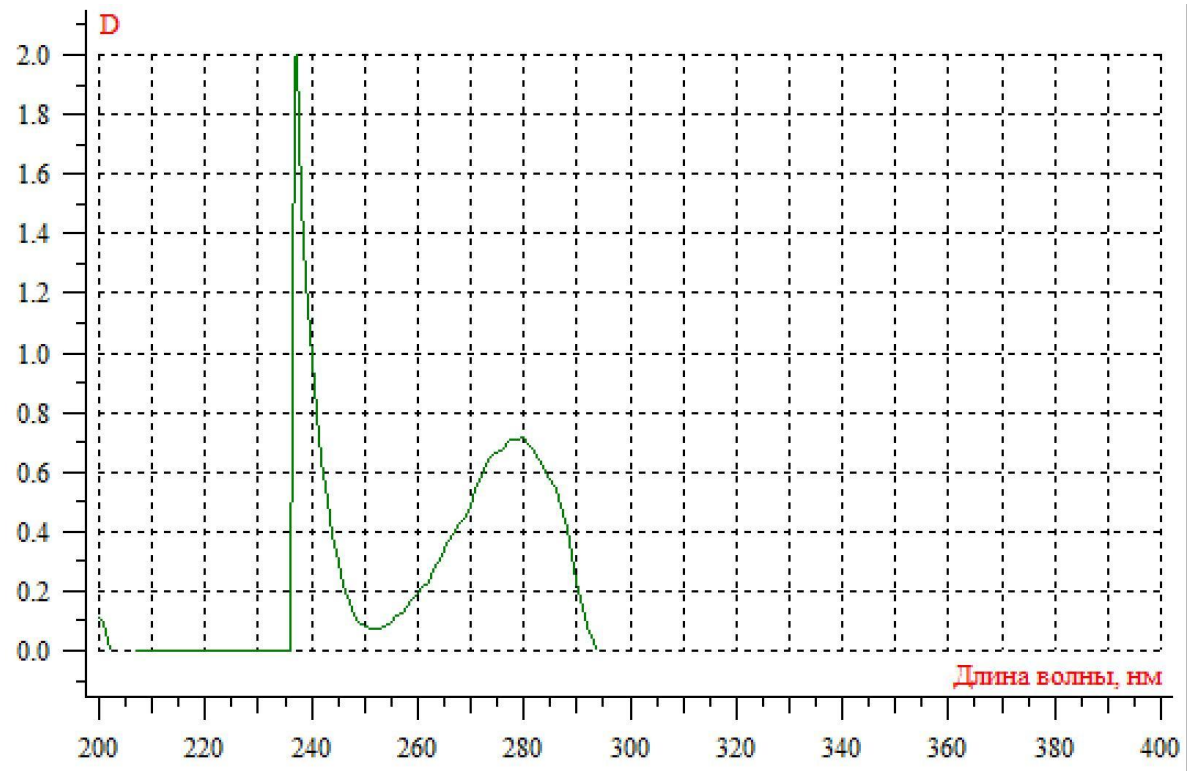


Рисунок 2. УФ-спектр эфирного масла, полученного методом гидродистилляции из листьев лавра

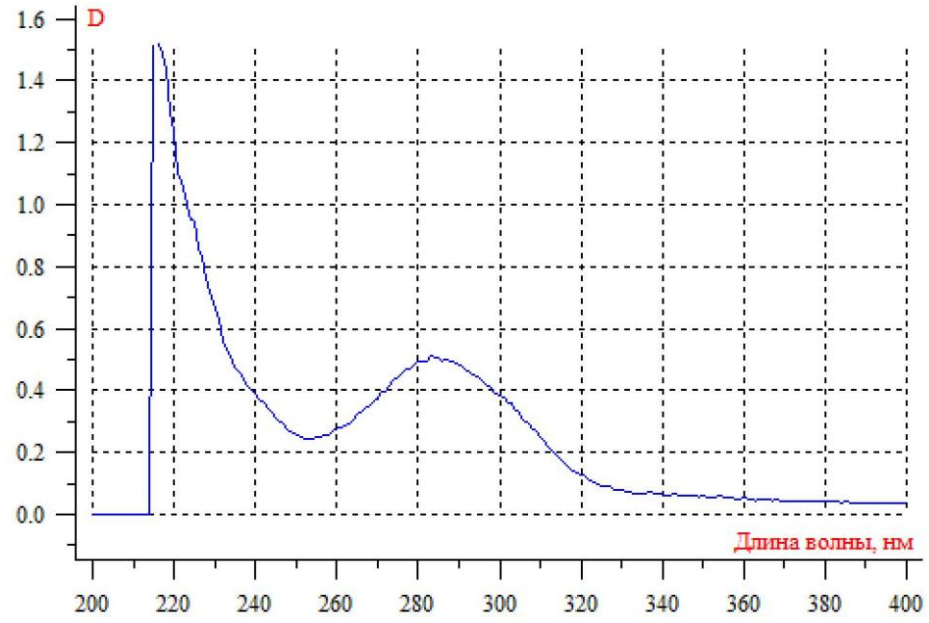


Рисунок 3. УФ-спектр эфирного масла, полученного методом гидродистилляции из коры коричника цейлонского

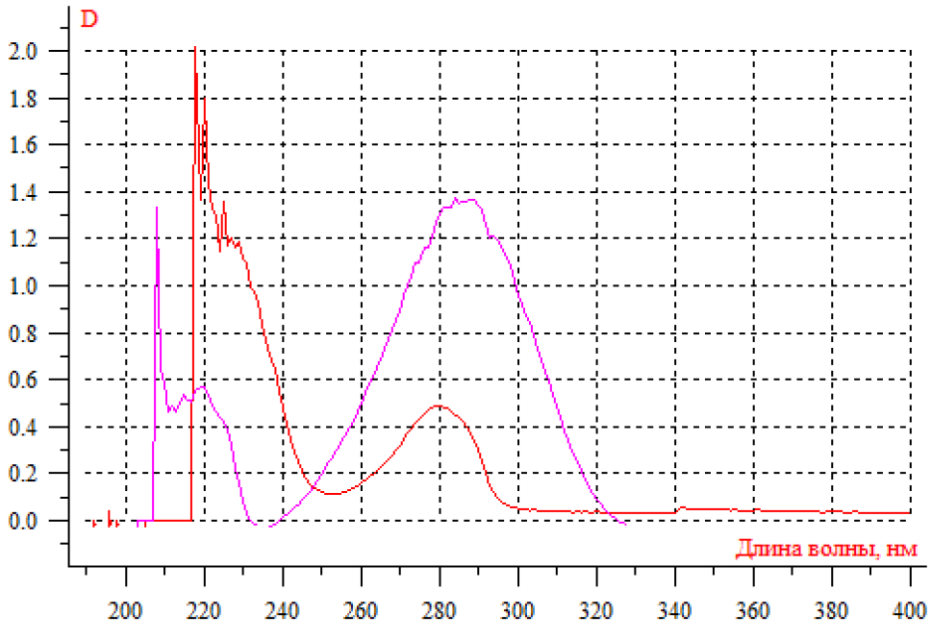


Рисунок 4. УФ-спектры эвгенола (красная линяя) и коричного альдегида (сиреневая линия)

Анализ вида кривой УФ-спектра и значений установленных экстремумов поглощения (табл. 1) позволяет сделать выводы, что главными компонентами эфирных масел гвоздики и лавра является эвгенол. Вполне логично и непротиворечиво предположить, что употребление их в пищу как пряности или в виде субстанции для получения лекарственного препарата или БАД обеспечивает антибактериальное действие. Известно, что в составе эфирного масла лавра присутствует значительное содержание 1,8-цинеола. Однако методы фотометрии для данного соединения не применимы, так как он в исследуемом диапазоне оптически не активен. Вместе с тем антисептическое действие лаврового листа может быть обеспечено и эвгенолом.

УФ-спектр извлечения из коры корицы имеет явный батохромный сдвиг относительно максимума эвгенола. Последнее обстоятельство может быть объяснено значительным содержанием в

эфирном масле корицы коричного альдегида, имеющего более длинноволновый максимум при длине волны 291 нм.

Таблица 1

**Экстремумы УФ-спектров исследуемых эфирных масел**

| Исследуемый образец | Экстремумы, нм | |
|---|---|---|
| | максимум | минимум |
| Гвоздики бутоны | 281 | 252 |
| Корицы кора | 286 | 253 |
| Имбиря корневища | 238 | 212 |
| Лавра листья | 280 | 252 |

Эфирное масло корневищ имбиря имеет резко отличный от других исследованных объектов УФ-спектр (рис. 5), что позволяет сделать вывод об отсутствии в его составе эвгенола. Полученный спектр более характерен для сесквитерпеноида цингиберена [25], и именно с ним связано фармакологическое действие препаратов имбиря и биологически активных добавок на его основе.

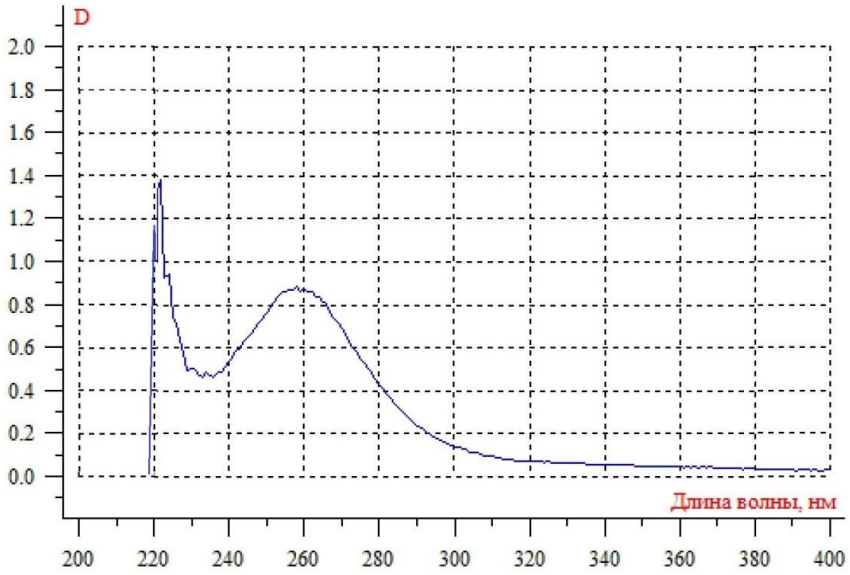


Рисунок 5. УФ-спектр эфирного масла, полученного методом гидродистилляции из корневищ имбиря

По измеренным величинам оптической плотности на длине волны характерных экстремумов и известным величинам экстинкции было определено содержание мажорных компонентов в исследуемых эфирных маслах (табл. 2).

Таблица 2

**Количественные характеристики полученных масел**

| Исследуемый образец | Содержание эфирного масла, % | Содержание эвгенола в масле, % | Содержание цингиберена, % |
|---|---|---|---|
| Гвоздики бутоны | 11,8 | 94,6 | – |
| Лавра листья | 1,8 | 0,95 | – |
| Корицы кора | 8,9 | 1,95 | – |
| Имбиря корневища | 14,2 | – | 6,8 |

*Заключение*

В целом можно сделать вывод о формировании бактерицидных и фунгистатических свойств исследуемых эфирных масел различными группами биологически активных соединений: эвгенола у лавра и гвоздики, суммы эвгенола и коричного альдегида у коры корицы и цингеберена в имбире лекарственном.

Важным является возможность использования УФ–спектров эвгенола, цингиберена и коричного альдегида в качестве стандартов, определяющих доброкачественность масла, обеспечивающего воспроизводимость фармакологического действия препаратов лавра, гвоздики, имбиря и корицы.

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## Тамақтық дәмдеуіш өсімдіктерінен алынған эфир майларының спектрлік сипаттамалары

Қазіргі уақытта дәмдеуіштер күнделікті тұрмыста тамақты дұрыс тұтынуда және фитосауықтыру үшін кеңінен қолданылады. Зерттеудің мақсаты олардың негізінде препараттарды стандарттау үшін қолдануға болатын ащы-хош иісті өсімдіктердің эфир майларының спектрлік сипаттамаларын анықтау. Зерттеу нысанына Сочи қаласынан гүлдену кезеңінде жиналған асыл лавр жапырақтары; өнеркәсіпте өндірілген қалампыр бүршіктері; Шри-Ланка Республикасынан импортталған «Альба» сортының даршын қабығы және сауда желісінде сатылатын балғын зімбір тамырсабақтары алынды. Эфир майы гидродистилляция әдісімен алынды және оның УК-спектрі 200-400 нм диапазонында зерттелді. Алынған спектрлер эвгенол, күнзелік альдегиді және цингибереннің стандартты үлгілерінің спектрлерімен салыстырылды. Қалампыр мен лавр эфир майларының негізгі компоненті эвгенол екендігі анықталды; даршын эфир майында екі компонент бар, ол даршын альдегиді және эвгенол; ал зімбір тамырсабағының эфир майынан эвгенол табылмады, оның негізгі компоненті — цингиберен сесквитерпеноиды. Жалпы алғанда, биологиялық белсенді қосылыстардың әртүрлі топтары зерттейтін эфир майларының бактерицидтік және фунгистатикалық қасиеттерінің қалыптасуы туралы мынадай қорытынды жасауға болады: лавр мен қалампырдағы эвгенол, даршын қабығындағы эвгенол мен күнзелік альдегиді және дәрілік зімбірдегі цингебереннің қосындысы. Эвгенол, цингиберен және күнзелік альдегидінің УК-спектрлерін лавр, қалампыр, зімбір және даршын препараттарының фармакологиялық әсерінің қайталануын қамтамасыз етуде майдың сапасын анықтайтын стандарттар ретінде пайдалану мүмкіндігі маңызды.

*Кілт сөздер:* лавр, даршын, қалампыр, зімбір, спектрофотометрия, эфир майы, негізгі компоненттер, шикізатты стандарттау.

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## Spectral characteristics of essential oils taken from widespread spicy food plants

Nowadays, spices are widely used for nutritional corrections and phytohealthing. The aim of present research was to determine the spectral characteristics of essential oils of aromatic plants, which can be used to standardize preparations based on them. The objects of the study were leaves of noble laurel, harvested during the flowering period in the city of Sochi; carnation buds of industrial production; cinnamon bark of the “Alba” variety, imported from the Republic of Sri Lanka, and fresh ginger rhizomes sold in the retail network. The essential oil was made by hydrodistillation and its UV-vis spectra in the range of 200–400 nm was studied. The obtained spectra were comparing with standard samples spectra of eugenol, cinnamaldehyde and zingiberene. It was found that the major components of the essential oils of clove and laurel are eugenol; in the essential oil of cinnamon there are two components — cinnamaldehyde and eugenol. At same time eugenol was not found in ginger essential oil and the main component is the sesquiterpenoid zingiberene. Concluding that the bactericidal and fungistatic properties of essential oils are formed by different groups of biologically active compounds: eugenol in laurel and cloves, the sum of eugenol and cinnamaldehyde in cinnamon bark and zingeberenes in ginger. It is shown ability use the UV spectra of eugenol, zingiberene and cinnamaldehyde as standards determining the good quality of the oil, ensuring the reproducibility of the pharmacological effect of laurel, clove, ginger and cinnamon preparations.

*Keywords:* Laurel, cinnamon, cloves, ginger, spectrophotometry, essential oil, major components, standardization of raw materials

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# Бақша қараот (*Portulaca oleracea* L.) ультрадыбыстық экстрактымен тазартқыш-пенканың антиоксиданттық белсенділігі мен қауіпсіздігін анықтау

Қазіргі уақытта өсімдік тектес шикізаттан өндірілген тері күтіміне арналған космецевтикалық өнімдер саны артып келеді. Күн сәулесінің әсері кезінде теріде бос радикалдар пайда болады, олар сәйкесінше эпидермис пен дерма деңгейінде қабыну реакцияларына әкеледі. Осы мәселені шешу үшін теріге антиоксиданттық әсер көрсететін космецевтикалық өнімдер көмекке келеді. Бақша қараот (*Portulaca oleracea* L.) ультрадыбыстық экстрактымен тазартқыш-пенканың антиоксиданттық белсенділігі DPPH радикалды жою сынағы арқылы, полифенолдар мен флаваноидтардың жалпы саны спектрофотометриялық әдіс арқылы, тазартқыш-пенканың қауіпсіздігі мен цитотоксикалық белсенділігі HaCat (*in vitro*) жасушалары арқылы анықталды. Зерттеу нәтижелері бойынша бақша қараот (*Portulaca oleracea* L.) ультрадыбыстық экстрактымен тазартқыш-пенканың антиоксиданттық белсенділігі 89,1±0,54, ал жасушалар өміршеңдігі 95 % екендігі анықталды.

*Кілт сөздер:* тазартқыш-пенка, ультрадыбыстық экстракт, бақша қараот экстракты, антиоксиданттық белсенділік, полифенолдар, флаваноидтар, жасушалардың өміршеңдігі.

## *Кіріспе*

Емдік-профилактикалық әсер ететін косметикалық өнімдер фармацевтикалық нарық сегментінде тұрақты жетекші орындардың бірін алады. Әдебиеттік шолу негізінде жүргізілген зерттеу жұмыстарының нәтижесі тұтынушылар қалауы бойынша табиғи өнімге деген сұраныстың басым екендігін көрсетті [1].

Өсімдік тектес ингредиенттерді косметикада қолдану көрсеткіші жануар тектес және синтетикалық өнімдерге қарағанда жоғары [2]. Өсімдік тектес компоненттер антиоксиданттық, қабынуға, микробқақарсы, тыныштандыратын/ылғалдандыратын, теріге қорғаныш қызметін көрсететін әсерлеріне байланысты тері, шаш және ауыз қуысы күтіміне арналған өнімдердің рецептурасында кеңінен қолданылады (Абурджаи және Натше, 2003) [3]. Әлемдік косметикалық нарықтың көлемі 2017 жылы 532 миллиард АҚШ долларын құраған, ал болжам бойынша 2023 жылы 805 миллиард АҚШ долларына шамалады деп хабарланған [4].

Соңғы бірнеше онжылдықта космецевтикалық өнімдердің антиоксиданттық қасиеттеріне қызығушылық артуда, бұл антиоксиданттардың тірі жүйелердегі әртүрлі еркін-радикалды процестерді жүзеге асыруымен қатар патологиялық жағдайларға қарсы тұрудың түбегейлі жаңа тәсілдерін дамытудағы қасиетіне негізделген [5].

Сонымен қатар, әдеби деректерде өсімдіктерден алынған фенолдық қосылыстардың, флавоноидтардың күшті антиоксиданттық қасиеті дәлелденген. Демек, тазартқыш-пенканың құрамындағы полифенолдар мен флаваноидтардың жоғары мөлшері оның антиоксиданттық қасиетінің кепілі бола алады [6].

Зерттеудің мақсаты — *Portulaca oleracea* L. ультрадыбыстық экстрактымен тазартқыш-пенканың антиоксиданттық қасиеттері мен цитотоксикалық белсенділігін бағалау.

## *Материалдар мен әдістер*

Зерттеу объектісі негізінен бақша қараот (*Portulaca oleracea* L.) ультрадыбыстық экстракты қосылған тазартқыш-пенка, шартты түрде атауы «Port&Ai».

Зерттеу базасы ҚазҰМУ Фармация мектебінің симуляциялық орталығында, зерттеу-аналитикалық зертханасында және Жешув қаласының «University of Information Technology and Management in Rzeszow» университеті базаларында жүргізілді.

Эксперимент барысында физика-химиялық, аналитикалық, технологиялық, статистикалық әдістер қолданылды.

*Ультрадыбыстық экстракция*

Экстрагент 70 % концентрациядағы сулы-этанол ерітіндісі. 150 г бақша қараот дәрілік өсімдік шикізатын конусты колбаға салып, 1:10 қатынасында 70 % сулы-этанол қатысында, 30 минутқа ультрадыбыстық (Ultrasonic cleanser, PS-20AD, Қытай) моншаға қойылды [7]. Роторда (Stegler RI-213, Ресей) буландырып, сұйық экстракт (1:1) алынды.

*Тазартқыш-пенканы алу*

Тазартқыш-пенканың оңтайлы құрамын таңдауда дайындалған сынамалардан 5 түрлі үлгі алынды. Негіз ретінде: тазартылған су, белсенді зат ретінде *Portulaca oleracea* L. ультрадыбыстық экстракты, беттік белсенді зат ретінде: кокамидопропил бетаин (Үндістан), коко-бетаин (Қытай), қосымша заттар: ылғалдандырғыш ретінде глицерин (Ресей), хош иіс беруші роза гүлінің майы (Франция), консервант ретінде лимон қышқылы (Қытай) қолданылды.

*Антиоксиданттық белсенділікті анықтау (DPPH радикалды жою сынағы)*

Port&Ai тазартқыш-пенканың бос радикалдарды жою қабілеті DPPH (2,2-дифенил-1-пикрилгидразил) талдауымен бағаланды. Тазартқыш-пенканың әр түрлі концентрациясында (1000 мг/мл, 500 мг/мл, 250 мг/мл және 125 мг/мл) 0,001 мл DPPH араластырылды. Қосынды фольгамен жабылып, қараңғыда 10 минут инкубацияланды. Сіңіру көрсеткіші λ=540 нм толқын ұзындығында өлшенді. Стандарт ерітіндісі ретінде еріткіштің бірдей көлемімен араласқан аскорбин қышқылы қолданылды. DPPH радикалдарын жою пайызы мына формуламен есептелді:

$$\frac{}{} \cdot 100\ \%;$$

Мұндағы Abs control-бақылау реакциясының жұтылуы (талданатын үлгіден басқа реагенттер), Abs sample-талданатын үлгінің жұтылуы.

Барлық спектрофотометрлік өлшеулер Solar PB 2201, УК-спектрофотометрінде (Беларусь) жүргізілді. Зерттеу нәтижелері Microsoft Excel 2010 бағдарламасында өңделді.

