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# BIOLOGICAL POTENTIAL OF JERUSALEM ARTICHOKE AS A FEEDSTOCK FOR FOOD AND PHARMACEUTICAL INDUSTRIES

Studies aimed to import pharmaceutical products, as well as to strengthen the food security of the Republic of Belarus, are highly relevant. In this connection an universal culture of Jerusalem artichoke is of interest, the value of which is determined due to the possibility of its use in feed, food and pharmaceutical industries. The paper presents the productivity research of Jerusalem artichoke varieties with different growing seasons, the estimation of mineral composition of tubers, the content of inulin as the most valuable component of mentioned agricultural crops was determined.

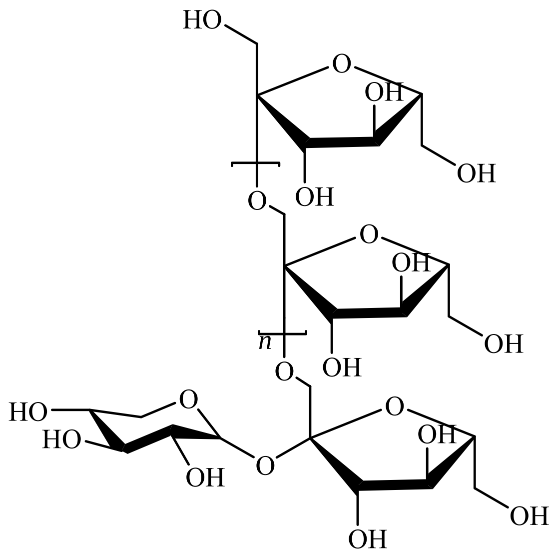
**Introduction.** Jerusalem artichoke, or artichoke (*Helianthus tuberosus* L.), is a plant of perennial Asteraceae family having the height from 40 cm to 4 m with erect branching, wooly stem and underground shoots in which tubers are formed.

The high content of various biologically active substances in Jerusalem artichoke shows the use perspectiveness of this culture in healthy diet and herbal medicinal products.

Jerusalem artichoke is one of the main sources of inulin among higher plants [1]. Jerusalem artichoke protein has a high nutritional value due to the presence of almost all the essential amino acids and their balanced content [2]. Another option of the potential use of this plant is a fodder crop [3]. In recent decades, Jerusalem artichoke is considered as a culture to produce biomass for ethanol production because Jerusalem artichoke contains high levels of carbohydrates [4]. Under certain conditions, the biogas production from biomass of Jerusalem artichoke is economically advantageous [5].

Studies on the nutritional value of Jerusalem artichoke has shown that that tubers contain important components for a balanced diet. Jerusalem artichoke contains a variety of vitamins and minerals. Iron content in Jerusalem artichoke is significantly higher than in other plants, such as carrots, potatoes, turnips, beets, etc. Furthermore, artichoke includes potassium, calcium, silicon, magnesium, sodium, fluoride, chromium and other minerals. Jerusalem artichoke contains fiber, pectin, organic acids, fats, proteins and essential amino acids. Jerusalem artichokes is rich in vitamins B1, B2, B6, C, PP, carotenoids, and contains essential amino acids: arginine, valine, lysine, leucine, and others. All this makes artichoke a necessary product for health maintaintence. Jerusalem artichoke is especially appreciated in the fact that its tubers, unlike other crops, accumulate as storage material not starch but inulin, which consumption does not change glycemic index. That is why Jerusalem artichoke is recommended primarily for patients with diabetes mellitus.

Inulin $(C_6H_{10}O_5)n$ is natural linear biopolymer molecules built from D-fructose joined by glycosidic bonds (Figure). In plants with inulin there are




The structural formula of inulin

related carbohydrates such as pseudoinulin, inulenin, levulin, heliantenin, sinistrin, irisin etc., that give D-fructose during hydrolysis. Inulin is increasingly being used in food production because it has unusual adaptational characteristics. It can be used to replace sugar, fat and flour.

