

Development of variety technologies for cultivation of potato in the Middle Urals

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Abstract. Potato is one of the most important human foods. It possesses high taste and nutritional properties. The optimal ratio in potato tubers of organic and mineral substances necessary for a person determines its value as a food product. The tubers contain on average 76–78 % of water and 13 to 36 % of dry matter, of which 12–15 % are starch, 1–3 % protein and about 1 % – mineral compounds. Potato proteins have a very high biological value, since they contain a complex of essential amino acids that are not synthesized in the human body and must be obtained from food. Potatoes are an essential source of vitamin C. The studies were carried out on the experimental field of the educational and experimental farm “Uralets” of the Ural State Agrarian University (USAU), the village of “Studencheskiy”, for three years (2016–2018) in the climatic zone of the Middle Urals. **Purpose of research.** The objective of this study was to study the influence of the feeding area of Gala potato, the use of fungicides on the yield and quality of tubers in the conditions of the Middle Urals. **Results.** The results analysis on the mineral and biochemical composition of tubers showed that the total nitrogen content changed from 0.25 to 0.37 % and did not depend on the feeding area. The phosphorus content varied from 0.034 to 0.063 % and depended on the feeding area, i. e. the less often the plantings were, the more phosphorus was contained. Potassium content fluctuated over the years. The starch content was stable and did not depend on weather conditions and feeding area and ranged from 11.3 to 15.4 %. The tasting result showed that the studied potato variety Gala has high taste. According to the taste assessment, the Gala variety was rated 5 points in the control variant. The variant with the use of the fungicide “Shirlan” yielded to it by 0.5 points. **Scientific novelty.** The scientific novelty lies in the fact that for the first time in the conditions of the Middle Urals, the influence of the feeding area on the mineral and biochemical composition of potato tubers (nitrogen, phosphorus, potassium, dry substances, vitamin C and others). **Keywords:** potato, tuber quality, mineral composition, biochemical composition, nutritional area, fungicide, tasting, taste assessment.

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Introduction

Potato is one of the most important crops and is rightly called the second bread. In the world production of crop products, it occupies one of the first places along with rice, wheat and corn. Potato contains almost all the essential enzymes and vitamins necessary for humans and animals, the most important of which is vitamin C. Its tubers contain up to 25 % of dry matter and vital mineral salts, as well as trace elements. The main minerals and proteins in the tubers are unevenly located, concentrated under the skin or in the immediate vicinity of the surface, so tubers with an intact skin retain all nutritional benefits during storage and, as a rule, are not damaged by diseases. Red, yellow, white and brown tubers provide the human body with a significant amount of vitamins and minerals. For example, one medium potato contains about 620 mg of potassium, which is more than bananas. Potassium is of great importance for humans, since it is involved in the regulation of muscle activity and affects the resistance of nerve cells to stress. Iron, which is found in potato, is involved in the conversion of food into energy, and is also important in the body's resistance to infections [15].

Potato is the fourth food crop in the world with a production of 377 million tonnes in 2016 after maize, rice, and wheat. China is the biggest producer of potato with an annual production of 99.13 million tonnes. Potato is commonly considered as a starch source due to the high starch content (65.90 to 74.08 g 100 g⁻¹ dry weight, which is higher than that of the most used starch source – wheat (65.18 g 100 g⁻¹ dry weight) [14].

Potato tubers contain about 25 % dry matter, including 14 ... 22 % starch, 1.4 ... 3.0 % protein, about 1 % fiber, 0.2 ... 0.3 % fat and 0.8 ... 1.0 % ash substances, organic acids – 0.6 %, sugars – 1 %, water – 75 %. Potatoes are rich in vitamins C, B₁, B₂, B₆, PP and minerals. Young tubers are especially rich in vitamins [3], [7], [8], [12].

The raw potato is an important source of antioxidants, dietary material, 325 kcal food energy, 7.6 g protein, 0.04 g fat, 72.8 g carbohydrates, 42 mg Ca, 231 mg P, 2.7 mg Fe, 70 IU vitamin A, 0.15 mg riboflavin, 4.4 mg niacin, and 64 mg ascorbic acid. Furthermore, the potato is one of the most important food crops [9].

Moreover, the resistant starch (22.50 %) that promoted the digestion and regular movement of large intestine in the potato starch was higher than that of maize starch (1.30 %), wheat starch (1.00 %), and rice starch (6.50 %) [6], [17].