*Фенолдардың жалпы құрамын анықтау*

Port&Ai тазартқыш-пенканың құрамындағы фенолдардың жалпы мөлшері Фолин-Чокалтеу әдісімен анықталды. 30 мл тазартқыш-пенка (10–100 мг/мл) сынамасына 150 мл Фолин-Чокалтеу реагентін қосып, қараңғы жерге 6 минут инкубациядан кейін әр үлгіге 120 μg/mL натрий карбонаты қосылды. Сосын қараңғы жерге 60 минуттық инкубациядан кейін сіңіру көрсеткіші λ = 740 нм толқын ұзындығында анықталды. Өлшеу бөлме температурасында (+25 °C) жүргізілді. Талданатын тазартқыш-пенкадағы фенолдардың жалпы концентрациясы галл қышқылының (GA) калибрлеу қисығымен (0–100 мг/мл) есептелді. Тазартқыш-пенкадағы фенолдық қосылыстар үш тәуелсіз өлшеу нәтижесімен анықталды және орташа мәндер алынды.

*Флавоноидтардың жалпы құрамын анықтау*

Флаваноидтардың [5] жалпы мөлшері сипатталған әдіс бойынша анықталды. Талданатын тазартқыш-пенкадағы флавоноидтардың жалпы мөлшері алюминий нитрат нонгидратының көмегімен бағаланды. 56, 60 мкл зерттелетін тазартқыш-пенканың әр түрлі концентрациядағы ерітінділеріне (10–100 мг/м л) 243, 300 мкл реакция қоспасы араластырылды. Бөлме температурасында 40 минуттық инкубациядан кейін, сіңіру көрсеткіші λ = 415 нм толқын ұзындығында өлшенді. Port&Ai тазартқыш-пенканың құрамындағы флавоноидтардың жалпы концентрациясы кверцетин (Qu) гидратының (0–100 мг/мл) калибрлеу қисығы арқылы есептелді және үш тәуелсіз өлшеудің нәтижелері бойынша орташа мәні алынды [8].

*HaCat жасушаларын дақылдандыру*

Эксперименттерде қолданылатын HaCat жасушалары (қалыпты адам кератиноциттері) L-глутамин қосылған модификацияланған Дульбекко ортасында (DMEM) болды. Өсірілген жасушалар 95 % ауадан және 5 % көмірқышқыл газынан тұратын ылғалдандырылған атмосферада 37°С температурада ұсталынды. Жасушалар бірігуге жеткенде, өсу ортасы мен жасушалар бір-бірінен ажыратылып, жасушаларды стерильді фосфат буферлі тұзды ерітіндімен (PBS) екі рет жуылды. Біріктірілген сынама трипсин/ЭДТА көмегімен трипсинизацияланды, содан кейін жаңа ортада қайта дақылдандырылды. HaCaT жасушалары 96 ұяшықтан тұратын микропланшетке орналастырылғаннан кейін, Port-Ai тазартқыш-пенканың 2 %, 5 %концентрацияларымен инкубацияланды.

*Жасушалардың өміршеңдігін талдау (in vitro)*

HaCaT жасушаларының өміршеңдігін бағалау үшін бейтарап қызылды сіңіруді талдау әдісі [9] қолданылды. Бұл жасушалардың өміршеңдігін бағалауға және өміршең, бұзылмаған жасушалардың лизосомаларында бейтарап қызыл бояғыштың жиналуын анықтауға мүмкіндік береді. Зерттелетін жасушалар 4000 жасуша / ұңғыма тығыздығы бар 96 ұяшықты планшеттерге орналастырылды. Тексеріс алдында 24 сағат бұрын Port&Ai тазартқыш-пенканың 2 %, 5 % концентрациясында өнімдер әр ұяшыққа қосылып, тағы 24 сағат бойы өсірілді. Бақылау тобы ретінде ашылмаған жасушалар қолданылды.

Бейтарап қызыл жұмыс ерітіндісі 1 % фосфатты-тұзды буфері бар 10 мл жасуша өсіру ортасын 100 мл бейтарап қызыл ерітіндісімен сұйылту арқылы дайындалды.

Содан кейін жасушалар 37°С температурада 3 сағат бойы инкубацияланды. Жасушалар 100 мкл фосфатты-тұзды буфермен жуылып, ұяшыққа 100 мл қышқылданған этанол ерітіндісі қосылды. Ұяшықтардағы жасушалар бейтарап қызыл түске ие болғанша 10 минут бойы араластырылды. Бейтарап қызыл бояғыштың сіңу көрсеткішін анықтау λ = 540 нм толқын ұзындығында өлшеу жүргізілді. Тәжірибелер тазартқыш-пенканың әр концентрациясы үшін 5 рет қайталанды.

*Нәтижелер және талдау*

Port&Ai тазартқыш-пенканың оңтайлы құрамы 25.05.2023 күні жасалып, сақтауға қойылды (1-кесте).

1 - к е с т е

**Port&Ai тазартқыш-пенканың құрамы**

| Ингредиенттер | 1-үлгі | 2-үлгі | 3-үлгі | 4-үлгі | 5-үлгі | Функционалдық қызметі |
|---|---|---|---|---|---|---|
| Тазартылған су | 100-ге дейін | 100-ге дейін | 100-ге дейін | 100-ге дейін | 100-ге дейін | Негіз |
| *Portulaca oleracea* L. ультрадыбыстық экстракты | 1.0 | 1.0 | 2.0 | 2.0 | 1.0 | Белсенді зат, антиоксиданттық, патогенді саңырауқұлаққа қарсы, тыныштандыратын әсер береді. |
| Кокамидопропил бетаин | 5.75 | 5.75 | 10.40 | 10.40 | 5.4 | Жұмсақ беттік белсенді зат, теріні зақымдамай тазалайды |
| Коко-бетаин | 10.75 | 10.75 | 5.75 | 10.75 | 5.75 | Жұмсақ беттік белсенді зат |
| Глицерин | 8.0 | 10.0 | 15.0 | 8.0 | 4.0 | Теріге терең еніп, ылғалдандырады. |
| Хош иіс беруші Роза гүлінің майы | q.s. | q.s. | q.s. | q.s. | q.s. | Тартымды хош иіс беруші |
| Консервант Лимон қышқылы | q.s. | q.s. | q.s. | q.s. | q.s. | Микроорганизмдердің енуінен қорғап, жарамдылық мерзімін арттырады. |

1-үлгі бойынша алынған тазартқыш-пенка жасалған уақыттан соң біртекті қалыпқа келмеді.

2-үлгі бойынша алынған тазартқыш-пенка 2 сағат өткен соң, біртекті қалпын жоғалтты.

3-үлгі бойынша алынған тазартқыш-пенканың 3 күн өткен соң, иісі бұзылып, патогенді зең саңырауқұлақтары пайда болды.

4-үлгі бойынша алынған тазартқыш-пенка біртекті қалыпта болып, сақтауға қойылды. 9 ай уақыт өткен соң өз қалпын жоғалтпады.

5-үлгі бойынша алынған тазартқыш-пенканың көбіктену қабілеті аз болды, бірақ біртекті қалпын жоғалтпады.

Нәтижесінде 4-үлгі оңтайлы болып саналды. Сапа спецификациясы МЕСТ-31679–2012 бойынша жасалды (2-кесте).

2 - к е с т е

**Port&Ai тазартқыш-пенканың сапа спецификациясы**

| Технологиялық көрсеткіштері | Сипаттамасы |
|---|---|
| Түсі | Ақ түсті |
| Иісі | Тартымды |
| pH мәні | 5,75 |
| Ауыр металдар As, Pb, Hg | Табылған жоқ |
| Микробиологиялық көрсеткіштері | Аэробты бактериялар, саңырауқұлақтар, энтеробактериялар саны 10 төмен;<br>Salmonella, E.coli штамдары жоқ. |
| Токсикологиялық (in vitro) көрсеткіштері | HaCat жасушаларының өміршеңдігі 95 % көрсетті |

Port&Ai тазартқыш-пенканың құрамындағы полифенолдар мен флаваноидтар мөлшері, антиоксиданттық белсенділігі және цитотоксикалық әсері *in vitro* әдіспен анықталды.

*Антиоксиданттық белсенділік*

Антиоксиданттық потенциал DPPH радикалды жою сынағы бойынша алынған мәліметтерге сүйене отырып, әр концентрацияның бос радикалдардың санын азайту қабілеті әртүрлі екендігі анықталды. Зерттеу нәтижелері 3-кестеде көрсетілген (3-кесте).

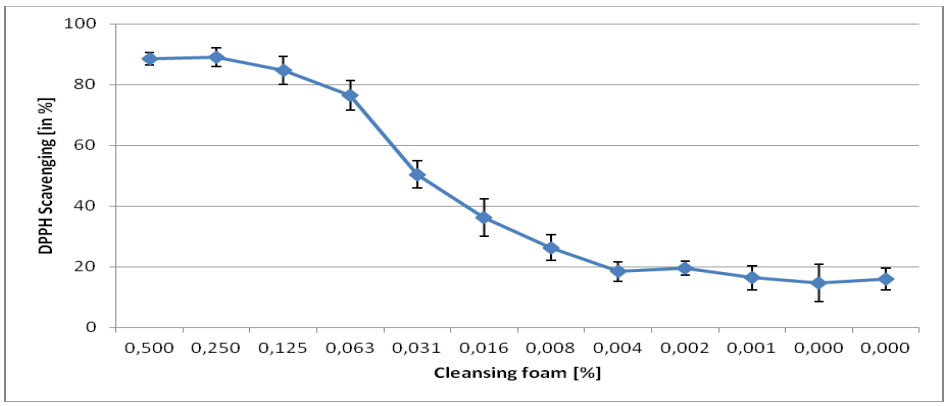
DPPH радикалдарын жоюдың ең жоғары қабілеті 250 мг/мл 89,1±0,54 көрсеткішіне тең. Ең төменгі 0,24 % концентрациясында бос радикалдардың деңгейі шамамен 15,9 % құрады. Талданған шамаларда концентрация мен тазартқыш-пенканың антиоксиданттық потенциалы арасындағы корреляция байқалды. Қолданылатын концентрация неғұрлым жоғары болса, бос радикалдардың қайта қалпына келу күші соғұрлым жоғары болады (1-сурет).

Аскорбин қышқылына қатысты DPPH-сынағы 96,4±0,83 ингибирлеу пайызын көрсетті, ал тазартқыш-пенканың антиоксиданттық белсенділігі 89,1±0,54 көрсетті.

3 - к е с т е

**Port&Ai тазартқыш-пенкадағы нейтралданған DPPH мөлшері**

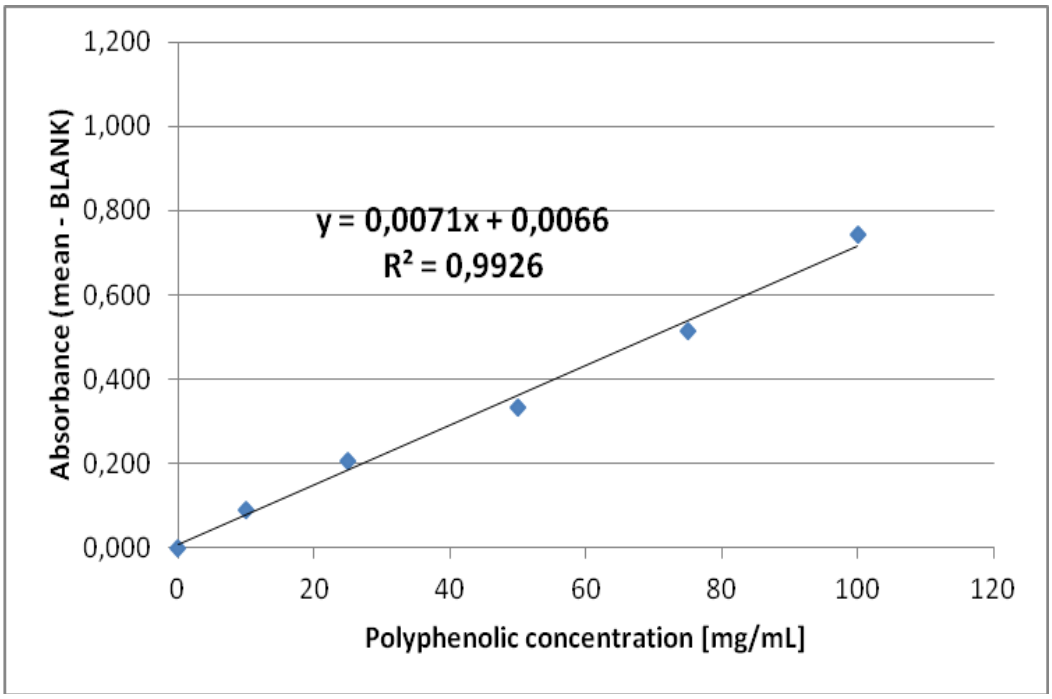
| Концентрация | 5100 мг/мл | 250 мг/мл | 12,5 мг/мл | 62,5 мг/мл | 31,25 мг/мл | 15,63 мг/мл | 7,81 мг/мл | 3,91 мг/мл | 1,95мг/мл | 0,98 мг/мл | 0,49 %мг/мл | 0,24 мг/мл |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Нейтралданған DPPH % | 87,0 | 88,5 | 84,3 | 67,9 | 53,0 | 42,8 | 26,1 | 16,1 | 24,1 | 16,8 | 22,9 | 10,1 |
| | 89,5 | 89,6 | 84,0 | 87,4 | 54,6 | 34,8 | 25,8 | 20,2 | 21,2 | 15,9 | 11,0 | 20,8 |
| | 89,1 | 89,1 | 85,6 | 74,1 | 43,5 | 30,6 | 26,7 | 19,0 | 13, | 16,3 | 9,9 | 16,8 |
| Арифметикалық орта | 88,6 | 89,1 | 84,6 | 76,4 | 50,4 | 36,1 | 26,2 | 18,4 | 19,6 | 16,3 | 14,6 | 15,9 |




1-сурет. Port-Ai тазартқыш-пенкадағы нейтралданған DPPH радикалының пайыздық көрсеткіші арасындағы корреляция

*Жалпы фенол мөлшері*

Әр түрлі концентрациядағы галл қышқылының ерітінділері дайындалды. Олар: 100, 75, 50, 25, 10, 0 мг/л. Содан кейін тазартқыш-пенкадағы галл қышқылының ерітінділері үшін калибрлеу кестесі жасалды. Полихромды қосылыстардың саны галл қышқылы көбігімен бөлінген калибрлеу профиліне сәйкес бөлінді (2-сурет).




2-сурет. Тазартқыш-пенканың галл қышқылымен калибрлеу сызығы

Талдау тазартқыш-пенканың төрт түрлі концентрациясымен жүргізілді (10 мг/мл, 25 мг/мл, 50 мг/мл, және 100 мг/мл). Нәтижелер фенолдық қосылыстардың ең көп мөлшері 10 мг/мл тазартқыш-пенкада — 36, 622 мг/мл (4-кесте) анықталғанын көрсетеді. Бұл қосылыстардың ең аз мөлшерін 100 мг/мл концентрациясында — 8, 948 мг/мл шамасын көрсетті.

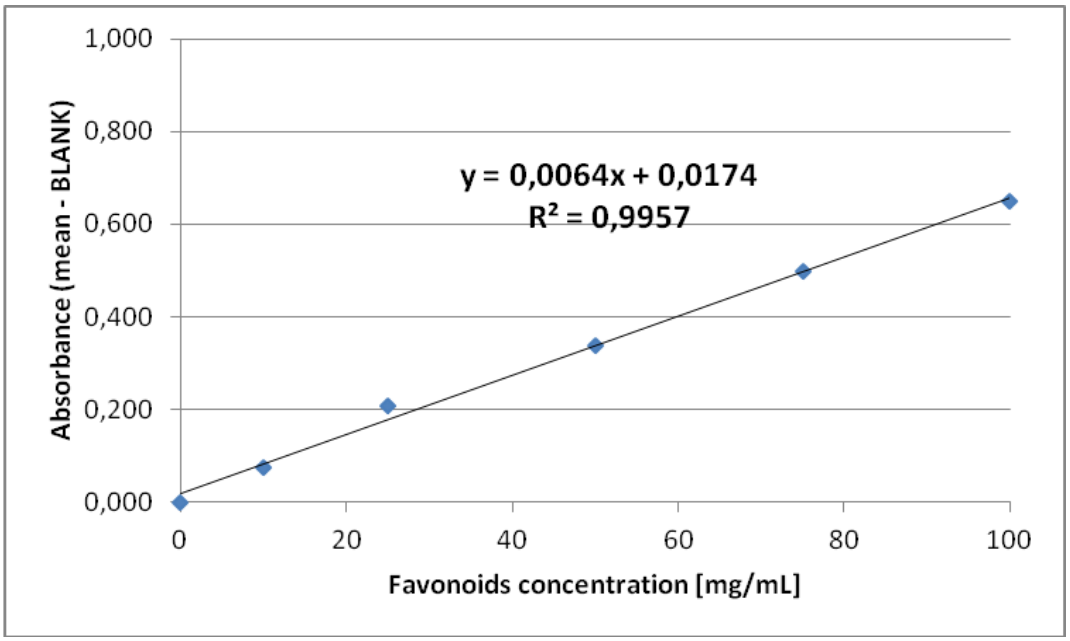
4 - к е с т е

**Port&Ai тазартқыш-пенка құрамындағы полифенолдар мөлшері**

| Port&Ai тазартқыш-пенка ерітінділері, концентрацияда [mg/mL] | Port&Ai сынама № 1 | Port&Ai сынама № 2 | Port&Ai сынама № 3 | Полифенол мөлшері [mg/mL] | | | Мәні |
|---|---|---|---|---|---|---|---|
| 10 | 0,3394 | 0,3414 | 0,3503 | 36,122 | 36,355 | 37,390 | 36,622 |
| 25 | 01981 | 0,1708 | 0,2044 | 19,767 | 16,593 | 20,500 | 18,953 |
| 50 | 0,1218 | 0,1512 | 0,1968 | 10,884 | 14,302 | 19,605 | 14,930 |
| 100 | 0,0806 | 0,1036 | 0,1326 | 6,041 | 8,715 | 12,087 | 8,948 |

*Флавоноидтардың жалпы мөлшері*

Әр түрлі концентрациядағы кверцетин ерітінділері дайындалды: 100, 75, 50, 25, 10, 0 мг / л. Содан кейін тазартқыш-пенкадағы кверцетин ерітінділері үшін калибрлеу кестесі жасалды. Кверцетинді калибрлеу критерийлері бойынша сандық анықтау жүргізілді (3-сурет).




3-сурет. Тазартқыш-пенкадағы кверцетинге арналған калибрлеу сызығы

Талдау үш түрлі тазартқыш-пенка концентрациясы үшін жүргізілді (50 мг/мл, 20 мг/мл, 10 мг/мл) (5-кесте). Port&Ai тазартқыш-пенка құрамында флаваноидтардың ең аз мөлшері 9, 896 мг/мл мәніне ие болды.

5 - к е с т е

**Port&Ai тазартқыш-пенка құрамындағы флаваноидтар мөлшері**

| Port&Ai тазартқыш-пенканың концентрациясы [mg/mL] | Флаваноид мөлшері [mg/mL] | | | Мәні |
|---|---|---|---|---|
| 50 | 9,703 | 10,719 | 11,484 | 21,271 |
| 20 | 6,055 | 3,586 | 2,367 | 16,010 |
| 10 | 1,063 | 0,875 | 1,031 | 9,896 |

*Цитоуыттылық*

Тазартқыш-пенканың қауіпсіздігі мен уыттылығын бағалаудағы өте маңызды аспект жасушалардың метаболизмі мен өміршеңдігіне әсерін бағалау болып табылады. Зерттеуде қолданылған сынақтар — бейтарап қызыл талдау, зерттелетін тазартқыш-пенканың 5 %, 2 % концентрациясында зерттеу ерітінділері дайындалды (6-кесте).

ISO 10993–5 стандарты негізінде, цитотоксикалық тест нәтижесінде жасушалардың өміршеңдігі 30 %-ға төмендесе цитотоксикалық әсерді бар екендігін көрсетеді [10]. Бірақ, жасушалар өміршеңдігі 95 % көрсетті, яғни тазартқыш-пенканың цитотоксикалық әсері жоқ, қауіпсіз екендігі дәлелденді (6-кесте).

6 - к е с т е

**Port&Ai тазартқыш-пенканың жасушаларға уыттылығын бағалау мөлшері**

| Port&Ai сынамалары | Өміршеңдігі, % | | | | | Орташа мәні |
|---|---|---|---|---|---|---|
| | Port&Ai сынама № 1 | Port&Ai сынама № 2 | Port&Ai сынама № 3 | Port&Ai сынама № 4 | Port&Ai сынама № 5 | |
| Тазартқыш-пенка 5 % | 96,3623 | 95,5379 | 94,7823 | 92,3244 | 96,4662 | 95,4662 |
| Тазартқыш-пенка 2 % | 98,4691 | 93,7289 | 96,8890 | 92,6755 | 94,4845 | 95,4494 |

*Қорытынды*

Port&Ai тазартқыш-пенканың оңтайлы құрамы алынды: тазартылған су, *Portulaca oleracea* L. ультрадыбыстық экстракты, кокамидопропил бетаин, коко-бетаин, глицерин, хош иіс беруші роза гүлінің майы, консервант ретінде лимон қышқылы.

Зерттеу нәтижесі бойынша Port&Ai тазартқыш-пенканың құрамындағы полифенолдар 36,622 мг/мл (λ = 740 нм) және флавоноидтар 33,612 мг/мл (λ = 415 нм) сандық көрсеткішіне ие болды.

Port&Ai тазартқыш-пенканың антиоксиданттық белсенділігі DPPH радикалдарын жоюдың ең жоғары қабілетімен анықталды: 250 мг/мл концентрациясында 89,1±0,54.