In the diet inulin is a form of soluble dietary fibers and is classified as a prebiotic. It also provides healthy influence on the absorption of some important elements, such as calcium, magnesium, etc.

In herbal medicine inulin is considered to be a natural nutritional component that has beneficial effect on the human body by reducing sugar and cholesterol levels in blood and it is used to treat patients with diabetes and cardiovascular disease. By the number of carbohydrate Jerusalem artichoke exceeds sugar beet and sugar cane.

Introduction of artichoke to the culture was restrained because of its insufficient state of knowledge, lack of the technology and machines for the commercial cultivation, as well as developments to its use and refining. Currently Jerusalem artichoke cultivation demonstrates high economic efficiency in many countries. Jerusalem artichoke is one of the most high-yielding plant. The yield of green mass is 120–150 t/ha, while the yield of tubers is 100 – 120 t/ha in the fertile lands in the United States, Canada, Brazil, France, Russia and other countries which requires special doses of organic and mineral fertilizers. The total harvest of biomass reaches from 200 to 270 t/ha or more, and such harvest is considered as normal. Jerusalem artichoke is unpretentious to the soil. It can be grown on the lands removed from agricultural use, former quarries and waste deposits, on sandy and sabulous soils. This plant is used for the revegetation of lands removed from agricultural use.

For the Republic of Belarus this crop remains "non-traditional" and little-known and is cultivated mostly only in private households and as decor-tive plant. In connection with the above, the purpose of the present study was to analyze the biological potential of collection varieties of Jerusalem artichoke, as raw materials for the food and pharmaceutical industry of the Republic of Belarus.

**Main part.** 10 varieties of artichoke, cultivated in the experimental field of the "Central Botanical Garden of the NAS of Belarus", among them 5 late-ripening (Dietichesky, Violet de Rennes, Sireniki-2, Kievsky Bely, Canadsky), 2 mid-ripening (Interes, Nahodka) and 3 early-ripering (Blanc Brekos, Gigant, Skorospelka) varieties were the object of the study. Identification of the most promising varieties of Jerusalem artichoke requires the study of many morphogenetic parameters, their stability and variability, which determine both the biochemical composition and stable productivity of tubers in different soil and climatic conditions. The breed, as a stable group of crops, possess stable genotype and phenotypic flexibility that is based on complex mechanisms of interaction "genotype – environment". The yield is determined primarily with the result of this interaction, where the environment is not only soil and climatic conditions, but also technologic methods of cultivation. And if such morphogenetic parameters of Jerusalem artichoke varieties as leafage, shape and color of the tuber, the shape and color of the stem, the color, shape, pubescence and the serrature of the leaf edges are stable and unchangeable, the biochemical parameters, as well as plant height and productivity of tubers are variable .

The vegetation period in 2013 was 178 days (from May 22 to October 16), and was characterized by a warm autumn. The average temperature during the summer season was +18,5 °C, which is 1,7ºC above normal. Over the summer season, the average level of atmosphere precipitation was 197 mm, which is 81% of the climatic norm of the summer season.

To study the variability of morphogenetic parameters of 10 varieties of artichoke at the end of the growing season the plant height, their weight, the average number of tubers per plant, tuber weight per plant and yield (t/ha) were registered (Table 1) .

The average plant height of individual varieties reached 3 m (Interes variety), Canadian variety distinguished by the above-ground biomass productivity, the average plant height was 2.94 m, and the average weight of plants was more than 1.5 kg. The greatest yield of tubers showed varieties Blanc Brekos (941 kg/ha), Gigant (993 kg/ha), Sireniki-2 (878 kg/ha), Kievsky Bely (1223 kg/ha) and Nahodka (1001 kg/ha).