Port&Ai тазартқыш-пенканың қауіпсіздігі мен уыттылығын бағалау HaCat жасушаларымен *in vitro* әдісімен бағалау нәтижесінде жасушалар өміршеңдігі 95 % көрсетіп, қауіпсіз екендігі дәлелденді. Port&Ai тазартқыш-пенкамен зерттеу жұмыстары жалғасуда.

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## Определение антиоксидантной активности и безопасность очищающей пенки с ультразвуковым экстрактом Портулака огородного (*Portulaca oleracea* L.)

В настоящее время растет количество космецевтических средств по уходу за кожей, производимых из растительного сырья. При воздействии солнечного света в коже образуются свободные радикалы, которые приводят к воспалительным реакциям на уровне эпидермиса и дермы соответственно. Для решения этой проблемы на помощь приходят космецевтические средства, оказывающие антиоксидантное действие на кожу. Антиоксидантная активность очищающей пенки с ультразвуковым экстрактом Портулака огородного (*Portulaca oleracea* L.) определялась с помощью теста на удаление радикалов DPPH, общее количество полифенолов и флаваноидов устанавливалось спектрофотометрическим методом, безопасность и цитотоксическая активность очищающей пенки определялись клетками HaCat (*in vitro*). По результатам выявлено, что антиоксидантная активность

очищающей пенки с ультразвуковым экстрактом Портулака огородного (*Portulaca oleracea* L.) составляет 89,1±0,54, а жизнеспособность клеток — 95 %.

*Ключевые слова:* очищающая пенка, ультразвуковой экстракт, экстракт портулака огородного, антиоксидантная активность, полифенолы, флаваноиды, жизнеспособность клеток.

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## Determination of antioxidant activity and safety of cleansing foam with ultrasonic extract of portulaca oleracea (*Portulaca oleracea* L.)

Currently, the number of cosmeceutical skin care products produced from vegetable raw materials is growing. When exposed to sunlight, free radicals are formed in the skin, which lead to inflammatory reactions at the level of the epidermis and dermis, respectively. To solve this problem, cosmeceuticals that have an antioxidant effect on the skin come to the rescue. The antioxidant activity of the cleansing foam with ultrasonic extract of *Portulaca oleracea* L. was determined using a DPPH radical removal test, the total amount of polyphenols and flavonoids was determined by spectrophotometric method, the safety and cytotoxic activity of the cleansing foam were determined by HaCaT cells (in vitro). According to the results, it was found that the antioxidant activity of the cleansing foam with ultrasonic extract of *Portulaca oleracea* L. is 89.1± 0.54, and cell viability is 95 %.

*Keywords:* cleansing foam, ultrasonic extract, portulaca oleracea extract, antioxidant activity, polyphenols, flavanoids, cell viability.

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# ГЕОГРАФИЯ
# GEOGRAPHY

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# Dynamics of accumulation of heavy metals in *Lissachatina fulica* living in contaminated geographical area of East Kazakhstan

In the article presents the results of a study of the dynamics of the accumulation of heavy metals and macroelements in the body of snails in the vicinity of the Ulbi metallurgical plant in the city of Ust-Kamenogorsk, East Kazakhstan region, where heavy metals are found in large quantities. Experimental work was carried out on 40 *Lissachatina fulica* snails over a period of 48 days. During the work, the snails were fed with soil contaminated with heavy metals and macroelements, and the dynamics of the accumulation of chemical elements in the snails' bodies were studied every week. In the course of studying the accumulation of macroelements and heavy metals, experimental animals were prepared using the method of two-stage euthanasia in compliance with ethical standards. During the study, mass spectrometry (ISP-MS) analyzed the amount of elements Ca, K, Mg, N, V, Co, Pb, As, Sr, Cu, Zn in the bodies of intact animals, control and research groups. A large amount of heavy metals and macroelements was found in the body of the animals of the research group. The amount of heavy metals accumulated in the body of snails increased on the 32nd day and then decreased again ($P<0.001$). According to research results, it is known that heavy metals accumulate in the body in one month, which means that this environmental situation is one of the problems that requires an urgent solution. Although the accumulation of heavy metals in the soil of geographical area and their amount in the soil were studied, their accumulation in living organisms, including snails, and the dynamics of their accumulation as a result of many years of research have been studied for the first time.

*Keywords:* geographical area, heavy metals, macroelements, bioindicator, *Lissachatina fulica*, mass spectrometry, environmental problem, accumulation.

## *Introduction*

According to the World Health Organization (WHO), human health is 20 % dependent on environmental conditions. Humanity is constantly exposed to the influence of environmental pollution factors. Radiation and chemical effects were especially harmful for people of ancient society. And now, the process of scientific and technological development has led to the fact that humanity is exposed to pollution factors from artificial sources. This stands for the reason of importance to study the impact of heavy metal production in the fields of medicine, ecology, radiobiology, and nutrition.

According to the data on soil pollution in the vicinity of the Ulba metallurgical plant in Ust-Kamenogorsk, the largest amount of uranium is concentrated in the snow cover located 300 meters north of the Ulba metallurgical plant, with a concentration of 1.7–19.7 mg/kg, the average content of uranium in the soil of Ust-Kamenogorsk was 2.9 mg/kg. The maximum concentration of thorium was determined in the soil

located 2 km from the north-west of the Ulba metallurgical plant [1]. In addition, academician of the foundations of Russian medical science Buldakov L.A. presents the positive effects of heavy metals on the body in his articles in the world literature [2]. Furthermore, according to a study by Italian scientists of workers who are under the Daily influence of heavy metals, noticed such changes in the organs of workers as hardening of the carotid arteries. And it is known that these changes lead to diseases such as premature aging and coronary atherosclerosis [3]. In addition, there are works by Chinese scientists who studied the accumulation of heavy metals in the bodies of aquatic animals to study sea pollution. The results of the study showed that the content of CD, Cu and Zn in some samples of gastropods and oysters exceeded the permissible levels established by WHO. Scientists have concluded that due to its unique ability to bioaccumulate, *Rapana venosa* and *Ruditapes philippinarum* can be used as biomonitors to control water pollution by heavy metals [4]. Meanwhile, the study conducted by Yuyu Jia together with her colleagues determined that the values of the metal pollution index (MPI-MLI) for mollusk species were placed in descending order C. fluminea > A. woodiana > S. cancellata > P. eximius > P. Canaliculata, and the need to take into account the environmental parameters associated with the season when using double-framed mollusks as indicators is noted by Indonesian scientists [5, 6].

In addition, Middle Mexican scientists I. Gaso, N. Segovia and O. Morton determined the levels of accumulation of heavy metals in the body of snails by using soil samples and wild *Helix aspersa Muller* snail types as bioindicators of radioactivity and heavy metals in their research. Accordingly, the bioindicator property of snails is directly related to the ability of heavy metals to accumulate in their body, and this phenomenon has been fully proven due to metallothioneine proteins capable of forming bonds with metals in their body [7].

From the mentioned literature, we can determine that the accumulation of heavy metals and macroelements in the substrate in the body of snails has been studied. However, the study of the dynamics of the accumulation of chemical elements aggregated in the soil near the geographical area — Ulba metallurgical plant, which is engaged in the production of heavy metals in the city of Ust-Kamenogorsk, for a certain period of time in the snail's body was not carried out. Accordingly, the purpose of our research was to study the dynamics of the accumulation of heavy elements in the body of *Lissachatina fulica* — a bioindicator of environmental pollution in laboratory conditions. In order to achieve the goal set, the following steps were established:

1. Adaptation of Lissachatina fulica snails to laboratory conditions, determination of the amount of chemical elements in the soil, which is a substrate for them.

2. Study of the dynamics of accumulation of heavy metals in the substrate in the body of experimental animals using a 4-day interval.

3. Study of accumulation of macroelements in Lissachatina fulica organism placed in polluted soil.

4. Correlation study of accumulated heavy metals and macroelements in the body of bioindicators — snails living in the soil of Ust-Kamenogorsk.

## *Materials and methods*

The research work was carried out in the laboratory at the Nazarbayev Intellectual School of Physics and Mathematics in Semey. 40 hermaphrodite *Lissachatina fulica* snails weighing 18±2 grams, 4±0.5 cm long and 2 cm high were taken as the object of study. 5 research objects were placed in each container with a length of 25 cm and a width of 15 cm. In order to adapt to the conditions of Experimental Research, bioobjects were fed for 14 days without soil, with a single sort of cucumbers (Table 1).

Table 1

**Division of animals into experimental groups**

| Research series | Number of animals |
|---|---|
| 1 | 2 |
| Determination of the amount of chemicals in the body of biobjects before initial research — placement on the substrate — control group | 5 |
| Determination of the amount of chemical elements in the first 4 days of the organism of snails placed in the substrate (soil) — "4$^{th}$ day, n=5" group | 5 |
| Determination of the content of chemical elements in the body of bioindicators 8 days after placement on the substrate — "8$^{th}$ day, n=5" group | 5 |

Continuation of Table 1.

| 1 | 2 |
|---|---|
| Determination of the content of chemical elements in the body of bioindicators 16 days after placement on the substrate — "16th day, n=5" group | 5 |
| Determination of the content of chemical elements in the body of bioindicators 32 days after placement on the substrate — "32nd day, n=5" group | 5 |
| Determination of the content of chemical elements in the body of bioindicators 40 days after placement on the substrate — "40th day, n=5" group | 5 |
| Determination of the amount of chemical elements in 48 days of the organism of bioindicators placed on the substrate — "48th day, n=5" group | 5 |
| Determination of the amount of chemical elements in 48 days of the organism of bioindicators not placed on the substrate — "48th day without substrate, n=5" group | 5 |
| Total | 40 |

In order to determine the content of heavy metals in the organism of snails, two-stage euthanasia was carried out before the analysis. The progress of euthanasia work was carried out through the research methodology proposed by Cody R. Gilbertson and Jeffrey D. Wyatt scientists in 2016. To determine the composition of the soil and the content of heavy metals and macroelements in the snail's body, mass spectrometry analysis was conducted in the Educational Center "Institute of Radiation Safety and Ecology" in Kurchatov, according to "General requirements for the competence of testing and Calibration Laboratories" to the requirements of Gost ISO/IEC 17025–2009 in the laboratory of elemental analysis accredited in the accreditation system of the Republic of Kazakhstan. During the analysis, the amount of about 14 chemical elements was determined: heavy metal group: V, Co, Ni, Cu, Zn, As, Cd, Pb, Cr, Cu, Sr, Cd, U. Group of macroelements: K, Ca, Mg, Na.

Statistical processing of the material was carried out by calculating the value of ±m, the average error of variational statistics according to the T-student method.

*Results*

In the course of the work, the dynamics of the accumulation of heavy metals and macroelements in the body of bioindicators was studied, the results of the study are shown in Tables 2–4 and Figures 1–3. According to the first and second graphs, heavy metals are absorbed by the snail's body between 0–4 days, as it can be observed that a given amount is higher ($p<0.001$) than the control group.

Table 2

**Content of chemical elements in the substrate, mg/kg**

| Chemical elements | V | Cr | Co | Ni | Cu | Zn | As |
|---|---|---|---|---|---|---|---|
| Substrate | 83.00±13.00 | 130.00±20.00 | 14.00±2.10 | 40.00±6.30 | 47.00±7.00 | 190.00±29.00 | 10.60±1.70 |
| | Cd | Pb | U | K | Na | Mg | Ca |
| | 1.60±0.44 | 61.00±9.50 | 0.50±0.08 | 9400±1400 | 1100±160 | 9300±1400 | 14.0±2.10 |

Table 3

**The content of heavy metals in the body of snails, mg/kg**

| Heavy metal | Control group | 4th day | 8th day | 16th day | 32nd day | 40th day | 48th day |
|---|---|---|---|---|---|---|---|
| V | 0.06±0.01 | 2.60±0.40** | 2.00±0.31** | 2.00±0.30** | 2.70±0.42** | 0.81±0.13** | 1.40±0.23** |
| Cr | 0.32±0.05 | 1.40±0.22** | 0.74±0.12** | 0.60±0.09** | 0.05±0.08** | 0.03±0.05** | 1.10±0.18** |
| Co | 0.12±0.02 | 3.00±0.47** | 1.80±0.27** | 2.30±0.36** | 2.50±0.38** | 1.00±0.16** | 2.40±0.37** |
| Ni | 0.27±0.05 | 5.80±0.90** | 2.90±0.45** | 3.80±0.59** | 3.70±0.57** | 2.30±0.36** | 4.30±0.68** |
| Cu | 81.0±13.0 | 32.0±5.00** | 36.0±6.00** | 41.0±6.00** | 48.0±7.00** | 34.0±5.00** | 59.0±9.00** |
| Zn | 50.0±8.00 | 130±20.0** | 110±17.0** | 130±20.0** | 180±27.0** | 58.0±9.00** | 110.0±17.0** |
| As | 2.30±0.36 | 5.20±0.81** | 4.30±0.67** | 4.60±0.71** | 6.30±0.97** | 3.10±0.51** | 6.10±0.98** |
| Cd | 0.65±0.11 | 1.80±0.28** | 1.60±0.24** | 2.20±0.35** | 3.20±0.05** | 1.20±0.21** | 2.60±0.42** |
| Pb | 0.61±0.10 | 2.50±0.38** | 2.00±0.30** | 2.30±0.36** | 3.60±0.55** | 1.50±0.24** | 3.10±0.48** |
| U | <0.003 | 0.41±0.06** | 0.19±0.03** | 0.17±0.03** | 0.36±0.03** | <0.003** | 0.17±0.03** |
| ** – accuracy of difference according to the control group ($p<0.001$) | | | | | | | |

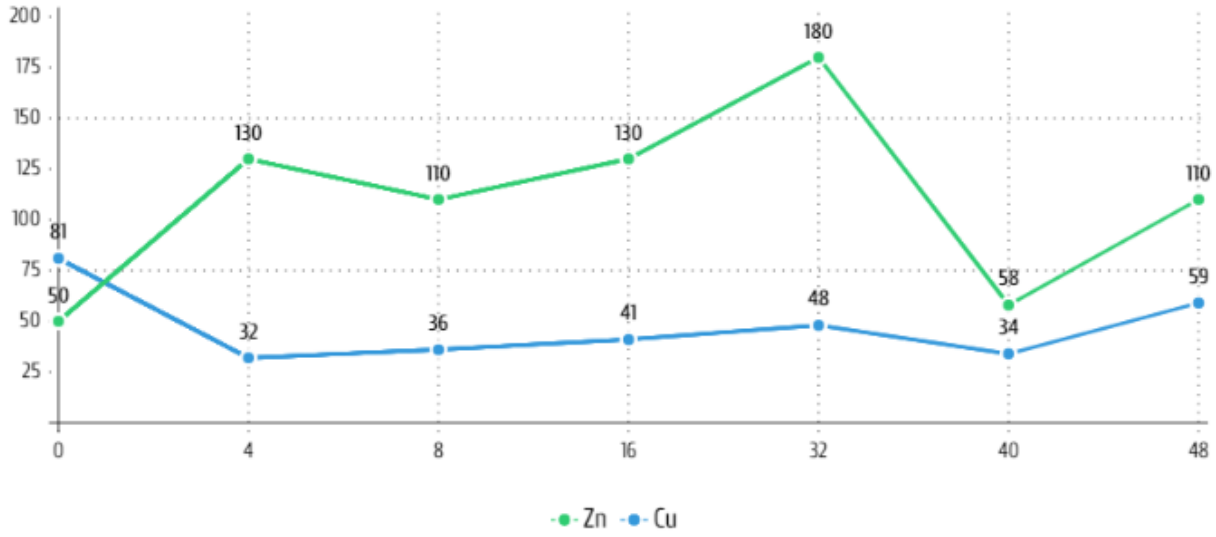
Table 4

**Content of macroelements in the body of snails, mg/kg**

| Macroelement | Control group | 4th day | 8th day | 16th day | 32nd day | 40th day | 48th day |
|---|---|---|---|---|---|---|---|
| K | 6400±940 | 6900±1100 | 5300±790 | 4800±710 | 5200±770 | 3000±440 | 5000±730 |
| Na | 2500±370 | 3500±590 | 2600±380 | 2600±380 | 2400±400 | 2000±290 | 2600±380 |
| Mg | 2700±390 | 3300±580 | 3400±500 | 3200±480 | 3800±560 | 1900±290 | 3400±510 |
| Ca | 12.0±1.8 | 25.0±4.2** | 8.8±1.3* | 9.9±1.5 | 12.0±1.7 | 5.3±0.8* | 14.0±2.1 |
| * – accuracy of difference according to the control group (p<0.05)<br>** – accuracy of difference according to the control group (p<0. 0.001) | | | | | | | |

However, it can be noted that up to the next 8 days, the amount decreases, and the snail's body tries to get rid of excess heavy metals. We find that heavy metals increase again up to the 16th day and accumulate in the snail's body. In the course of the study, according to the indicators of the content of heavy metals in the bodies of the biobject, you can find interesting data: according to the 32nd day, the indicators take the highest values on the graph.

Figure 1. Dynamics of accumulation of heavy metals




One of the most abundant accumulating heavy metals, Zn, showed a significantly higher value, reaching 50.0±8.00 mg/kg at 32 — day (p<0.001) to 180±27.0 mg/kg. Later, by the 40th day, the amount of heavy metals decreased again, but the amount of heavy metals was higher than the initial control group. If in the indicators of the control group the content of the element cobalt was 0.12±0.02 mg/kg, then within 40 days it increased by 0.88 mg/kg. However, when it comes to day 48, the size increases again, however, the size takes on a much lower value than on day 32. For example, the cadmium content on day 32 shows a maximum of 3.20±0.05 mg/kg, while on day 48 it is 2.60±0.42 mg/kg.

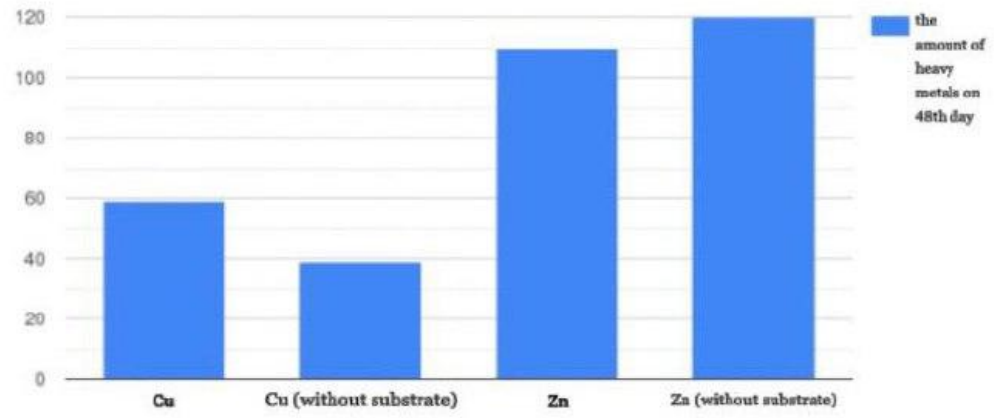



Figure 2. Differences in the dynamics of accumulation of heavy metals in the body of living and non-living snails on the substrate

From the graphs, we can observe a significant difference in the indicators of heavy metals in the body of snails that lived in soil and without soil until the 48th day. The content of heavy metals in the body of snails that lived without a substrate assumes a lower indicator than the amount of heavy metals accumulated in the body of snails that lived in the soil for 48 days. For example, if nickel is 4.30±0.68 mg/kg on Day 48, the nickel content in the body of snails living without a substrate is only 1.00±0.16 mg/kg, which is about 4 times less ($p<0.\ 0.001$).

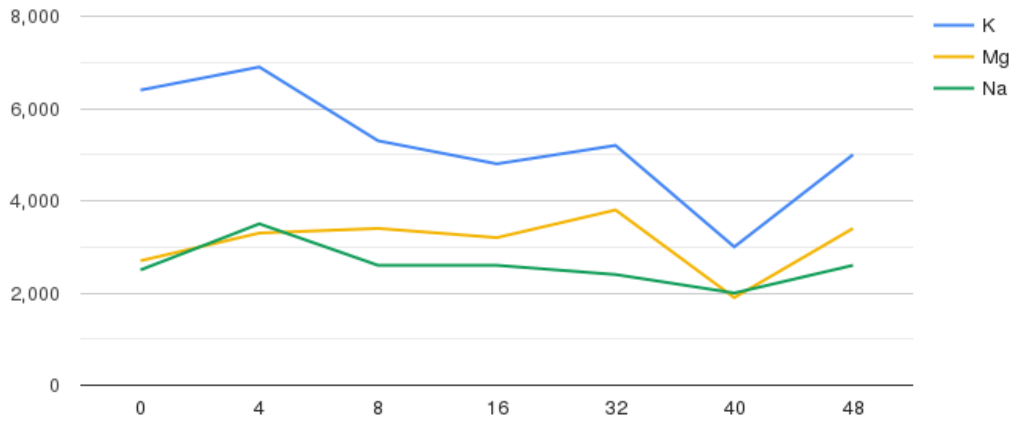



Figure 3. Dynamics of accumulation of macroelements

Indicators of changes in the accumulation of macroelements are similar to the graph of the dynamics of the accumulation of heavy metals (Fig. 3). Macroelements are absorbed by the snail's body between 0–4 days, as it can be seen that a given amount is higher than the control group ($p<0.001$). During the 4th day of the experiment, it can be seen that the content of macroelements in the bodies of the biobject has the highest values. One of the most abundant accumulating macroelements, potassium, increased from 6400±940 mg/kg to 6900±1100 mg/kg on Day 4 ($p<0.05$), showing a significantly higher value. It can be noted that up to the next 8 days, its amount decreases, and the snail's body tries to get rid of the excess accumulated amount of macroelements. It can be seen that the content of macroelements in the snail's body increases in small quantities again at intervals of up to the 16th day and accumulates throughout the biobject. On day 40, the

amount of heavy metals decreased again compared to day 32, but the amount of macroelements was lower than the initial control group. In the last 48 days, the amount of macroelements increased again, showing significantly more values than in the 32nd day. If in the indicators of a group of snails that lived in the substrate for 32 days, the content of the most necessary and important element calcium in snail frogs was 12.0 mg/kg, then by the 48th day it increased to 14 mg/kg.

It can be said that during the period of one month, the amount of heavy metal and macroelements decreases at first, and then reaches the greatest values (Fig. 1–3). However, after a period of time of one month, we can observe that the amount of heavy metals continues to decline. For example, if the most dangerous cadmium content in the snail's body under normal conditions is 0.65±0.11 mg/kg, on the 32nd day the maximum value is 3.20 mg/kg. The most interesting thing is that it drops to 2.60 mg/kg between 48 days. And the content of important macroelements in the organisms of snails, on the contrary, increases. For example, the content of calcium, the main forming component of the snail shell, under normal conditions was 12.0±1.8 mg/kg, and during 48 days increased by 14.0±2.1 mg/kg due to a decrease in the content of heavy metals. In addition, if we pay attention to the results of research by world scientists, it has been proven that an excess of some heavy metals, namely Pb and Cd heavy metals, negatively affects the amount of macroelements [3, 7]. For example, an excess of the element cadmium disrupts the absorption of calcium ions, and a lack of iron and calcium elements increases the toxicity of lead. According to the control group, taking into account the intervals of day 32 and day 48, we can conclude that the amount of heavy metals gradually decreases after day 40, and the amount of macroelements tries to accumulate in the body. In the organism of snails, the dynamics of chemical elements increases between the initial interval and then decreases sharply, however, this size indicates a value higher than normal, that is, the control group. For example, a strong relationship between CR and Na elements was established, and a decrease in Cr content between 8–16 and 16–32 days also led to a decrease in sodium in the macroelement dynamics figure. However, after the 40th day, it can be determined that the snail's body is trying to get rid of excess heavy metals by increasing the amount of macroelements.

This corresponds to the “triad” of stress, which was emphasized by G. Selye as the total force of external influences affecting the body and its response to the body, that is, the period of alarm to 32 days and resistance after 40 days.

## *Conclusions*

1. The content of heavy metals in the soil, which is a substrate for Lissachatina fulica snails, had a significantly high value.

2. During a 48-day study of the dynamics of accumulation of heavy metals in the body of experimental animals using a 4-day interval, the amount of heavy metals showed the highest value on the 32nd day.

3. In the study of the accumulation of macroelements in Lissachatina fulica, which was placed in polluted soil, their amount was on the contrary increased.

4. It was found that the amount of heavy metal and macroelements accumulated in the body of bioindicators — snails living in the soil of Ust-Kamenogorsk depends on time. After 40 days in the environment of a new geographical object, the process of adaptation begins in the body of snails.

## *Research recommendation*

By analyzing the dynamics of the accumulation of studied heavy metals, snails can be used as bioindicators in order to determine the level of pollution of the environment under the influence of antropogenic factors. The accumulation of heavy metals reaches its peak on day 32. The results of the research obtained are fundamental research for ecologists, biologists and scientists interested in environmental issues.

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## Шығыс Қазақстанның ластанған географиялық объектісінде мекендейтін *Lissachatina fulica* организмінде ауыр металдардың жинақталу динамикасы

Мақалада ауыр металдар аса көп кездесетін Шығыс Қазақстан облысы Өскемен қаласындағы Үлбі металлургиялық зауытының маңайындағы ауыр металдар мен макроэлементтердің ұлулардың ағзасына жинақталу динамикасын зерттеу нәтижелері берілген. Эксперименттік жұмыс 40 *Lissachatina fulica* ұлуларына 48 күн аралығында жүргізілген. Жұмыс барысында ұлулар ауыр металдар мен макроэлементтермен ластанған топырақпен қоректендіріліп, апта сайын ұлу ағзасындағы химиялық элементтердің жинақталу динамикасы зерттелген. Макроэлементтер мен ауыр металдардың жинақталуын зерттеу барысында эксперименттік жануарларды препараттау этикалық нормаларды сақтай отырып, екі сатылы эвтаназия әдісі арқылы жүзеге асырылған. Масс-спектрометрия (ISP–MS) әдісімен зерттеу барысында бақылау және зерттеу топтарының бұзылмаған жануарларының денелеріндегі Ca, K, Mg, N, V, Co, Pb, As, Sr, Cu, Zn элементтерінің санын талдады. Зерттеу тобының жануарларының денесінде көптеген ауыр металдар мен макронутриенттер табылды. Ұлулардың денесінде жинақталған ауыр металдардың саны 32-ші күні өсті, содан кейін қайтадан төмендеді ($p<0,001$). Зерттеу нәтижелері бойынша ауыр металдар денеде бір айда жиналатыны белгілі, яғни бұл экологиялық жағдайда шұғыл шешуді қажет ететін мәселелердің бірі болып саналады. Топырақтағы ауыр металдардың жиналуы және олардың топырақтағы мөлшері зерттелгенімен, олардың тірі ағзада, соның ішінде ұлуларда жиналуы және олардың көпжылдық зерттеулерден жинақталу динамикасы алғаш рет зерттеліп отыр.

*Кілт сөздер:* географиялық объект, ауыр металдар, макроэлементтер, биоиндикатор, *Lissachatina fulica*, масс-спектрометрия, экологиялық мәселе, аккумуляция.

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## Динамика накопления тяжелых металлов у *Lissachatina fulica*, обитающей в загрязненном географическом объекте Восточного Казахстана

В статье представлены результаты изучения динамики накопления тяжелых металлов и макроэлементов в организме улиток в окрестностях Ульбийского металлургического завода города Усть-Каменогорска Восточно-Казахстанской области, где тяжелые металлы встречаются в большом количестве. Экспериментальная работа проводилась на 40 улитках *Lissachatina fulica* в течение 48 дней. В ходе работы улиток кормили почвой, загрязненной тяжелыми металлами и макроэлементами, и каждую неделю изучали динамику накопления химических элементов в организме улиток. В ходе изучения накопления макроэлементов и тяжелых металлов подготовку экспериментальных животных проводили методом двуэтапной эвтаназии с соблюдением этических норм. В ходе исследования методом масс-спектрометрии (ISP–MS) анализировали количество элементов Ca, K, Mg, N, V, Co, Pb, As, Sr, Cu, Zn в телах интактных животных контрольной и исследовательской групп. В организме животных исследовательской группы обнаружено большое количество тяжелых металлов и макроэлементов. Количество тяжелых металлов, накопленных в организме улиток, увеличивалось на 32-е сутки, а затем снова снижалось ($P<0,001$). По результатам исследований известно, что тяжелые металлы накап-

ливаются в организме за один месяц, а это означает, что данная экологическая ситуация является одной из проблем, требующих безотлагательного решения. Хотя накопление тяжелых металлов в почве и их количество в почве изучены, накопление их в живых организмах, в том числе улиток, и динамика их накопления в результате многолетних исследований изучаются впервые.

*Ключевые слова*: географический объект, тяжелые металлы, макроэлементы, биоиндикатор, *Lissachatina fulica*, масс-спектрометрия, экологическая проблема, аккумуляция.

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# Analysis of long-term dynamics of air temperature fluctuations in the Nura River basin

In recent decades, a different frequency of dry years has been observed in the Nura River basin in Central Kazakhstan. This article examines the trend of changes in temperature fluctuations over a long period using materials from a separate climate element from the Besoba and Karaganda meteorological stations located in the Nura River basin and the Arkalyk meteorological station located outside the basin, to the west of it, but characterized by similar natural conditions. In the course of research over an 81-year time interval from 1939 to 2019, the absolute and relative frequency of average monthly air temperatures in July in the Nura River basin were established. The meteorological stations under consideration are part of the global international network of meteorological data of Kazhydromet and have constant, accurate series of values of meteorological indicators. Based on the use of the method of statistical analysis, an assessment of the spatio-temporal fluctuations of the temperature regime over a long-term period in the Nura River basin was identified. The study expressed the formation of an arid climate associated with an increase in the average monthly air temperature in the basin of the study area.

*Keywords:* atmospheric air temperature, dynamics of temperature fluctuations, absolute and relative frequency, cumulative frequency, long-term constant, temperature regime, river basin, statistical analysis, frequency.

## *Introduction*

The leading role in a number of natural factors that determine the conditions of human life is performed by the characteristics of the climate, and first of all, the conditions of heat and moisture supply. As a rule, the environmental assessment of the climate is based on the average annual and monthly average values of meteorological indicators (precipitation, air temperature, etc.), as well as extreme values in the long-term aspect. However, in the conditions of global climate change (Pachauri & Meyer, 2014; Sada et al., 2019) [1, 2] this approach should be complemented by an assessment of the main long–term trends of the most important meteorological characteristics — atmospheric air temperature and precipitation for ecosystems and humans (Kuzmina, Treshkin, 2007, 2016) [3, 4].

The purpose of the study is to analyze the trend of temperature fluctuations in the air in the Nura River basin, which is the basis for a geoecological assessment of the territory.

## *Materials and methods*

We used constant data for the hot month — July, which were divided into 4 periods (I-IV), for an 81-year time interval since 1939 to 2019, obtained at two meteorological stations — Karaganda, Besoba (Karaganda region) and one meteorological station in Kostanay region (m/s Arkalyk) to analyze the long-term dynamics of temperature fluctuations, as well as temperature conditions in the territory of the Nura River basin. The data obtained at meteorological stations and agricultural posts reflect the features of the landscape structure of the Nura River basin.

The oldest Besoba meteorological station (49.3° north latitude, 74.4° east longitude) is located in the upper reaches, Karaganda meteorological station (49.8° north latitude, 73.1° east longitude) is located in the middle reaches, Kobetey agricultural post (50.2° north latitude, 72.1° east longitude) is located in the lower reaches, but, Kobetey has large gaps in a number of observations, therefore, the Arkalyk meteorological station (50.2° north latitude, 63.3° east longitude), which is located outside the basin, to the west of it, but is characterized by similar natural conditions, was used as representative for the territory of dry-steppe lake-alluvial plains [5, 6].

To analyze the spatial and temporal fluctuations of temperature and precipitation across the region of Northern Kazakhstan with greater precision, the authors use the method of statistical analysis to identify dry

periods at the Blagoveshchenka and Atbasar meteorological stations [7, 8]. Based on this, we also used the statistical analysis method in our article, where the relative and absolute repeatability of $m_i$. and $p_i$, were determined, demonstrating the number of repetitions when we sampled data on atmospheric air temperature $n$.

*Results and discussion*

Examining the meteorological data presented in Table 1 and Figure 1, we ascertain the absolute and relative reproducibility of the average monthly air temperature in July at the Besoba meteorological station. This investigation reveals that over the duration of the I period (1939–1958), the number of years with an average monthly air temperature of 14–15.9 °C is 1, with an air temperature of 16–17.9 °C is 6, with an air temperature of 18–19.9 °C is 10, with an air temperature of 20–21.9 °C is 3.

Based on this, a high relative repeatability of values (50 %) was determined within the average monthly air temperature of 18–19.9 °C. The accumulated repeatability (80 %) is the average monthly air temperature in July in the range of 16–19.9 °C. The duration of the constant of the average monthly air temperature in July at the Besoba meteorological station is +18.9 °C. As the Table 1 and Fig. 1 show, the relative repeatability of the values of the average monthly air temperature in July during the first period (1939–1958) within the normal range in the upper reaches of the Nura River basin is 50 %. The correspondence of air temperature values with the highest frequency in the long-term norm was revealed.

In the II period (1959–1978), there were 3 years with an average monthly air temperature ranging from 14 to 15.9 °C, 5 years with a temperature between 16 and 17.9 °C, 9 years with temperatures ranging from 18 to 19.9 °C, and 3 years with temperatures between 20 and 21.9 °C. Accordingly, the highest relative consistency of values, at 45 %, was identified within the average monthly air temperature range of 18–19.9 °C. In the investigated upper reaches of the Nura River basin, a cumulative repeatability of 100 % is observed across the spectrum of average monthly air temperatures in July, spanning from 14 °C to 21.9 °C. During the II period, the relative repeatability of the values of the average monthly air temperature in July within the normal range shows 45 %, and the correspondence of the July air temperature value +18.9 °C with the highest frequency in the Besoba meteorological station was revealed.

Table 1

**The number of absolute and relative repeatability values of the average monthly air temperature in July since 1939 to 2019 at the Besoba meteorological station**

| Period I (1939–1958) | | | Period II (1959–1978) | | | Period III (1979–1998) | | | Period IV(1999–2019) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Air t, °C | | | Air t, °C | | | Air t, °C | | | Air t, °C | | |
| t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % |
| 14–15,9 | 1 | 5 | 14–15,9 | 3 | 15 | 14–15,9 | 0 | 0 | 14–15,9 | 0 | 0 |
| 16–17,9 | 6 | 30 | 16–17,9 | 5 | 25 | 16–17,9 | 3 | 15 | 16–17,9 | 8 | 39 |
| 18–19,9 | 10 | 50 | 18–19,9 | 9 | 45 | 18–19,9 | 13 | 65 | 18–19,9 | 10 | 48 |
| 20–21,9 | 3 | 15 | 20–21,9 | 3 | 15 | 20–21,9 | 4 | 20 | 20–21,9 | 3 | 14,3 |
| 22–23,9 | 0 | 0 | 22–23,9 | 0 | 0 | 22–23,9 | 0 | 0 | 22–23,9 | 0 | 0 |
| 24–25,9 | 0 | 0 | 24–25,9 | 0 | 0 | 24–25,9 | 0 | 0 | 24–25,9 | 0 | 0 |

In the III period under consideration (1979–1998), the occurrences are as follows: 3 years with an average monthly air temperature falling between 16 °C and 17.9 °C, 13 years with temperatures ranging from 18 °C to 19.9 °C, and 4 years with temperatures between 20 °C and 21.9 °C. Consequently, a notably high relative repeatability of values, amounting to 65 %, is identified within the range of average monthly air temperatures of 18 °C to 19.9 °C. Furthermore, an accumulated repeatability of 85 % is noted for average monthly air temperatures in July ranging from 18 °C to 21.9 °C. The enduring average monthly air temperature in July recorded at the Besoba meteorological station stands at +18.9 °C.

Table 1 and Figure 1 show the relative repeatability of the values of the average monthly air temperature in July during the III period (1979–1998) within the normal range in this area and it is equal to 65 %, which also corresponds to the long-term norm.

During the IV period (1999–2019), the number of years with an air temperature of 16–17.9 °C is 8, with a temperature of 18–19.9 °C is 10, with the average air temperature for each month of 20–21.9 °C is 3, which allows us to determine a high relative repeatability of values — 10 % within the average monthly air temperature of 18–19,9 °C. According to the analysis of the data, it can be observed that the share of accumulated repeatability is 87 % in the range of 16–19.9 °C, and the relative repeatability of the values of the average

monthly air temperature in July within the normal range shows 48 %, i.e. the highest repeatability in the Besoba meteorological station has a value that corresponds to the long-term norm of July air temperature +18.9 C.

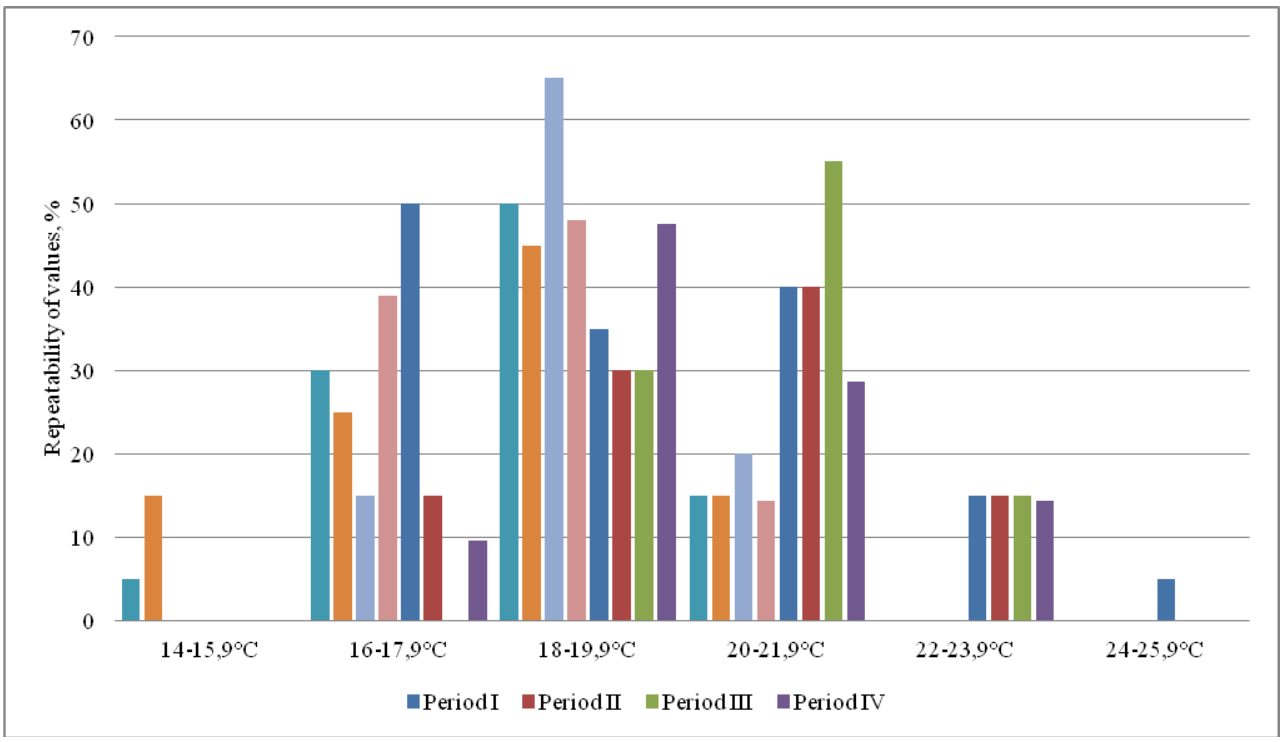


Figure 1. Dynamics of the values of the relative repeatability of the average monthly air temperature in July at the Besoba meteorological station for the I-IV periods

If we compare the data of the first and second periods, we can observe a decrease of 5 % in the repeatability of the average monthly air temperature of 18–19.9 °C, and an increase of 15 % compared to the third period. In comparison with the III period, in the IV period (1999–2019), the repeatability of the average monthly air temperature of 18–19.9 °C decreased by 17 %, and the repeatability of the average monthly air temperature of 20–21.9 °C in the III period (1979–1998) compared with the II period (1959–1978) increased by 1 % (Fig. 1).

The data presented in Table 2 characterizes the absolute and relative repeatability of the average monthly air temperature in July at the Karaganda meteorological station. During the I period (1939–1958), the number of years with an average monthly air temperature of July 16–17.9 °C is 1, with an air temperature of 18–19.9 °C is 7, with an air temperature of 20–21.9 °C is 8, with an air temperature of 22–23.9 °C is 3 and with an air temperature of 24–25.9 °C is 1.

As follows from this Figure 1, the highest relative repeatability of values within the average monthly air temperature of 20–21.9 % °C is equal to 40 %. At the same time, the cumulative repeatability — 95 % is the average monthly air temperature in July in the range of 18–21.9 °C. The long-term constant of the average monthly air temperature in July at the Karaganda meteorological station is +20.3 °C. The relative repeatability of the values of the average monthly air temperature in July during the I period (1939–1958) within the normal range in this area of the middle course of the Nura River basin is 35 %.

Analysis of data from the II period (1959–1978) of the Karaganda meteorological station shows that the number of years with an average monthly air temperature of 16–17.9 °C is 3, with an air temperature of 18–19.9 °C is 6, with an air temperature of 20–21.9 °C is 8 and with an air temperature of 22–23.9 °C is 3. According to the analysis of the dynamics of the relative repeatability of the average monthly air temperature in July is 20–21.9 °C, the highest repeatability of values was determined as 40 %, while the accumulated repeatability as 85 % is the average monthly air temperature in July in the range of 16–21.9 °C. The relative repeatability of the values of the average monthly air temperature in July during the II period (1959–1978) within the normal range (+20.3 °C) in this area is 30 %, the highest repeatability at the Karaganda meteoro-

logical station is 20–21.9 C, the highest repeatability is the air temperature value corresponding to the long-term norm.

During the III period (1979–1998), the number of years with an average monthly air temperature of 18–19.9 °C is 6, with an air temperature of 20–21.9 C is 11, with an air temperature of 22–23.9 C is 3. From this data analysis, the highest repeatability of values was determined as 55 % within the average monthly temperature the air temperature is 20–21.9 C. Cumulative repeatability — 85 % is the average monthly air temperature in July in the range of 18–21.9 C. The relative repeatability of the values of the average monthly air temperature in July during the III period (1979–1998) within the normal range (+20.3 °C) in this area is 55 %. As in the second period (1959–1978), the highest repeatability at the Karaganda meteorological station has a value of 20–21.9 C, i.e. the highest repeatability has an air temperature value corresponding to a long-term norm.

During the IV period (1999–2019), the number of years with an average monthly air temperature of 16–17.9 °C is 2, with an air temperature of 18–19.9°C is 10, with an air temperature of 20–21.9 C is 6, with a temperature of 22–23.9 C is 3. Based on this, the highest repeatability of values was determined as 47.6 % within the average monthly air temperature of 18–19.9 °C. The accumulated repeatability of 90.5 % is the average monthly air temperature in July in the range of 18–23.9 C. The relative repeatability of the values of the average monthly air temperature in July during the IV period (1999–2019) within the normal range (+20.3 C) in this area is 55 %, the highest repeatability at the Karaganda meteorological station is 18–19.9 °C, which is 1–2 °C lower than the long-term norm of July air temperature.