Table 1

**Plant height, productivity of the tops and tuber collection varieties of Jerusalem artichoke**

| Variety | Mean altitude at the end of the growing season, m | Average weight of the tops, kg | Tubers quantity from 5 plants, pieces | Mean yield of tubers per plant, kg | Yield of tubers in fresh weight, dt/ha |
|---|---|---|---|---|---|
| Dietichesky | 2,56 ± 0,04 | 1,266 ± 0,220 | 76 | 0,508 ± 0,220 | 290,28 |
| Violet de Rennes | 2,46 ± 0,06 | 1,036 ± 0,100 | 68 | 0,446 ± 0,200 | 254,86 |
| Blanc Brekos | 1,89 ± 0,07 | 0,268 ± 0,030 | 215 | 1,646 ± 0,350 | 940,57 |
| Gigant | 2,77 ± 0,06 | 1,158 ± 0,090 | 208 | 1,738 ± 1,290 | 993,15 |
| Sireniki-2 | 2,60 ± 0,06 | 1,030 ± 0,160 | 272 | 1,538 ± 0,470 | 878,86 |
| Kievsky Bely | 2,69 ± 0,06 | 1,226 ± 0,330 | 252 | 2,140 ± 1,220 | 1 222,86 |
| Nahodka | 1,95 ± 0,09 | 1,312 ± 0,100 | 236 | 1,752 ± 1,380 | 1 001,14 |
| Interes | 3,08 ± 0,05 | 1,310 ± 0,170 | 170 | 1,140 ± 0,060 | 651,43 |
| Skorospelka | 2,44 ± 0,06 | 1,180 ± 0,200 | 125 | 0,828 ± 0,240 | 473,14 |
| Canadsky | 2,94 ± 0,16 | 1,530 ± 0,370 | 160 | 1,300 ± 0,420 | 742,86 |

The statistical analysis of the data showed that the most stable indicator was the plant height, while yield of the above-ground biomass and of tubers were variable (Table 1). The standard deviation of the height of plants in the samples ranged from 1.62% (Interes variety) to 5.44% (Canadsky variety). The least variable grade in terms of "above-ground biomass" had variety Nahodka (7.62%) and the most variable was variety Kievsky Bely (26.92%). All varieties except Interes variety (5.26%) were shown a high level of variability from 21.26% (Blanc Brekos variety) to 74.22% (Gigant variety). The analysis of the received data was shown that the most stable variety of artichoke to obtain stable yields of tubers is Interes variety.

The accumulation of data about the productivity of different varieties, as well as the content of minerals and bioactive compounds (especially inulin) will allow to predict the prospects of attracting the different varieties for the industrial use. In this connection the inulin content and the mineral components in the tubers of Jerusalem artichoke was analyzed.

As the first we have analyzed the literature on modern methods of analysis of plant polysaccharides [2]. Thus, the technique of the determination of inulin in fresh tubers of Jerusalem artichoke was adapted.

Tubers of Jerusalem artichoke were grated and the succus was decanted. The bagasse was washed with hot water (80 °C). The rinsewaters were combined with the succus. Ascorbic acid (0.5 g per 100 ml) was added to the solution to clarify it and the solution was heated to 80 °C. To form a residuum two parts of isopropanol were added to one part of the hot solution, and the mixture was left in the refrigerator. The supernatant was decanted and the residuum was centrifuged at 6000 $min^{-1}$. The obtained residuum was reprecipitated by addition of hot water. To remove proteins QAE Sephadex (5 ml of fully turgid gel per 100 ml solution) was added. The solution was stirred occasionally and the temperature was maintained about 60 °C to prevent of inulin precipitation. The gel particles acted as sorbing agent for colored substances and proteins. In one hour the supernatant was decanted and the residuum was washed with a small amount of hot water. The rinsewaters were combined with the decanted liquid and isopropanol was added in the same ratio. The obtained homogenate was used to the inulin crystallization. The residuum of inulin (color from white to creamy) was separated by centrifugation at 6000 $min^{-1}$and was air-dried. At the average, the content of inulin in samples was 13%, the minimum amount of inulin was found in tubers of variety Interes (9.8%), the maximum was found in tubers of variety Violet de Rennes (15.2%).