Table 2

**The number of absolute and relative repeatability values of the average monthly air temperature in July since 1939 to 2019 at the Karaganda meteorological station**

| Period I (1939–1958) | | | Period II (1959–1978) | | | Period III (1979–1998) | | | Period IV(1999–2019) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Air t, °C | | | Air t, °C | | | Air t, °C | | | Air t, °C | | |
| t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % |
| 14–15,9 | 0 | 0 | 14–15,9 | 0 | 0 | 14–15,9 | 0 | 0 | 14–15,9 | 0 | 0 |
| 16–17,9 | 1 | 5 | 16–17,9 | 3 | 15 | 16–17,9 | 0 | 0 | 16–17,9 | 2 | 9,5 |
| 18–19,9 | 7 | 35 | 18–19,9 | 6 | 30 | 18–19,9 | 6 | 30 | 18–19,9 | 10 | 47,6 |
| 20–21,9 | 8 | 40 | 20–21,9 | 8 | 40 | 20–21,9 | 11 | 55 | 20–21,9 | 6 | 28,6 |
| 22–23,9 | 3 | 15 | 22–23,9 | 3 | 15 | 22–23,9 | 3 | 15 | 22–23,9 | 3 | 14,3 |
| 24–25,9 | 1 | 5 | 24–25,9 | 0 | 0 | 24–25,9 | 0 | 0 | 24–25,9 | 0 | 0 |

Compared to period I, in period II the relative frequency of average monthly air temperatures of 16–17.9 °C increased by 10 %, air temperatures of 18–19.9 C decreased by 5 %. Compared to period II, in period III, the relative frequency of average monthly air temperature of 20–21.9 C increased by 15 %, compared to period III, in period IV, the relative frequency of average monthly air temperature of 18–19.9°C increased by 17.6 %, air temperature 22–23.9 °C decreased by 0.7 % (Fig. 2)

According to the data presented in the Table 3 and in Figure 3, the absolute and relative frequency of average monthly air temperature in July for the Arkalyk meteorological station differs as follows. During period I (1939–1958), the number of years with an average monthly air temperature of 16–17.9 °C is 1, with an air temperature of 18–19.9 °C is 2, the number of days with an air temperature of 20–21.9 °C is 10, with an air temperature of 22–23.9 °C it is 5 and with an air temperature of 24–25.9 °C it is 2, respectively.

The analysis of this data indicates that the most frequent occurrence, constituting 50 % of the total, falls within the average monthly air temperature range of 20–21.9 °C. Additionally, a cumulative occurrence of 85 % encompasses average monthly air temperatures in July ranging from 18 °C to 25.9 °C. The sustained average monthly air temperature recorded over the long term in July at the Arkalyk meteorological station stands at +21.3 °C. The relative frequency of average monthly air temperature in July during the first period (1939–1958) within the normal range in this area is 50 %, which corresponds to the long-term norm.

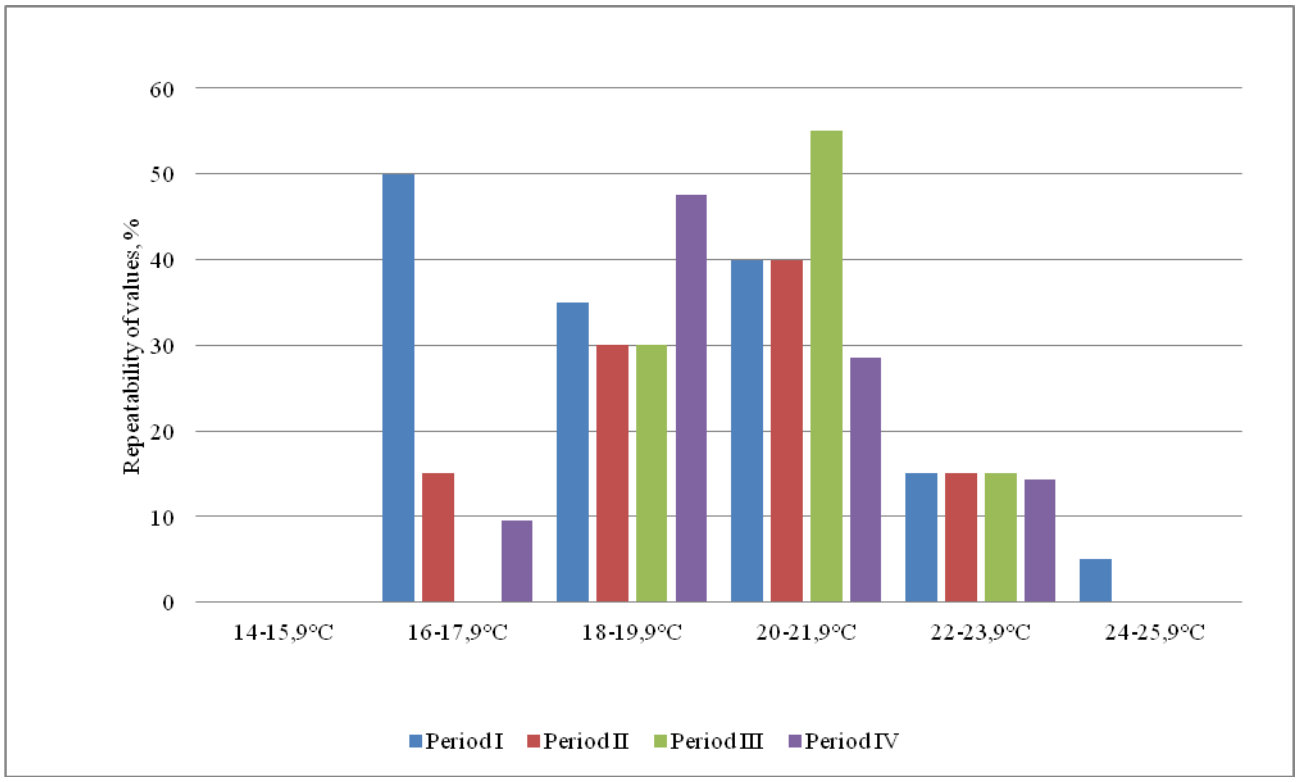


Figure 2. Dynamics of the relative frequency values of the average monthly air temperature in July at the Karaganda meteorological station for periods I-IV

Table 3

**The number of absolute and relative repeatability values of the average monthly air temperature in July since 1939 to 2019 at the Arkalyk meteorological station**

| Period I (1939–1958) | | | Period II (1959–1978) | | | Period III (1979–1998) | | | Period IV(1999–2019) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Air t, °C | | | Air t, °C | | | Air t, °C | | | Air t, °C | | |
| t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % | t | $m_i$ | $p_i$, % |
| 14–15,9 | 0 | 0 | 14–15,9 | 0 | 0 | 14–15,9 | 0 | 0 | 14–15,9 | 0 | 0 |
| 16–17,9 | 1 | 5 | 16–17,9 | 0 | 0 | 16–17,9 | 0 | 0 | 16–17,9 | 0 | 0 |
| 18–19,9 | 2 | 10 | 18–19,9 | 3 | 15 | 18–19,9 | 5 | 25 | 18–19,9 | 1 | 4,8 |
| 20–21,9 | 10 | 50 | 20–21,9 | 12 | 60 | 20–21,9 | 11 | 55 | 20–21,9 | 11 | 52,4 |
| 22–23,9 | 5 | 25 | 22–23,9 | 5 | 25 | 22–23,9 | 2 | 10 | 22–23,9 | 8 | 38 |
| 24–25,9 | 2 | 10 | 24–25,9 | 0 | 0 | 24–25,9 | 2 | 10 | 24–25,9 | 1 | 4,8 |

During period II (1959–1978), the number of years with an average monthly air temperature of 18–19.9 °C is 3, with an air temperature of 20–21.9 °C is 12, with an air temperature of 22–23.9 °C is 5, respectively. It follows herefrom that it should be noted that the highest relative frequency of values is 60 % within the average monthly air temperature of 20–21.9 C, while the cumulative frequency is 85 % and falls on the average monthly air temperature in July of 20–23.9 C. The relative frequency of average monthly air temperature in July during the second period (1959–1978) within the normal range (+21.3 C) in this area is 60 %, that is, the highest frequency in the Arkalyk meteorological station is the value corresponding to the long-term temperature norm July air, which is +21.3 C.

Analysis of data from period III (1979–1998) shows that the number of years with an average monthly air temperature of 18–19.9 C is 5, with an air temperature of 20–21.9 C is 11, with air temperatures of 22–23, 9 C and 24–25.9 C is 2.

On the basis of the foregoing, the highest relative repeatability of values was determined, which is equal to 55 %, within the average monthly air temperature of 20–21.9 C. The cumulative frequency, which is 80 %, is the average monthly air temperature in July within the range of 18–21.9 C. The relative frequency

of average monthly air temperature in July during period III (1979–1998) within the normal range in this area is 55 %, which characterizes compliance with a long-term constant.

During the IV period (1999–2019), the number of years with an average monthly air temperature of 18–19.9°C is 1, with an air temperature of 20–21.9°C is 11, with an air temperature of 22–23.9 C is 8, with an air temperature of 24–25.9 C is 1. When analyzing data from the IV period (1999–2019) from the Arkalyk meteorological station, the highest relative frequency of values was determined, which is equal to 52.4 %, within the average monthly air temperature July 20–21.9°C. The cumulative frequency, the value of which is 90.4 %, is the average monthly air temperature in July within the range of 20–23.9 C. The relative repeatability of the average monthly July air temperature during period IV is 52.4 %, which corresponds to the long-term July air temperature norm of +21.3°C.

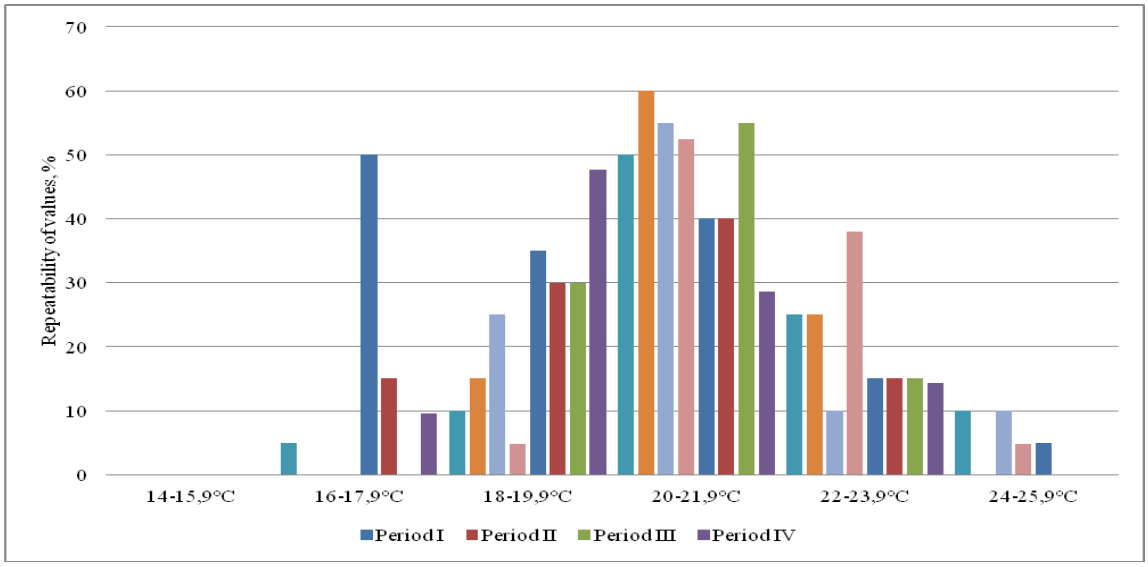


Figure 3. Dynamics of the relative frequency values of the average monthly air temperature in July at the Arkalyk meteorological station for periods I-IV

When comparing data between period I and period II, there was a 5 % increase in the relative frequency of average monthly air temperatures ranging from 18–19.9 °C, and a 10 % increase in temperatures from 20–21.9 °C. In contrast, comparing period II to period III, there was a 10 % decrease in the relative frequency of average monthly air temperatures between 18–19.9 °C, and a 15 % decrease in temperatures falling within the ranges of 20–21.9 °C and 22–23.9 °C, respectively. In period IV, compared to period III, the relative frequency of average monthly air temperature 18–19.9 °C decreased by 20.2 %, air temperature 20–21.9 °C decreased by 2.6 %, air temperature 22–23.9 increased by 28 %, air temperatures of 24–25.9 °C decreased by 5.2 % (Fig. 3).

Thus, at the meteorological stations under consideration, the correspondence of average monthly air temperatures in July +18 — +21.9°C to the long-term constant is generally observed.

## *Conclusion*

Thus, based on the study conducted, it is revealed that:

1. The highest frequency of occurrence at the Besoba meteorological station during all four periods (1939–2019) is the average monthly air temperature in July of 18–19.9 °C, corresponding to the long-term norm. Compared to period I, in period II at the Besoba meteorological station, the frequency of average monthly air temperature of 18–19.9 °C decreased by 5 %, and the frequency of average monthly air temperature of 18–19.9 °C increased by 15 % compared to period III. Compared with the III period, in the IV period (1999–2019), the frequency of average monthly air temperature of 18–19.9 °C decreased by 17 %, and the frequency of average monthly air temperature of 20–21.9 °C in the III period (1979–1998) compared to period II (1959–1978) increased by 1 %.

2. From periods I to III at the Karaganda meteorological station, the air temperature has the highest frequency within the range of 20–21.9 °C, which corresponds to the long-term norm (+20.3 °C). The relative frequency of average monthly air temperature in July during the IV period (1999–2019) within the normal

range in this area is 55 %, the highest frequency at the Karaganda meteorological station is 18–19.9 °C, which is 1–2 °C below the long-term norm for air temperature in July.

3. At the Arkalyk meteorological station during period II, the average monthly air temperature in July has the highest frequency of 20–21.9 °C with a value of 60 % of the relative frequency. Compared to period I, in period II the relative frequency of average monthly air temperatures of 18–19.9 °C increased by 5 %, air temperatures of 20–21.9 °C increased by 10 %. In all periods, the air temperature value corresponding to a long-term constant has the highest repeatability.

4. For all meteorological stations there is an increase in the values of average monthly air temperatures in July, which has the highest recurrence. In the studied basin of the Nura River, moisture depletion in the summer period is currently expected, which leads to an increase in the number of dry years, i.e. the formation of arid climate associated with an increase in atmospheric air temperature.

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## Нұра өзені алабындағы ауа температурасының ауытқуының ұзақ мерзімді динамикасын талдау

Соңғы онжылдықта Орталық Қазақстандағы Нұра өзені алабының аумағында құрғақ жылдардың әр түрлі қайталануы байқалады. Мақалада Нұра өзенінің алабында тұрған Бесоба және Қарағанды метеорологиялық станциялары мен бассейннің сыртында, оның батысында орналасқан, бірақ ұқсас табиғи жағдайлармен сипатталатын Арқалық метеостанциясы климатының жекелеген элементінің материалдарын пайдалана отырып, көпжылдық кезеңдегі температура ауытқуының өзгеру үрдісі зерттелді. Зерттеу барысында 1939 жылдан 2019 жылға дейінгі 81 жыл уақыт аралығында, яғни шілде айында Нұра өзені алабының аумағында орташа айлық ауа температурасы мәндерінің абсолютті және салыстырмалы қайталануы анықталды. Қарастырылып отырған метеорологиялық станциялар Қазгидрометтің Жаһандық халықаралық метеорологиялық деректер (ХМЖ) желісінің құрамына кіреді және метеорологиялық көрсеткіштер мәндері ұзақ мерзімді, тексерілген және сәйкес келеді. Статистикалық талдау әдісін қолдану негізінде Нұра өзені алабының аумағында көп жылдық кезеңдегі температуралық ауытқудың көпжылдық динамикасын бағалау анықталды. Зерттеу барысында зерттелетін аумақтың алабындағы атмосфералық ауаның орташа айлық температурасының жоғарылауымен байланысты құрғақ климаттың қалыптасуы көрсетілген.

*Кілт сөздер*: атмосфералық ауа температурасы, температуралық тербелістің өзгерісі, абсолюттік және салыстырмалы жиілік, куммулятивтік қайталану, қайталанатын константа, температуралық режим, өзен алабы, статистикалық талдау, жиілік.

Г.М. Жангожина, К.Д. Кенжина, Д.Е. Сайлауов, А.А. Рахметова, М.Б. Жанаева

# Анализ многолетней динамики температурного колебания воздуха в бассейне реки Нуры

В последнее десятилетие на территории бассейна реки Нуры в Центральном Казахстане наблюдается различная повторяемость засушливых лет. В настоящей статье исследована тенденция изменения колебания температуры за многолетний период с применением материалов отдельного элемента климата метеорологических станций Бесоба и Караганда, расположенных в бассейне реки Нуры, и метеостанция Аркалык, находящаяся за пределами бассейна, к западу от него, но характеризующаяся сходными природными условиями. В ходе исследований за 81-годовой временной интервал с 1939 по 2019 гг. была установлена абсолютная и относительная повторяемость значений среднемесячной температуры воздуха в июле на территории бассейна реки Нуры. Рассматриваемые метеорологические станции входят в состав Глобальной международной сети метеорологических данных Казгидромета и имеют постоянные, точные ряды значений метеорологических показателей. На основе использования метода статистического анализа выявлена оценка многолетней динамики температурного колебания за многолетний период на территории бассейна реки Нуры. В ходе исследования выражено формирование аридного климата, связанного с увеличением среднемесячного температуры атмосферного воздуха в бассейне исследуемой территории.

*Ключевые слова*: температура атмосферного воздуха, динамика температурного колебания, абсолютная и относительная повторяемость, куммулятивная повторяемость, продолжительная константа, температурный режим, бассейн реки, статистический анализ, частота.

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# Geochemical state of small rivers of Syrym District of West Kazakhstan region (on the example of the Rivers Buldyrty, Yesenankaty, Shiderty, Olenty)

Despite the fact that small rivers are called Small, their importance in terms of ecology is high. This is because the condition of large rivers will depend on smaller rivers. The degradation of small rivers negatively affects the state, is an important and urgent task. The purpose of the study was to geochemically analyze the composition of the waters of small rivers in the Syryms district and assess their quality. Water samples were taken from each river ecological state of medium and large rivers, because they feed at the expense of these small rivers. It is easy to see that every day the waters of these rivers are receding and the banks are expanding. Currently, one of the main tasks that environmental science sets for itself is to monitor the ecological state of water bodies. In connection with the conditions of increasing anthropogenic factors, determining the ecological state of small rivers plays an important role in maintaining the composition of the natural ecosystem. Small rivers are very sensitive to anthropogenic factors and react to these factors in the opposite way. The study of the chemical composition of small river waters, as well as their ecological state, is an important and urgent task. The aim of the study is a geochemical analysis of the composition of small river waters in the Syrymsky district and an assessment of their quality. Water samples were taken from each river to determine the composition of the water quality. The cameral stage was held in the laboratory of environmental and biogeochemical testing of M. Utemisov West Kazakhstan University. Chemical analysis was carried out using the widely used methods GOST 26449.1 — 85. After analyzing the indicators of water samples taken from the research area, it was found that the maximum raual concentration level did not exceed, except for the total hardness.

*Keywords:* small river, ecological situation, Buldyrty River, Shiderty River, Olenty River, Yesenankaty River, Water Resources, anthropogenic factor, chemical analysis.

## *Introduction*

Water-occupies 71 % of the globe. Of these, 98 % is accounted for by the oceans and seas, and only 0.46 % by fresh waters (lakes, rivers, swamps). 150,000 animal species (7 % of the total animal species) and 10,000 plant species (8 %) live in the aquatic environment. Water resources of Kazakhstan include: groundwater, glaciers, waters of the Caspian and Aral Seas on the border of Kazakhstan, rivers, lakes, ponds, reservoirs, etc. [1, 2]. And of the water arteries in the Republic of Kazakhstan, 85,022 rivers are formed. 84694 of them are up to 100 km long, 305 — 500 km long, 23 — 1000 km long. As we can see, most of the flowing rivers in Kazakhstan belong to small, even very small ones. They, like blood vessels, mesh the entire territory of Kazakhstan.

There are more than 200 rivers on the territory of the West Kazakhstan region. 65 of them are those that almost completely dry up by the end of the summer months. Most rivers do not have a channel of 10 km. Therefore, they are classified as small rivers. Small rivers also flow in the syrym district. The largest of them are the Buldyrty, Olenty, Yesenankaty, Shiderty rivers.

Buldyrty is a river in the Ural Basin. 1 km north-west of the village of Aksuat in the Syrym District of the West Kazakhstan region. From the confluence of the bylylkandyk and Zhosaly Springs, it is called Buldyrty, in the south it flows into Lake Zhaltyrkol. The length is 195 km, the catchment area is 4660 $km^2$. There are 8 tributaries with a total length of 258 km. The main tributaries: Shildi, Tamdy, Zhympity. The average annual water flow is 1.6 $m^3/s$ (in the village of Abay). From the source to the village of Elmash, the river valley has a very steep slope (up to 20 m high). In some places, sand dunes stretch along its banks. The total volume of water in the basin of the buldyrty River is 0.85 million tons. 6 ponds with an area of $m^3$ are built. Water is used for irrigation of Meadows.

The Olenty river-crosses the middle part of the Syrym district (229 km long, of which 163 km are located just above the current of the right tributary of the Ashchysai — Olenty rivers, its area to the southern border flows within the district). It originates from the koltaban within the large floodplain of the Ural

plateau, located within the slightly undulating plain of the Cretaceous Basin. The main tributaries: Shiderty, Shkaty, Karmyssay, Marsh.

The Shiderty river plays a significant role as the largest tributary of the Olenty river, which originates among a group of separate Hills on the Ural plateau. The upper reaches of the river are 10 km from the source, ends on the ground and its fall height will be 21 meters. In the upper reaches of the plain of the Shiderty River, the V-shaped floodplain is not clear. In the middle and lower reaches, the intermittent floodplain moves from one bank to another. Floodplain sections have a length of no more than 300 meters and a width of up to 50 meters. The channel matures well, deepening to 8–15 meters. The collar is straight, sometimes drooping. The channel is characterized by deep bends, shallow water parts between them. The banks of the estuaries are low and the flat channel is shallow, in some places it dries up in summer. The outflow of groundwater is fragmented, accumulating mainly in the middle reaches. The bottom is muddy with sand, the spinners are muddy. In the upper and lower reaches there are formations of calcareous gravel and small toadstools.

Yesenankaty-lies in the north-west of Syrym District (total length 127 km., 77 km in the area). Its head is located on the right slope of the Ural plateau 8 km northeast of the village of Red Banner., Akkudyksai (left length 17 km.) and cover (right length 13 km. it is located at the confluence of the ravines), and in the West, in the village of Araltobe, it reaches the boundaries of the district. The floodplain, which stretches from the beginning to the village of Araltobe, is intermittent and moves from one bank to another. The main industries: Isandybulak, Yerubai, Tanas, Kuperanqaty [3].

Despite the fact that small rivers are called Small, their importance in terms of ecology is great. This is because the condition of large rivers will depend on smaller rivers. The degradation of small rivers negatively affects the ecological state of medium and large rivers, because they feed at the expense of these small rivers [4]. It is easy to see that every day the waters of these rivers are receding and the banks are expanding. Currently, one of the main tasks that environmental science sets for itself is to monitor the ecological state of water bodies. In connection with the conditions of increasing anthropogenic factors, determining the ecological state of small rivers plays an important role in maintaining the composition of the natural ecosystem. Small rivers are very sensitive to anthropogenic factors and respond to these factors in a negative way [5–7].

The main scientific and practical interest is to determine the ecological state of the water quality of these rivers. Currently, the study of small rivers is not fully considered, since not all methodologies for monitoring the ecological state of these rivers have been prepared. Protection of nature and protection of water resources from harmful waste due to lack of information, creating difficulties in research [8].

One of the main, fundamental principles of environmental monitoring is complexity. Monitoring programs consist in monitoring the environment, identifying pollutants by chemical methods, as well as biota response to anthropogenic factors. The diversity of hydrobinotes and their relationship with each other, with the environment, their response to various anthropogenic influences, all this gave rise to many natural water bodies assessment methodologies [9, 10].

Concern about the chemical and environmental condition of surface waters is growing worldwide. Many studies have been devoted to the development of integrated strategies for the protection of small river watersheds in order to improve the ecological condition of the surrounding landscapes and the quality of river waters [11–13]. To assess the quality of natural waters, there is a certain number of parameters by which the degree of pollution is determined [14].

The study of the chemical composition of the waters of small rivers, as well as their ecological state, is an important and urgent task. The purpose of the study was to geochemically analyze the composition of the waters of small rivers in the Syrym district and assess their quality.

## *Materials and Methods*

The assessment of the ecological and chemical state of small rivers in the Syrym district was carried out based on the results of studies carried out in the summer in 2023. The water quality was assessed in accordance with the established sanitary rules and norms for the protection of surface waters from pollution for reservoirs of two categories — reservoirs for fishery purposes and reservoirs for drinking and cultural purposes.

During the study period, a total of 12 water samples were taken in order to determine the chemical and ecological state of the waters of this river. The sampling was carried out in accordance with the requirements of GOST 31861–2012 “Water. General requirements for sampling”. To determine the composition of water quality, water samples were taken from each river (Buldyrty, Olenty, Shiderty, Yesenankaty) at points № 1

near the route, № 2 near the village, № 3 near the steppe. The cameral stage was held in the laboratory of environmental and biogeochemical testing of M. Utemisov West Kazakhstan University. Chemical analysis was carried out using widely used GOST methods.

According to GOST 26449.1–85, carbonate, bicarbonate, chloride ions in the composition of water samples were determined by the method of titration of total hardness, ph by the device pH-meter I — 150, and when determining copper, iron, nickel, lead, sulfate ions by the method of photoelectrocolorimeter.

*Results and Discussion*

Chemical analysis of water samples taken from high Rivers was carried out and the results of the study were obtained. The results of the study obtained were shown in Tables 1–5, respectively.

Table 1

**Indicators of water samples taken from the Buldyrty River**

| Received Point | Total hardness (mmol/dm$^3$) | $SO_4^{2-}$ (mg/dm$^3$) | $CL^-$ (mg/dm$^3$) | pH | $CO_3^{2-}$ (mg/dm$^3$) | $HCO_3^-$ (mg/ m$^3$) | $Pb^{2+}$ (mg/l) | $Cu^{2+}$ (mg/l) | $Ni^{2+}$ (mg/l) | $Fe^{2+}$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| № 1 | 9.4 | 349.7 | 149.1 | 8.01 | 72 | 463 | 0.01 | 0.77 | 0.08 | 0.19 |
| № 2 | 9 | 371 | 163.3 | 8.04 | 60 | 561.2 | 0.008 | 0.75 | 0.072 | 0.12 |
| № 3 | 6,4 | 283,1 | 156.2 | 7.8 | 36 | 280.6 | 0.007 | 0.56 | 0.063 | 0.1 |
| Average value | 8.3 | 334.6 | 156.2 | 7.95 | 56 | 434.9 | 0.008 | 0.69 | 0.072 | 0.14 |
| MPC | 7–10 | 500 | 350 | 6–9 | - | - | 0.03 | 1 | 0.1 | 0.3 |

As for the indicators of water samples taken from the Buldyrty River, the total hardness in the sample № 1 is equal to 9.4 mmol/3, № 2 — 9 mmol/ dm3, № 3 — 6.4 mmol/ dm3, MPC (7–10 mmol/ dm3). Sulfate ion in sample № 1 — equal to 349.7 mg/ dm3, № 2 — 371 mg/ dm3, № 3 — 283.1 mg/ dm3, MPC (500 mg/ dm3). Chloride ion in sample № 1 — equal to 149.1 mg/ dm3, № 2 — 163.3 mg/ dm3, № 3 — 156.2 mg/ dm3, MPC (350 mg/ dm3). The pH of the sample № 1 is equal to 8.01, № 2 is equal to 8.04, № 3 is equal to 7.8, does not exceed the MPC(6–9). The carbonate ion in sample № 1 is equal to 72 mg/ dm3, № 2 — 60 mg/ dm3, № 3 — 36 mg/ dm3. The bicarbonate ion in the sample № 1 is equal to 463 mg/ dm3, № 2 — 561.2 mg/ dm3, № 3 — 280.6 mg/ dm3. Lead ion in sample № 1 — 0.01 mg/l, № 2 — 0.008 mg/l, № 3 — 0.007 mg/l, MPC (0.03 mg/l). Copper ion in sample № 1 — 0.77 mg/l, № 2 — 0.75 mg/l, № 3 — 0.56 mg/l, no more than MPC (1 mg/l). Nickel ion in sample № 1 — 0.08 mg/l, № 2 — 0.072 mg/l, № 3 — 0.063 mg/l, MPC (0.1 mg/l). Iron ion in sample № 1 — 0.19 mg/l, № 2 — 0.12 mg/l, № 3 — 0.1 mg/l, MPC (0.3 mg/l).

Table 2

**Indicators of water samples taken from the Olenty River**

| Received Point | Total hardness (mmol/dm3) | $SO_4^{2-}$ (mg/ dm$^3$) | $CL^-$ (mg/ dm$^3$) | pH | $CO_3^{2-}$ (mg/ dm$^3$) | $HCO_3^-$ (mg/ dm$^3$) | $Pb^{2+}$ (mg/l) | $Cu^{2+}$ (mg/l) | $Ni^{2+}$ (mg/l) | $Fe^{2+}$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| № 1 | 17 | 404.2 | 355 | 7.92 | 84 | 207 | 0.017 | 0.82 | 0.09 | 0,2 |
| № 2 | 15 | 386 | 426 | 7.86 | 72 | 183 | 0.01 | 0.71 | 0.087 | 0.17 |
| № 3 | 13 | 350 | 203 | 7.74 | 68 | 170.8 | 0.009 | 0.7 | 0.08 | 0.13 |
| Average value | 15 | 380 | 328 | 7.84 | 74.7 | 186.9 | 0.012 | 0.74 | 0.085 | 0.16 |
| MPC | 7–10 | 500 | 350 | 6–9 | - | - | 0.03 | 1 | 0.1 | 0.3 |

As for the indicators of water samples taken from the Olenty River, the total hardness is equal to mmol/ dm3 in sample № 1, mmol/ dm3 № 2, mmol/dm3 № 3 — 13 mmol/ dm3, MPC (7–10 mmol / dm3). Sulfate ion in sample № 1 — equal to 404.2 mg/ dm3, № 2 — 386 mg/ dm3, № 3 — 350 mg/ dm3, MPC (500 mg/ dm3). Chloride ion in sample № 1 is equal to 355 mg/ dm3, № 2 — 426 mg/ dm3, № 3 — 203 mg/ dm3, samples № 1, № 2 are higher than MPC (350 mg/ dm3). pH in sample № 1 is equal to 7.92,

№ 2 is equal to 7.86, № 3 is equal to 7.74, does not exceed the MPC (6–9). The carbonate ion in sample № 1 is equal to 84 mg/ dm3, № 2 — 72 mg/ dm3, № 3 — 68 mg/ dm3. The bicarbonate ion in sample № 1 is equal to 207 mg/ dm3, № 2 — 183 mg/ dm3, № 3 — 170.8 mg/ dm3. Lead ion in sample № 1 — 0.017 mg/l, № 2 — 0.01 mg/l, № 3 — 0.009 mg/l, MPC (0.03 mg/l). Copper ion in sample № 1 — 0.82 mg/l, № 2 — 0.71 mg/l, № 3 — 0.7 mg/l, no more than MPC (1 mg/l). Nickel ion in sample № 1 — equal to 0.09 mg/l, № 2 — 0.087 mg/l, № 3 — 0.08 mg/l, does not exceed MPC (0.1 mg/l). The Iron ion in sample № 1 is equal to 0.2 mg/l, № 2 — 0.17 mg/l, № 3 — 0.13 mg/l, does not exceed MPC (0.3 mg/l).

Table 3

**Indicators of water samples taken from the Shiderty River**

| Received Point | Total hardness (mmol/dm$^3$) | $SO_4^{2-}$ (mg/ dm$^3$) | $CL^-$ (mg/ dm$^3$) | pH | $CO_3^{2-}$ (mg/ dm$^3$) | $HCO_3^-$ (mg/ dm$^3$) | $Pb^{2+}$ (mg/l) | $Cu^{2+}$ (mg/l) | $Ni^{2+}$ (mg/l) | $Fe^{2+}$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| № 1 | 9.2 | 327.1 | 85.2 | 7.75 | 48 | 305 | 0.01 | 0.71 | 0.083 | 0.17 |
| № 2 | 6.4 | 318.9 | 78.1 | 7.74 | 36 | 256 | 0.009 | 0.68 | 0.076 | 0.12 |
| № 3 | 5.8 | 253.7 | 71 | 7.7 | 24 | 183 | 0.006 | 0.59 | 0.061 | 0.1 |
| Average value | 7.1 | 299.9 | 78.1 | 7.73 | 36 | 248 | 0.008 | 0.66 | 0.073 | 0.13 |
| MPC | 7–10 | 500 | 350 | 6–9 | - | - | 0.03 | 1 | 0.1 | 0.3 |

As for the indicators of water samples taken from the Shiderty River, the total hardness in the sample № 1 is equal to mmol/ dm3, № 2 — mmol/dm3, № 3 — mmol/dm3, MPC (7–10 mmol/dm3). Sulfate ion in sample № 1 — equal to 327.1 mg/ dm3, № 2 — 318 mg/ dm3, № 3 — 253.7 mg/ dm3, MPC (500 mg/ dm3). Chloride ion in sample № 1 — equal to 85.2 mg/ dm3, № 2 — 78.1 mg/ dm3, № 3 — 71 mg/ dm3, MPC (350 mg/ dm3). pH in sample № 1 — 7.75, № 2 — 7.74, № 3 — 7.7, no more than MPC (6–9). The carbonate ion in sample № 1 is equal to 48 mg/ dm3, № 2 — 36 mg/ dm3, № 3 — 24 mg/ dm3. Hydrocorbanate ion in sample № 1 — equal to 305 mg/ dm3, № 2 — 256 mg/ dm3, № 3 — 183 mg/ dm3. Lead ion in sample № 1 — 0.01 mg/l, № 2 — 0.009 mg/l, № 3 — 0.006 mg/l, MPC (0.03 mg/l). Copper ion in sample № 1 — equal to 0.71 mg/l, № 2 — 0.68 mg/l, № 3 — 0.59 mg/l, does not exceed MPC(1 mg/l). Nickel ion in sample № 1 — equal to 0.71 mg/l, № 2 — 0.68 mg/l, № 3 — 0.59 mg/l, does not exceed MPC (0.1 mg/l). Iron ion in sample № 1 — 0.17 mg/l, № 2 — 0.12 mg/l, № 3 — 0.1 mg/l, MPC (0.3 mg/l).

Table 4

**Indicators of water samples taken from the Yesenankaty River**

| Received Point | Total hardness (mmol/dm$^3$) | $SO_4^{2-}$ (mg/ dm$^3$) | $CL^-$ (mg/ dm$^3$) | pH | $CO_3^{2-}$ (mg/ dm$^3$) | $HCO_3^-$ (mg/ dm$^3$) | $Pb^{2+}$ (mg/l) | $Cu^{2+}$ (mg/l) | $Ni^{2+}$ (mg/l) | $Fe^{2+}$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| № 1 | 10,8 | 402,3 | 241 | 7,75 | 120 | 378,2 | 0,012 | 0,8 | 0,09 | 0,19 |
| № 2 | 10 | 378,1 | 208,3 | 7 | 84 | 207,4 | 0,01 | 0,76 | 0,083 | 0,14 |
| № 3 | 9,4 | 363,3 | 149,1 | 6,83 | 78 | 204,5 | 0,009 | 0,61 | 0,059 | 0,01 |
| Average value | 10,1 | 381,2 | 199,4 | 7,2 | 94 | 263 ,4 | 0,01 | 0,72 | 0,08 | 0,11 |
| MPC | 7–10 | 500 | 350 | 6–9 | - | - | 0,03 | 1 | 0,1 | 0,3 |

As for the indicators of water samples taken from the yesenankaty River, the total hardness is equal to 10.8 mmol/ dm3 in sample № 1, № 2 — 10 mmol/ dm3, № 3 — 9.4 mmol/ dm3, and MPC(7–10 mmol/ dm3) in sample № 1. Sulfate ion in sample № 1 — equal to 402 mg/ dm3, № 2 — 378.1 mg/ dm3, № 3 — 363.3 mg/ dm3, MPC (500 mg/ dm3). Chloride ion in sample № 1 — equal to 241 mg/ dm3, № 2 — 208.3 mg/ dm3, № 3 — 149.1 mg/ dm3, MPC (350 mg/ dm3). pH in sample № 1 is equal to 7.75, № 2 is equal to 7, № 3 is equal to 6.83, does not exceed the MPC (6–9). The carbonate ion in sample № 1 is equal to 120 mg/ dm3, № 2 — 84 mg/ dm3, № 3 — 78 mg/ dm3. The bicarbonate ion in sample № 1 is equal to 378.2 mg/ dm3, № 2 — 207.4 mg/ dm3, № 3 — 204.5 mg/ dm3. Lead ion in sample № 1 — 0.012 mg/l, № 2

— 0.01 mg/l, № 3–0.009 mg/l, MPC (0.03 mg/l). Copper ion in sample № 1 — equal to 0.8 mg/l, № 2 — 0.76 mg/l, № 3 — 0.61 mg/l, does not exceed MPC(1 mg/l). Nickel ion in sample № 1 — equal to 0.09 mg/l, № 2 — 0.083 mg/l, № 3 — 0.059 mg/l, does not exceed MPC (0.1 mg/l). Iron ion in sample № 1 — 0.19 mg/l, № 2 — 0.14 mg/l, № 3 — 0.01 mg/l, MPC (0.3 mg/l).

Table 5

**Average indicators of water samples taken from the Rivers Buldyrty, Olenty, Shiderty, Yesenankaty**

| River | Total hardness (mmol/dm$^3$) | $SO_4^{2-}$ (mg/ dm$^3$) | $CL^-$ (mg/ dm$^3$) | pH | $CO_3^{2-}$ (mg/ dm$^3$) | $HCO_3^-$ (mg/ dm$^3$) | $Pb^{2+}$ (mg/l) | $Cu^{2+}$ (mg/l) | $Ni^{2+}$ (mg/l) | $Fe^{2+}$ (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| Buldyrty | 8,3 | 334,6 | 156,2 | 7,95 | 56 | 434,9 | 0,008 | 0,69 | 0,072 | 0,14 |
| Olenty | 15 | 380 | 328 | 7,84 | 74,7 | 186,9 | 0,012 | 0,74 | 0,085 | 0,16 |
| Shiderty | 7,1 | 299,9 | 78,1 | 7,73 | 36 | 248 | 0,008 | 0,66 | 0,073 | 0,13 |
| Yesenankaty | 10,1 | 381,2 | 199,4 | 7,2 | 94 | 263,4 | 0,01 | 0,72 | 0,08 | 0,11 |
| MPC | 7–10 | 500 | 350 | 6–9 | - | - | 0,03 | 1 | 0,1 | 0,3 |

Comparing the indicators of water samples taken from the rivers Buldyrty, Olenty, Shiderty, Yesenankaty, we can conclude that the total hardness is higher than that of the Olenty River — 15 mmol/dm3, the MPC is higher than 5 mmol/ dm3, the lower content is 7.1 mmol/ dm3. A high sulfate ion content was recorded in water samples from the Yesenankaty River (381.2 mg/ dm3), a lower content in the Shiderty River — 299.9 mg/ dm3. The high content of chloride ion is 328 mg/ dm3 in the Olenty River, the lower content is 78.1 mg/ dm3 in the Shiderty River. The high pH of the river is 7.95, the low pH of the river is 7.2. The high content of carbonate ions in the Yesenankaty River is 94 mg/ dm3, the lower content in the Shiderty River is 36 mg/ dm3. The high content of the bicarbonate ion in the turbid River is 434.9 mg/ dm3, the low content in the Olenty River is 186.9 mg/ dm3. The high content of lead ions in the river of poetry is 0.012 mg/l, the low content of the river of poetry is 0.008 mg/l. the high content of copper ions in the river of poetry is 0.74 mg/l, the low content of the river of poetry is 0.66 mg/l. the high content of nickel ions in the river of poetry is 0.085 mg/l, the low content in the river of poetry is 0.072 mg/l. The high content of iron ions in the river Olenty is 0.16 mg/l, the low content in the river Yesenankaty is 0.11 mg/l.

## *Conclusion*

After analyzing the indicators of water samples taken from the research area, we found that the total hardness did not exceed the MPC level, except for the size. Comparing the indicators of water samples of the studied small rivers of the Syrym district, we can conclude that the content of the Olenty River (carbonate, bicarbonate, chloride ion, ph, copper, iron, nickel, lead, sulfate ions) is much higher than the indicators of water samples of the remaining rivers. This suggests that the ecological situation of the Olenty River is more dangerous than the turbid, Shiderty and Yesenankaty rivers.

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## Батыс Қазақстан облысы Сырым ауданының кіші өзендерінің геохимиялық жағдайы (Бұлдырты, Есенаңқаты, Шідерті, Өленті өзендерінің мысалында)

Кіші өзендер кіші деп аталғанымен, олардың экология тұрғысынан алғандағы маңызы жоғары. Себебі, ірі өзендердің жағдайы кіші өзендерге байланысты болады. Кіші өзендердің деградацияға ұшырауы орта және ірі өзендердің экологиялық жағдайына кері әсерін тигізеді, себебі олар осы кіші өзендер есебінен қоректенеді. Күн сайын осы өзендердің суының тартылып, жағасының кеңейіп келе жатқанын байқау қиын емес. Қазіргі уақытта экология ғылымының алдына қойған басты міндеттерінің бірі су нысандарының экологиялық жағдайын бақылау. Антропогендік факторлардың арту жағдайына байланысты, кіші өзендердің экологиялық жағдайын анықтау, табиғи экожүйенің құрамын сақтап қалуда маңызды рөл атқарады. Кіші өзендер антропогендік факторларға өте сезімтал және бұл факторларға кері әсерде жауап қайтарады. Кіші өзендер суларының химиялық құрамын, сондай-ақ олардың экологиялық жағдайын зерттеу маңызды және өзекті міндет. Зерттеудің мақсаты Сырым ауданының кіші өзендері суларының құрамын геохимиялық талдау және олардың сапасын бағалау. Су сапасының құрамын анықтау үшін әр өзеннен су сынамалары алынды. Камералдық кезеңі М. Өтемісов атындағы Батыс Қазақстан университетінің экология-биогеохимиялық сынақ зертханасында өткізілді. Химиялық талдау кеңінен қолданылатын МемСТ 26449.1–85 әдістері арқылы өткізілді. Зерттеу аймағынан алынған су сынамаларының көрсеткіштерін саралай келе, жалпы кермектілік мөлшерінен басқалары ШРК деңгейінен аспағандығы анықталды.

*Кілт сөздер:* кіші өзен, экологиялық жағдай, Бұлдырты өзені, Шідерті өзені, Өленті өзені, Есенаңқаты өзені, су ресурстары, антропогендік фактор, химиялық талдау.