Composition of mineral components in tubers of Jerusalem artichoke was determined in the ash residual using a scanning electron microscope JSM-5610 LV, equipped with the system of electron probe energy-dispersive analysis EDX JED-2201 (JEOL, Japan). The results are shown in Table 2.

Comparative analysis of determination of the mineral composition of Jerusalem artichoke tubers was showed that the predominant component in all samples is potassium (from 69.1 to 78.5% of the total content of minerals). Also Jerusalem artichoke contains large amounts of calcium, magnesium, phosphorus, sulfur and copper, which is important when using this culture as a raw material for the food industry.

Table 2

**The composition of the mineral components in the ashes of Jerusalem artichoke tubers**

| Variety | The total content of elements, % | The content, % of the total amount of minerals calculated as oxides | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Al | Ca | Fe | K | Mg | P | Si | S | Cu | Zn |
| Dietichesky | 8.20 | – | 2.9 | – | 75.0 | 2.6 | 10.9 | – | 4.0 | 1.8 | – |
| Violet de Rennes | 3.74 | 0.2 | 2.4 | – | 71.9 | 2.7 | 16.6 | – | 2.3 | 1.4 | 0.2 |
| Blanc Brekos | 7.35 | 0.3 | 3.3 | 0.9 | 72.6 | 1.6 | 9.7 | 3.8 | 3.7 | 0.4 | 1.8 |
| Gigant | 9.21 | 0.4 | 2.2 | 0.2 | 75.9 | 1.7 | 12.0 | 0.2 | 3.7 | 0.9 | 0.6 |
| Sireniki-2 | 5.47 | – | – | – | 76.5 | 2.9 | 14.5 | – | 2.3 | 0.9 | 1.5 |
| Kievsky Bely | 5.06 | 0.3 | – | 0.4 | 78.5 | 2.1 | 8.2 | 0.7 | 3.1 | 1.4 | 1.1 |
| Nahodka | 7.24 | – | – | 0.4 | 75.4 | 2.4 | 13.8 | 0.6 | 4.7 | 1.4 | 0.3 |
| Interes | 6.14 | – | – | – | 72.1 | 3.0 | 16.3 | 0.4 | 2.8 | 2.1 | 0.3 |
| Skorospelka | 6.14 | 0.6 | – | 0.2 | 70.0 | 3.0 | 15.5 | 0.7 | 5.6 | 1.6 | 1.4 |
| Canadsky | 7.18 | 0.3 | – | 0.3 | 69.1 | 2.7 | 18.2 | 0.4 | 5.5 | 0.9 | 0.3 |

**Conclusion.** The obtained results show that early-ripering varieties yield in average 370 kg/ha tubers of artichoke, mid- ripening varieties yield 430 kg/ha, and late-ripening varieties yield 360 kg/ha. The amount increase of the tops ranged from 6.4 to 7.9 cm per day for all varieties. The inulin content in all varieties is almost the same, but the content of mineral components is quite different. Among the analyzed samples in terms of the productivity, the ash and minerals contents (especially phosphorus and magnesium) varieties Sireniki-2 and Interes were stand out. The productivity of these varieties is 513 and 575 kg/ha, ash content is 9.21 and 7.24% phosphorus content in the ash is 14.5 and 16.3%, the magnesium content is 2.9 and 3.0% respectively. These varieties allow us to recommend it for planting and transfer to competitive trial for subsequent implementation to the industry.

Presented results of the research were obtained during in the realization of the scientific research "Development of biochemical criteria for the identification of genotypes of Jerusalem artichoke (*Helianthus tuberosus* L.) with a balanced content of biologically active compounds for industrial production of medicines and dietary supplements".

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