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## Геохимическое состояние малых рек Сырымского района Западно-Казахстанской области (на примере рек Булдырты, Есенанкаты, Шидерты, Оленты)

Хотя малые реки называются малыми, они имеют большое значение с точки зрения экологии. Это связано с тем, что состояние крупных рек будет зависеть от малых. Деградация малых рек отрицательно сказывается на экологическом состоянии средних и крупных рек, поскольку они питаются за счет этих малых рек. Нетрудно заметить, что с каждым днем вода этих рек высыхает, а берега расширяются. В настоящее время одной из главных задач, поставленных перед экологической наукой, является контроль за экологическим состоянием водных объектов. В связи с состоянием возрастания антропогенных факторов определение экологического состояния малых рек играет важную роль в сохранении состава природной экосистемы. Малые реки очень чувствительны к антропогенным факторам и реагируют на эти факторы в обратном направлении. Изучение химического состава вод малых рек, а также их экологического состояния является важной и актуальной задачей. Целью исследования является геохимический анализ состава вод малых рек Сырымского района и оценка их качества. Были взяты пробы воды из каждой реки, чтобы определить состав качества воды. Камеральный этап проводился в эколого-биогеохимической испытательной лаборатории Западно-Казахстанского университета имени М. Утемисова. Химический анализ проводился по широко применяемым методам

ГОСТ 26449.1–85. Дифференцируя показатели проб воды, взятых из зоны исследования, установлено, что все, кроме величины общей жесткости, не превышали уровень ПДК.

*Ключевые слова:* малая река, экологическое состояние, река Булдырты, река Шидерты, река Оленты, река Есенанкаты, водные ресурсы, антропогенный фактор, химический анализ.

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# Потенциал загрязнения атмосферы на территории Республики Казахстан по данным реанализа ERA5 за 2021 год

Рассчитан потенциал загрязнения атмосферы в пограничном слое атмосферы, по данным реанализа ERA5, и описан характер его распределения по территории Республики Казахстан, выявлены области наибольшей и наименьшей повторяемости условий формирования потенциала загрязнения атмосферы. Атмосфера считается практически неисчерпаемым ресурсом, обеспечивающим безопасные условия для населения и сохранения экосистем. Однако в результате хозяйственной деятельности человека в атмосфере появляется большое количество загрязняющих веществ, наиболее значительные изменения качества атмосферного воздуха наблюдаются в крупных городах. Исследование подчеркивает важное воздействие метеорологических параметров на концентрацию загрязняющих веществ в атмосфере, их перемещение и способность атмосферы к самоочищению. Были выполнены расчеты, направленные на определение климатического потенциала, что позволило выявить уровень самоочищения атмосферы на территории Республики Казахстан. В настоящее время механизм самоочищения не справляется с большим количеством загрязняющих веществ в атмосфере, впоследствии чего идет образование высоких концентраций примесей. Потенциал загрязнения атмосферы является одним из широко используемых методов для оценки способности атмосферы к самоочищению от загрязняющих веществ. Этот метод основан на расчете отношения средних уровней концентраций вредных веществ при фактических выбросах в определенном регионе к условным концентрациям.

*Ключевые слова:* потенциал загрязнения атмосферы, атмосферный воздух, температурные инверсии, осадки, скорость ветра, рассеивающая способность атмосферы, загрязняющие вещества.

## *Введение*

Атмосферный воздух — это ценный природный ресурс, который обеспечивает жизнедеятельность всех живых организмов на планете Земля. Он предоставляет не только кислород для дыхания, но и участвует во множестве других экосистемных процессов, таких как климатические регуляции и обеспечение водного цикла. Однако в современном мире наша промышленная и транспортная деятельность приводит к выбросу вредных и загрязняющих веществ в атмосферу. Эти загрязнения включают в себя такие вещества, как углекислый газ ($CO_2$), азотные оксиды ($NO_x$), сернистые соединения ($SO_x$), метан ($CH_4$) и другие. Эти загрязнения могут оказывать серьезное отрицательное воздействие на окружающую среду и здоровье человека. Поэтому важно постоянно контролировать качество атмосферного воздуха и предпринимать меры для снижения выбросов вредных веществ. Мониторинг атмосферы и разработка экологически чистых технологий становятся все более важными задачами в современном мире. Эффективное управление качеством атмосферного воздуха не только способствует здоровью человека, но и сохраняет экосистемы и биоразнообразие нашей планеты для будущих поколений.

Степень загрязнения атмосферы у земной поверхности обусловливается не только количеством и интенсивностью выбрасываемых загрязняющих веществ и параметрами источников, но и пространственно-временными масштабами, зависящими от орографических особенностей и метеорологических условий местности. В атмосфере работает механизм самоочищения, однако увеличение количества антропогенных выбросов привело к недостижимости полного обезвреживания загрязнения, которое привело к формированию высоких концентраций примесей.

Потенциал загрязнения атмосферы — это понятие, которое отражает возможность или склонность определенной области или источника к загрязнению атмосферы. Он определяет вероятность или степень, с которой данная область или источник могут способствовать загрязнению воздуха.

Как и в случае с другими странами, потенциал загрязнения атмосферы на территории Республики Казахстан зависит от различных факторов, включая промышленные процессы, автотранспорт, энергетический сектор, аграрную деятельность и городскую застройку. Вот некоторые аспекты, которые влияют на потенциал загрязнения атмосферы в Казахстане:

*Промышленность*: Казахстан имеет развитую промышленную базу, которая включает нефтеперерабатывающие заводы, металлургические комбинаты, химические предприятия и другие отрасли. В результате производственных процессов и выбросов от этих предприятий в атмосферу могут попадать различные загрязняющие вещества, такие как диоксид серы, диоксид азота, тяжелые металлы и др.

*Энергетика:* Генерация электроэнергии в Казахстане осуществляется в основном за счет угля, природного газа и нефти. Электростанции, работающие на этих ископаемых топливах, могут выбрасывать вредные газы, включая углеродные оксиды, сернистый и азотистый диоксиды, которые способствуют атмосферному загрязнению и изменению климата.

*Транспорт*: Увеличение автомобильного парка и объема автотранспорта в Казахстане может привести к значительным выбросам выхлопных газов, таких как оксиды азота, углеводороды и твердые частицы. Это особенно актуально для крупных городов с плотным автотранспортным движением.

*Сельское хозяйство:* Животноводство и использование агрохимикатов в сельском хозяйстве могут быть источниками выбросов аммиака, метана и других газов, которые оказывают влияние на качество воздуха и климатические условия.

*Пыль и сухой климат:* В некоторых регионах Казахстана, особенно в степных и пустынных районах, может наблюдаться значительное количество пыли, вызванной эрозией почвы, строительством и другими факторами. Это также может приводить к загрязнению атмосферы.

Необходимо отметить, что Казахстан принимает меры для сокращения загрязнения атмосферы и охраны окружающей среды. В стране внедряются программы по снижению выбросов, улучшению технологий и энергоэффективности, а также развитию возобновляемых источников энергии.

## *Материалы и методы*

Потенциал загрязнения атмосферы (ПЗА) представляет собой важный инструмент для оценки способности атмосферы к самоочищению от загрязняющих веществ [1]. Этот параметр позволяет определить, во сколько раз средний уровень загрязнения воздуха превышает условный уровень, который определяется на основе реальных метеорологических данных для конкретного региона [2]. Потенциал загрязнения атмосферы учитывает различные факторы, такие как низкие скорости ветра, задержка движения воздуха и частота приземных температурных инверсий. Для расчета ПЗА используется специальная формула, которая учитывает эти факторы и позволяет оценить, насколько атмосфера способствует накоплению загрязняющих веществ в приземном слое. Этот показатель важен для понимания потенциальных рисков для качества воздуха в данном регионе и может быть использован при разработке стратегий по снижению выбросов вредных веществ и улучшению экологической ситуации.

$$\frac{Ри+Рш}{}$$

где *Рш* — повторяемость скоростей ветра 0–1 м/с; *Рт* — повторяемость числа дней с температурными инверсиями; *Ро* — повторяемость числа дней с осадками ≥ 0,5 мм; *Рв* — повторяемость скоростей ветра ≥ 6 м/с [3].

Таким образом, с помощью указанной выше формулы стало возможным использовать простую метеорологическую информацию для расчета метеорологического потенциала атмосферы, учитывая факторы, которые способствуют как накоплению вредных примесей в атмосфере, так и ее самоочищению. Предложенный метод определения метеоемкости атмосферы может быть применен не только в планировании и экспертизе природоохранных мероприятий, но и для оценки влияния метеорологических факторов на уровень загрязнения атмосферы в прошлом времени [4].

По данным реанализа ERA5, рассчитан потенциал загрязнения атмосферы за 2021 год в пограничном слое атмосферы и описан характер его распределения по территории Республики Казахстан. Ввиду наличия большого количества точек сетки на территории исследования реанализ обеспечивает равномерное покрытие территории и дает возможность на основе этих данных построить карты и вы-

делить области повышенных и пониженных значений ПЗА [5]. В целях учесть максимально возможное количество случаев, приводящих к загрязнению атмосферы, были взяты наблюдения за каждый час, 24 сроков. Частая повторяемость таких неблагоприятных метеоусловий приводит к скоплению примесей в атмосфере.

Вертикальное распределение температуры воздуха в пограничном слое атмосферы оценивалось путём приращения данных по температуре на трех геопотенциальных высотах:

– высоте изобарической поверхности 1000 гПа, соответствующей уровню Земли;

– высоте изобарической поверхности 925 гПа, соответствующей уровню 750 м;

– высоте изобарической поверхности 850 гПа, соответствующей уровню 1500 м.

В результате были получены три слоя ΔТ1, ΔТ2, определенные по формулам:

$$\Delta T1 = T1000 - T925.$$

$$\Delta T2 = T925 - T850.$$

Оценка потенциала загрязнения атмосферы помогает определить приоритетные области или источники для принятия мер по снижению выбросов и улучшению качества воздуха. Это может способствовать разработке и реализации политик и программ, направленных на защиту окружающей среды и здоровья людей.

*Результаты и их обсуждение*

За температурную инверсию принимались случаи с отрицательными значениями одновременно $\Delta T_1$ и $\Delta T_2$. В сочетании с различными скоростями ветра инверсии температуры могут усиливать опасность накопления примесей или создавать благоприятные условия для их диффузии. Минимальные концентрации наблюдаются при отсутствии инверсионных слоев, когда создаются условия хорошего перемешивания воздушной массы [3]. Повторяемость температурных инверсий заметно увеличивается в центральной части страны, протягиваясь на восток (рис. 1).

Известно, что наиболее эффективное рассеивание выбросов загрязняющих веществ происходит при наличии благоприятных метеорологических условий, которые характеризуются активной циклонической активностью, частыми осадками и сильными ветрами. Ветровой режим — один из основных метеопараметров, влияющий на перенос и рассеивание примесей в атмосфере.

Условия аккумуляции примесей особенно обостряются при наличии застойных ситуаций, когда штиль или слабый ветер сопровождается приподнятой инверсией, в таком случае создается особо опасное загрязнение приземного слоя атмосферы [1].

Ветра со скоростью больше 6 м/с наблюдаются в юго-западных регионах (рис. 2), в то время как ветра со скоростью менее 1 м/с (штилей) господствуют в западных и южных окраинах страны (рис. 3).

Следующим метеопараметром, способствующим очищению атмосферного воздуха от примесей, являются осадки, влияние которых учитывается через повторяемость числа дней с осадками ≥ 0,5 мм за сутки. Такое количество осадков способно осадить придорожную пыль и другие аэрозоли. К примеру, при выпадении осадков, концентрации сернистых газов и диоксида азота понижаются, окислители в виде озона и других веществ летом после дождя исчезают из атмосферы почти полностью [6]. Недостаток осадков испытывает страна практически повсеместно, сильнее всего выражена юго-западная часть. Сравнительно в лучшем положении предгорные районы на востоке и юге (рис. 4).

Метеорологические условия играют роль в накоплении примесей, определяя высокий потенциал загрязнения атмосферы (ПЗА). В то же время благоприятные метеорологические условия способствуют рассеиванию примесей и определяют низкий ПЗА [7].

Территория Казахстана отличается значительным разнообразием климатических условий, которые влияют на потенциал загрязнения атмосферы. Эти условия определяют способность переноса и рассеивания примесей, которые поступают в воздушный бассейн от промышленных предприятий и автотранспорта. Потенциал загрязнения атмосферы дает возможность расчитать вклад метеорологических явлений и их характеристик в формирование уровня загрязнения воздуха. Для выражения способности атмосферы к самоочищению, измеряемой в условных единицах, основным средством визуализации является цвет. В данном случае использовано шесть различных оттенков, которые отражают шесть градаций этой способности (рис. 5). Различают несколько зон ПЗА:

– зона низкого ПЗА — южная и центральная части Кызылординской области и северо-восток Мангистауской области;

– зона умеренного ПЗА — Западно-Казахстанская и Атырауская области, запад Павлодарской области;
– зона повышенного ПЗА — Карагандинская, Павлодарская, Акмолинская области;
– зона высокого ПЗА — Улытауская, Костанайская, Абайская области;
– зона опасного ПЗА — южные части Туркестанской, Жамбылской областей, север Алматинской области, центральная часть Восточно-Казахстанской области;
– зона чрезвычайно опасного ПЗА — южные части Туркестанской, Жамбылской, Алматинской областей, юго-восточная часть Жетысуской и Восточно-Казахстанской областей.

В среднем за рассматриваемый год большая часть территории Республики Казахстан имела благоприятные условия для рассеивания примесей. Неблагоприятные условия устойчиво отмечались только на восточной и южной периферии страны.

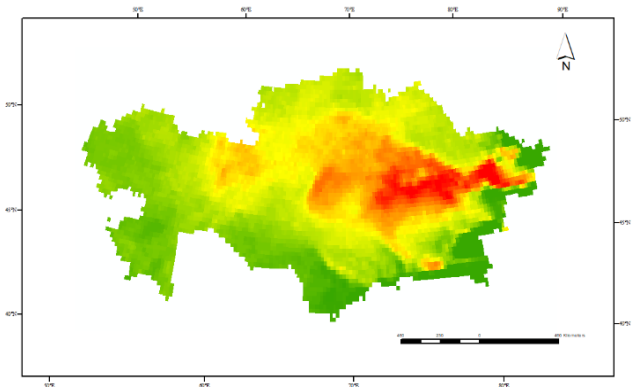

Рисунок 1. Распределение повторяемости температурных инверсий на территории Республики Казахстан

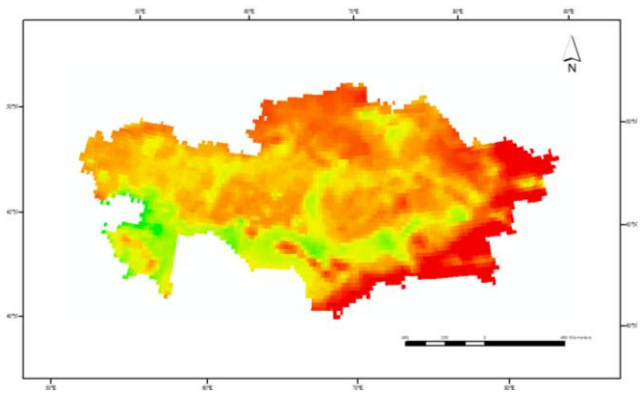

Рисунок 2. Распределение повторяемости скоростей ветра ≥ 6 м/с на территории Республики Казахстан

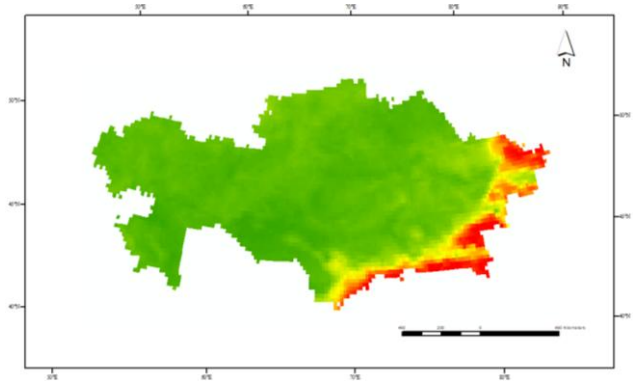

Рисунок 3. Распределение повторяемости скоростей ветра 0–1 м/с на территории Республики Казахстан

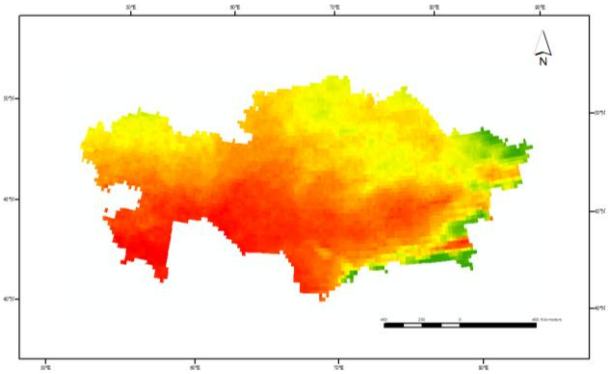

Рисунок 4. Распределение повторяемости числа дней с осадками ≥ 0,5 мм на территории Республики Казахстан

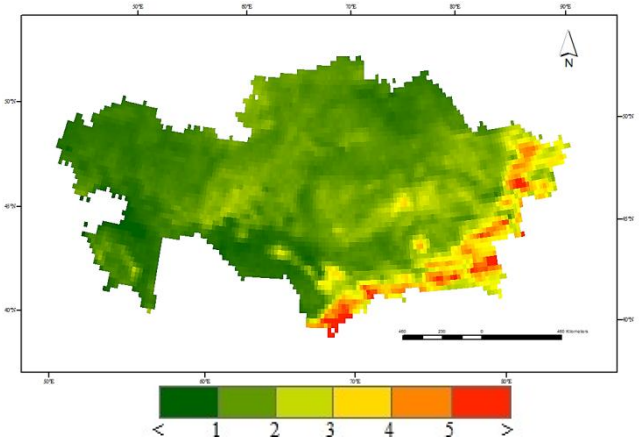


Рисунок 5. Распределение потенциала загрязнения атмосферы на территории Республики Казахстан

*Заключение*

Таким образом, для оценки воздействия на окружающую среду был проведен расчет потенциала загрязнения атмосферы. ПЗА, или потенциал загрязнения атмосферы, представляет собой совокупность погодных условий, которые определяют способность атмосферы к рассеиванию выбросов вредных веществ и формированию определенного уровня концентрации примесей в приземном слое.

Детальные карты распределения климатических характеристик пограничного слоя атмосферы Республики Казахстан на основе данных реанализа ERA5 позволили выявить области наибольшей и наименьшей повторяемости условий формирования потенциала загрязнения атмосферы. Проведенный анализ показывает, что на территории республики могут образовываться зоны с низким, средним и высоким уровнями потенциала загрязнения атмосферы. В распределении ПЗА на территории республики в 2021 году выделяются 6 зон с различными значениями. Рассчитанный ПЗА распределен неоднородно по территории Республики Казахстан. Такие области, как Кызылординская, Мангистауская и западная часть Туркестанской области имеют очень хорошую рассеивающую способность. И, наоборот, плохая рассеивающая способность и очень высокий потенциал загрязнения атмосферы отмечаются на восточных и южных частях страны (рис. 5).

Эти исследования позволяют более полно понимать, как метеорологические факторы влияют на экологическую обстановку, и выявить условия, при которых атмосфера способствует более эффективному рассеиванию загрязняющих веществ. Эта информация может быть полезной при разработке мероприятий по снижению загрязнения атмосферы и улучшению качества воздуха в регионе. Однако в настоящее время системы гидрометеорологических служб не обладают достаточными оперативными данными, чтобы полностью заполнить такие модели.

В заключение следует отметить, что мероприятия по обеспечению чистоты воздуха городов следует планировать на те периоды, когда наиболее вероятны неблагоприятные метеорологические условия. Понятно, что невозможно избежать таких погодных условий, но на промышленных объектах, расположенных в этих районах следует уделять большое внимание очистным сооружениям и эффективности их работы. Полученные результаты могут быть применены при планировании размещения промышленных предприятий на территории республики с целью уменьшения уровня загрязнения атмосферного воздуха путем разумного использования рассеивающей способности метеорологических факторов и явлений.

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## ERA5 реанализінің деректері бойынша Қазақстан Республикасының аумағындағы 2021 жылғы атмосфераның ластану потенциалы

Атмосфералық шекаралық қабаттағы ауаның ластану потенциалы ERA5 реанализінің деректері бойынша есептелді және оның Қазақстан Республикасының аумағы бойынша таралуы сипатталды, атмосфераның ластану потенциалының қалыптастыру жағдайларының ең көп және ең аз қайталану аймақтары анықталды. Атмосфера халық пен экожүйелерді сақтау үшін қауіпсіз жағдайларды қамтамасыз ететін іс жүзінде сарқылмас ресурс болып саналады. Алайда, адамның шаруашылық әрекетінің нәтижесінде атмосферада көптеген ластаушы заттар пайда болады, атмосфералық ауа сапасының едәуір өзгеруі ірі қалаларда байқалады. Зерттеу метеорологиялық параметрлердің атмосферадағы ластаушы заттардың концентрациясына, олардың қозғалуына және атмосфераның өзін-өзі тазарту қабілетіне маңызды әсерін көрсетеді. Климаттық әлеуетті анықтауға бағытталған есептеулер жүргізілді, бұл Қазақстан Республикасының аумағындағы атмосфераның өзін-өзі тазарту деңгейін анықтауға мүмкіндік берді. Қазіргі уақытта өзін-өзі тазарту механизмі атмосферадағы ластаушы заттардың көп мөлшерін жеңе алмайды, содан кейін қоспалардың жоғары концентрациясы пайда болады. Атмосфераның ластану әлеуеті атмосфераның ластаушы заттардан өзін-өзі тазарту қабілетін бағалаудың кең қолданылатын әдістерінің бірі. Бұл әдіс белгілі бір аймақтағы нақты шығарындылардағы зиянды заттардың орташа концентрациясының шартты концентрацияға қатынасын есептеуге негізделген.

*Кілт сөздер:* атмосфераның ластану әлеуеті, атмосфералық ауа, температураның инверсиясы, жауын-шашын, желдің жылдамдығы, атмосфераның таралу қабілеті.

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## The potential of atmospheric pollution on the territory of the Republic of Kazakhstan according to the ERA5 reanalysis for 2021

According to the data of the reanalysis of ERA5, the potential of atmospheric pollution in the boundary layer of the atmosphere was calculated and the nature of its distribution over the territory of the Republic of Kazakhstan was described, the areas of the greatest and least repeatability of the conditions for the formation of the potential of atmospheric pollution were identified. As a result of human economic activity, a large number of pollutants appears in the atmosphere, the most significant changes in the quality of atmospheric air are observed in large cities. At the moment, the self-cleaning mechanism cannot cope with a large number of pollutants in the atmosphere, which leads to the formation of high concentrations of impurities. The potential of atmospheric pollution is one of the widely used ways to assess the self-purification of the atmosphere from pollutants. This method represents the ratio of average concentrations of harmful substances with actual emissions in a specific and conditional region.

*Keywords:* atmospheric pollution potential, atmospheric air, temperature inversions, precipitation, wind speeds, atmospheric scattering capacity.

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# The study of the city of Rudny as a "heat island"

The annual increase in surface air temperatures contributes to climate change. This phenomenon is widespread over the entire surface of the Earth and is typical for any point of the planet. The purpose of this study was to identify patterns of changes in meteorological indicators in the city of Rudny, Kostanay region, Republic of Kazakhstan over the summer period 2018–2022. The scientific novelty of the work lies in the fact that for the first time the spatial distribution of the heat index in the territory of the city of Rudny was determined. To conduct the study, data from local automated weather stations were used, meteorological data was analyzed, compared for each year of the study, and the heat index was calculated. The reliability of the results is ensured by mathematical processing of daily empirical temperature and humidity data (calculation of the average for the day, the average for the month), coefficient of variation, coefficient of dispersion. The conducted research provides a clear description of climate changes in the city of Rudny, which can be used by municipal authorities to form measures to reduce the thermal impact on public health, heat loss in the housing and communal services system, and to improve air quality when planning urban infrastructure in the territory of the studied city.

*Keywords*: heat island, heat wave, heat index, coefficient of variation, coefficient of dispersion, meteorological indicator, trend line, atmospheric humidity, atmospheric temperature.

## *Introduction*

According to Kazhydromet, over the past 100 years, the average annual temperature in Kazakhstan has increased by 1.5 degrees Celsius [1]. This situation indicates local climate change and implies an annual increase in surface air temperature indicators.

Therefore, the purpose of this study was to identify patterns of changes in meteorological indicators. The place of research is the city of Rudny. The summer period 2018–2022 was chosen for the study.

In accordance with the goal, the following tasks were set:

– study the factors influencing the formation and intensity of heat island propagation in the city of Rudny;
– analyze the temperature and humidity indicators for the summer period 2018–2022 for the city under study.
– calculate the heat index for the summer period 2018–2022 for the city under study.
– identify the relationship between changes in indicators in the city of Rudny over time (for the summer period 2018–2022).

The relevance of this work is determined by the intensive development of urbanization, which affects the local climate of the territory, characterized by the appearance of the so-called "heat island". The calculated data can be used by municipal authorities to formulate measures to reduce the heat impact on the health and life of the population, on heat losses in the housing and communal services system, and on improving air quality when planning urban infrastructure.

The scientific novelty of the work lies in the fact that for the first time the spatial distribution of the heat index over the territory of the city of Rudny was determined.

The object of research was the city of Rudny, Kostanay region, Republic of Kazakhstan.

The subject of the study was the indicators of temperature and humidity of atmospheric air, as well as the patterns of their interaction. These meteorological indicators for the summer period 2018–2022 were taken from the official website of Kazhydromet [1]. Data for the summer months of 2023 are not published on the site.

*Materials and methods*

Analyzing the urban “heat island” is one of the easiest ways to see how human impact can change our planet [2–4]. Urban “heat island” is a meteorological phenomenon that involves an increase in the temperature of urban space relative to the surrounding rural areas [5–8]. To identify the “heat island”, the difference between the values of the heat indices calculated from the temperature and humidity of atmospheric air is used [9–11].

The formation and intensity of the «heat island» spread is influenced by the following factors:

– geographical location;

– size of the city;

– specialization of the city;

– weather conditions;

– time;

– city type [12–15].

Each of these factors is considered in relation to the city of Rudny [16]:

1 Geographical location:

Rudny is a city located on the Tobol River in Kostanay region. The territory is characterized by a relatively flat terrain. Rudny is bordered by 2 cities (Kostanay, Lisakovsk) and 4 districts (Taranovsky, Auliekolsky, Fedorovsky, Altynsarinsky).

2 City size:

By the volume of the occupied territory, the city occupies the 2nd place in the region after Moscow, Kostanay and its area is 195.11 km2.

3 Specialization of the city:

Rudny is a city of regional subordination. The city is rich in ore resources, including coal, iron ore and other metals. Its emergence is associated with the development of an iron ore deposit and the construction Sokolovsko-Sarbaysky Mining and Processing Plant (JSC SSGPO). This is a single-industry town.

4 Weather conditions:

The climate is sharply continental, with a pronounced alternation of four seasons. Winters are long and frosty, with strong winds and blizzards, and summers are hot and dry.

5 The time taken for the study is the summer season, with the vegetation available during this period and hot weather conditions.

6 City type:

city geometry: houses on the territory of the city are located in a block and parallel street system.

landscaping: there is a small amount of shrubby vegetation, trees, including those with pruned crowns — the vegetation is small.

materials: the asphalt surface strongly prevails, there is a mirror reflecting surface of buildings (windows, building cladding), metal and stone monuments on the territory of the city, metal lamp posts, a large flow of cars.

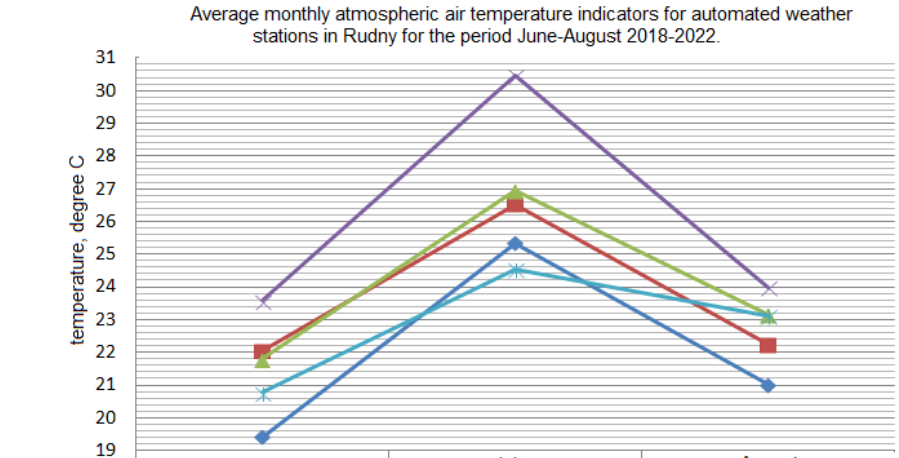
Having recognized the factors influencing the formation and intensity of the spread of the “heat island” in Rudny, then we consider the indicators of temperature and humidity of atmospheric air taken from the official website of Kazhydromet for the summer period 2018–2022 for 2 automated weather stations located in Rudny [1]:

Rudny PNZ No. 5 (S), Molodoy Gvardii str. / 4th pereulok.

Rudny PNZ No. 6 (S), Komsomolsky ave., mosque district.

Since data on meteorological indicators are available only for the PNZ No. 6 (S) weather station, then only these indicators will be used in the study.

After analyzing the temperature and humidity indicators of atmospheric air for the summer period 2018–2022, comparative graphs are constructed, presented in Figures 1 and 2.

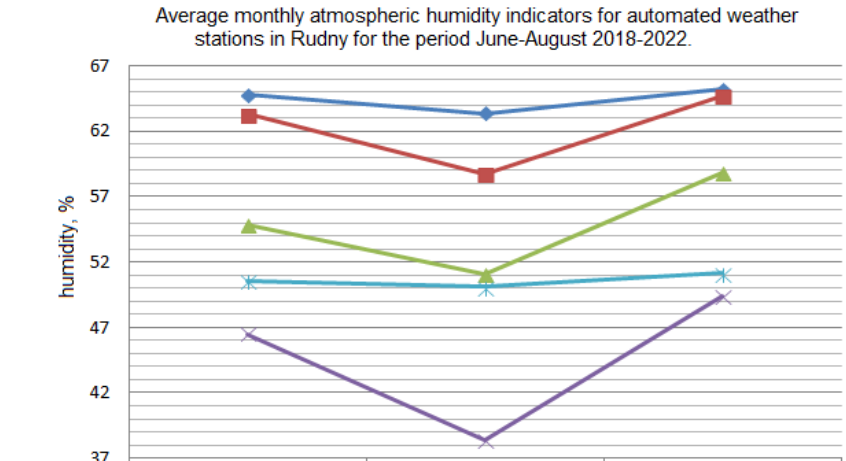



| | June | July | August |
|---|---|---|---|
| 2018 year | 19,42 | 25,33 | 21,02 |
| 2019 year | 22,06 | 26,53 | 22,26 |
| 2020 year | 21,8 | 26,94 | 23,16 |
| 2021 year | 23,57 | 30,45 | 24 |
| 2022 year | 20,77 | 24,53 | 23,11 |

Figure 1. Monthly average air temperature indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June-August 2018–2022

According to the graph, the following conclusions were drawn on the monthly average atmospheric temperature indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June-August 2018–2022:

1. The highest annual figures for atmospheric air temperature, among those presented, were revealed in 2021, and the lowest — in 2018.
2. High temperature indicators are more pronounced in July and less pronounced in June.
3. Every year there is an increase in the average value of atmospheric air temperature by about 0.5–1.5°C.




| | June | July | August |
|---|---|---|---|
| 2018 year | 64,81 | 63,39 | 65,18 |
| 2019 year | 63,29 | 58,74 | 64,72 |
| 2020 year | 54,81 | 51,05 | 58,81 |
| 2021 year | 46,47 | 38,33 | 49,36 |
| 2022 year | 50,56 | 50,08 | 51,13 |

Figure 2. Monthly average atmospheric humidity indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June-August 2018–2022

According to the constructed schedule, the following conclusions were drawn on the average monthly atmospheric humidity indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June-August 2018–2022:

1. The highest annual humidity indicators were revealed in 2018, and the lowest — in 2021.
2. Indicators of high humidity are more pronounced in August, less so in June.
3. Every year there is a decrease in the average value of atmospheric humidity by about 7–15 %.

The calculated coefficients of variation and variance presented in Table 1 are used to confirm changes in meteorological indicators for the summer period 2018–2022.

According to the calculated values, a conclusion is made on the coefficients of variation and variance based on the data of atmospheric temperature and humidity for the period June-August 2018–2022. The greater the difference between the resulting coefficients, the more the initial data differ from the average (normal for the region and season) indicators, i.e. there are abrupt changes in the indicators.

The study uses the following methods:

– to obtain data on the regularities of the formation of "heat island": study and determine the factors of formation and intensity of the spread of "heat island" in the city under study;

– to collect initial weather data in the object under study: method for analyzing weather station data, HORIBA software package, Kazhydromet official website https://www.kazhydromet.kz;

– for mathematical data processing, identifying trends in their changes, and visualizing results: the capabilities of the Excel, Google Earth, and Humindex computer programs.

Table 1

**Coefficients of variation and variance based on atmospheric temperature and humidity data for the period June-August 2018–2022**

| Year | Coefficient of variation, % | | Coefficient of variance | |
|---|---|---|---|---|
| | According to temperature data | According to humidity | According to temperature | According to humidity |
| 2018 | 15,33 | 10,23 | 0,46 | 0,56 |
| 2019 | 11,82 | 10,89 | 0,27 | 0,64 |
| 2020 | 13,76 | 14,37 | 0,37 | 1,10 |
| 2021 | 3,61 | 6,91 | 0,02 | 0,25 |
| 2022 | 9,17 | 2,42 | 0,16 | 0,03 |

*Results and Discussion*

Having the values of temperature and humidity of atmospheric air, it is possible to calculate the heat index using the online calculator Humindex. This indicator is necessary to determine the equivalent temperature perceived by a person [17].

Based on the calculated heat index data for the period June-August 2018–2022 for the automated weather station PNZ No. 6 (S) in Rudny, presented in Table 1 of Appendix A, the following conclusions are drawn:

This indicator has low values in the morning, compared to the rest, and high values are seen in the daytime.

The lowest indicator in the summer season (5.8-morning) was revealed in 2018, the highest (37.9-day) — in 2019.

After analyzing the heat index indicators for the summer period 2018–2022, comparative graphs are constructed, shown in Figure 3.

According to the World Meteorological Organization, heat waves are considered to be a period with a maximum daily air temperature exceeding the average maximum temperature by $5^0$C or more, lasting continuously for 5 days or more [18]. In the branch of RSE "Kazhydromet" in Kostanay region, there are data on the average maximum air temperature in the summer season for the city of Rudny and are equal to: in June +19.9$^0$C, in July +21.1$^0$C, in August +18.9$^0$C [19]. These values are determined based on already available data for the last 50 years for the city under study. The impact of heat waves on climate change is significant [20]. This is also typical for the Republic of Kazakhstan. The phenomenon affects every city in the country, including the city of Rudny (the object of research).

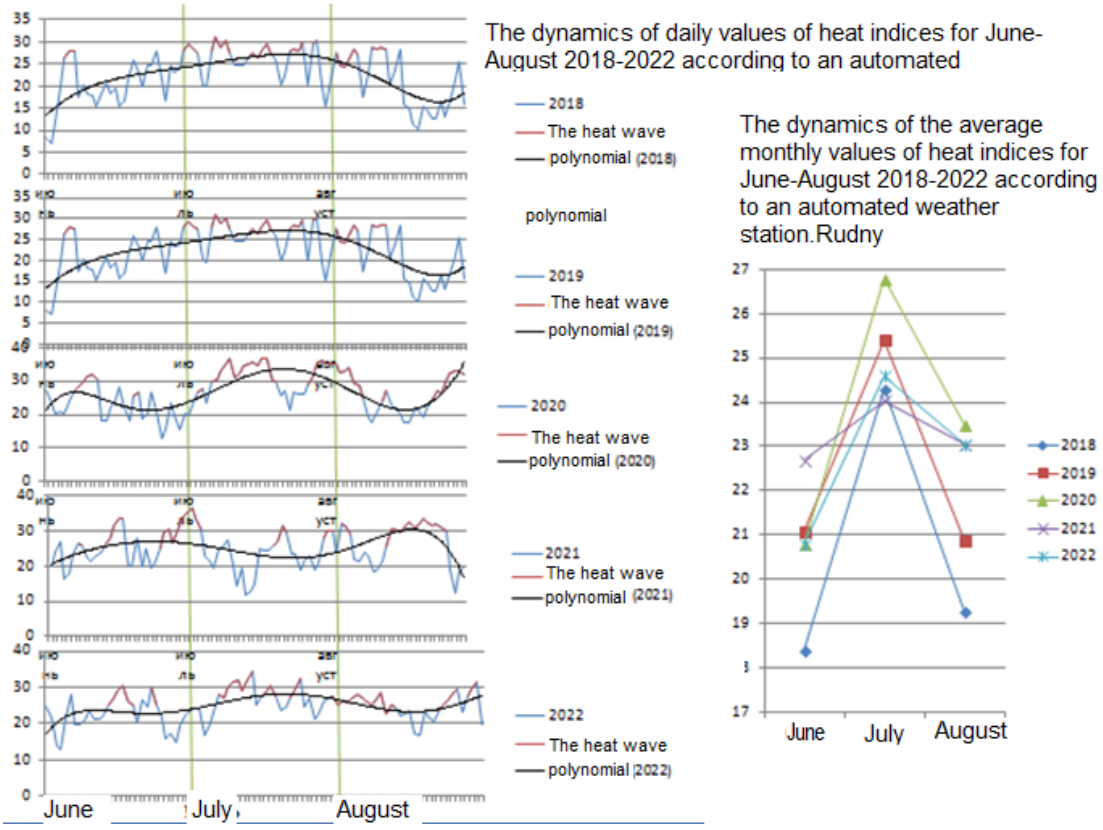



Figure 3. Heat index indicators for the summer period 2018–2022

According to the constructed graphs, the following conclusions were drawn on the heat index indicators for the summer period 2018–2022:

1. Thanks to the built-up trend lines, the variability of the heat index indicators by month can be clearly traced. Since mid-June, the index has been growing, and by mid-August it is declining.
2. Over the years, the dynamics of increasing the values of the thermal index is noticeable.
3. The lowest overall figures were found in 2018, and the highest overall figures were found in 2020.

The increased risk of heat waves affecting human health can be traced in the daytime during the entire summer season. The average duration of heat waves is 7–16 days. The intervals between them are 5–10 days. At least 1 heat wave is recorded every month, and most of them are traced in July and August.

Table 2 shows the number of days with increased heat index values and the number of heat waves during the study period.

According to the calculated values, conclusions are drawn on the number of days with increased heat index values and the number of heat waves for the period June-August 2018–2022.:

1. The month of June is least affected by heat waves and increased heat index values.
2. The months of July and August are comparatively similar.
3. Data for 2020 are presented as anomalous.

Table 2

**The number of days with increased heat index values and the number of heat waves for the period June-August 2018–2022**

| Month | Total number of days with increased heat index values / number of heat waves | | | | |
|---|---|---|---|---|---|
| | 2018 | | 2018 | | 2018 |
| June | 5/-6 | June | 5/-6 | June | 5/-6 |
| July | 21/2 | July | 21/2 | July | 21/2 |
| August | 12/1 | August | 12/1 | August | 12/1 |
| TOTAL: | 38 days / 3 heat waves | TOTAL: | 38 days / 3 heat waves | TOTAL: | 38 days / 3 heat waves |

*Conclusions*

As a result of the research work, the goals and objectives set earlier were fulfilled and the following conclusions were obtained:

1. The following regularities of changes in the temperature and humidity of atmospheric air in the city of Rudny during the studied period were revealed:

– During the summer period 2018–2022, there is an annual increase in the average value of atmospheric air temperature by about 0.5–1.5 °C and a decrease in the average value of atmospheric air humidity by about 7–15 % during the summer months;

– Among the summer months, the month of June is distinguished by low temperature and humidity indicators for the entire study period, the month of July is distinguished by high temperature values, and the month of August is characterized by high data on atmospheric humidity in the city of Rudny.

2. The regularity of the peak temperature and the values of the heat index in the daytime, respectively, and the greatest danger of finding a person in the open air is confirmed. The safest time for a person is in the morning.

3. During the period June-August 2018–2022, an increase in the number of days with a high heat index is observed. Heat waves can be traced in the summer period 2018–2022.

4. Since 2020, there has been a jump in the increase in meteorological indicators, and this trend continues.

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А.В. Голушко

## Рудный қаласын «жылу аралы» ретінде зерттеу

Жер бетіндегі ауа температурасының жыл сайынғы жоғарылауы климаттың өзгеруіне ықпал етеді. Бұл құбылыс Жердің бүкіл бетіне кең таралған және планетаның кез келген нүктесіне тән. Зерттеудің мақсаты 2018–2022 жылдардағы жазғы кезеңде Қостанай облысы Рудный қаласындағы (Қазақстан) метеорологиялық көрсеткіштердің өзгеру заңдылығын анықтау. Жұмыстың ғылыми жаңалығы мынада: алғаш рет Рудный қаласының аумағында жылу көрсеткішінің кеңістікте таралуы анықталғанында. Зерттеуді жүргізу үшін жергілікті автоматтандырылған метеостанциялардың мәліметтері пайдаланылды, метеорологиялық деректерге талдау жасалды, зерттеудің әрбір жылына салыстыру жүргізілді және жылу индексі есептелді. Нәтижелердің сенімділігі температура мен ылғалдылықтың тәуліктік эмпирикалық деректерін математикалық өңдеу арқылы қамтамасыз етілді (орташа тәуліктік, орташа айлық есептеу), яғни вариация коэффициенті және дисперсия коэффициенті. Зерттеу Рудный қаласы бойынша климаттың өзгеруіне нақты сипаттама береді, оны муниципалды органдар тұрғындардың денсаулығына жылу әсерін, тұрғын үй-коммуналдық шаруашылық жүйесіндегі жылуды жоғалтуды азайту және зерттелетін қаланың аумағында қалалық инфрақұрылымды жоспарлау кезінде ауа сапасын жақсарту шараларын қалыптастыру үшін қолдана алады.

*Кілт сөздер:* жылу аралы, жылу толқыны, жылу индексі, вариация коэффициенті, дисперсия коэффициенті, метеорологиялық көрсеткіш, тренд сызығы, атмосфералық ауаның ылғалдылығы, атмосфералық ауа температурасы.

А.В. Голушко

## Исследование города Рудный как «острова тепла»

Ежегодное повышение температурных показателей приземного воздуха способствует изменению климата. Данное явление распространено по всей поверхности Земли и характерно для любой точки планеты. Целью данного исследования являлось выявление закономерности изменения метеорологических показателей в городе Рудном Костанайской области (Казахстан) за летний период 2018–2022 годов. Научная новизна работы заключается в том, что впервые было определено пространственное распределение индекса тепла на территории города Рудного. Для проведения исследования использовались данные местных автоматизированных метеостанций, проводился анализ метеорологических данных, их сравнение за каждый год исследования, а также вычислялся индекс тепла. Достоверность результатов обеспечивалась математической обработкой ежедневных эмпирических данных температуры и влажности (подсчет среднего за день, среднего за месяц), коэффициента вариации, коэффициента дисперсии. Проведенное исследование дало четкую характеристику изменениям в климате по городу Рудному, которая может использоваться муниципальными органами для формирования мер по уменьшению теплового воздействия на здоровье населения, на потери тепла в системе жилищно-

коммунального хозяйства, на улучшение качества воздуха при планировании городской инфраструктуры на территории исследуемого города.

*Ключевые слова*: остров тепла, волна жары, индекс тепла, коэффициент вариации, коэффициент дисперсии, метеорологический показатель, линия тренда, влажность атмосферного воздуха, температура атмосферного воздуха.

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