In terms of nutrition, potato is a complex source of nutrients (vitamins, carotenoids, anti-oxidant phenolics, proteins, magnesium etc.), and some anti-nutrients (primarily glycoalkaloids). On average, potato tubers contain 77 % water, 20 % carbohydrates, and less than 3 % of proteins, dietary fiber, minerals, vitamins and other compounds [16].

A hectare of potatoes provides up to four times the calories of a grain crop and up to 85 % of the plant is edible human food, compared to around 50 % in cereals. Potato produces more food per liter of freshwater used through irrigation than cereals and thus is more sustainable to mitigate the effects of climate change [1].

According to Hengsdijk H. W., De Boer J. [5], the causal factors enhance post-harvest losses through changes in the chemical composition and physical properties of the tuber in the process of respiration, loss of moisture from the tuber, sprouting, and spread of diseases.

Nitrogen is important in fuelling the growth by ensuring optimal photosynthetic production in leaves. Phosphate, particularly foliar phosphate is applied during inhabitation to increase the tuber and tuber size, thereby increasing the tuber yield. Potassium is absorbed in larger quantities throughout the growing seasons; it is required for high yields, it also influences the number of tubers. Calcium and Magnesium are applied during the bulking process to increase the size of the tuber. Micronutrients such as boron, copper, iron, sodium and zinc present in potato are essential for plant growth. So the deficiency of anyone may affect their growth. Boron is important for growth of plants in the structural and functional virtue of the plant cell. Copper aids in protein synthesis. Iron and zinc are essentially useful for crop growth and high yielding of plants [11].

Modern ideas about the consumer qualities of table potato varieties are associated with the shape and size of tubers, the depth of the eyes, the color of the peel and pulp, as well as the absence of external and internal defects due to the tendency of certain varieties to overgrowth, the formation of growth cracks, dullness, and a change in the color of the pulp (discoloration) and other internal defects that may arise in tubers due to mechanical influences, especially during harvesting, transportation, sorting. In recent years, ideas about the nutritional value of potatoes as the most important product in human dietary nutrition have changed, due to the intensive development of selection in the direction of increasing the nutritional value of potato, as well as conducting in-depth studies in the field of its biochemistry. The biochemical composition depends on many factors: variety, soil and weather conditions, fertilizers, growing technology, degree of ripening, storage, etc. [13]

Several breeding and molecular approaches have been employed for trait improvement in potato. Conventional breeding techniques for potato improvement are directed to increase yield, processing, and storage-quality [4].

Although conventional breeding has been successfully employed for targeted trait improvement with less intraspecific variability, the progress is relatively slow and limited due to

the phenotypic characterization of leading individuals in successive generations [2].

Many former studies have determined the nutritional qualities of potato cultivars which were planted in different areas, and indicated significantly different nutrients among different potato cultivars, which might be related to soil, climate, cultivation technologies, etc. [10] Some studies on potato cultivars were mainly concentrated on cultivating varieties of high yield and disease resistance, the information about nutritional and functional properties of different cultivars are scarce. Therefore, it is necessary to determine the nutrition compounds and evaluate the comprehensive value of different potato cultivars in order to increase the varieties which are adapted to the potato staple food [17].

In the Middle Urals, a new high-yielding, medium-early variety Gala has recently been spreading, characterized by relative resistance to diseases and good tuber preservation in winter. The cultivation technology of the variety under these conditions has not been studied; therefore, the study of the methods of cultivation of this variety is justified and relevant. The variety is included in the State Register of Breeding Achievements in 2008, and is approved for cultivation in the 2nd, 3rd and 4th regions of the Russian Federation. The variety was used in this experiment by order of the Belorechensk farm of the Beloyarsk district of the Sverdlovsk region, where it is annually cultivated on large areas.

Purpose of the research: to study the effect of the food area of potato variety Gala, the use of fungicides on the yield and quality of tubers in the conditions of the Middle Urals.

Objectives: determine biochemical parameters and tasting assessment of potato tubers.

Methods

The object for the study was a variety of table potato, medium-early high-yielding Gala, bred by German breeders.

The research was carried out on the experimental field of the educational and experimental farm “Uralets” of the Ural State Agrarian University (USAU), the village “Studencheskiy”, for three years (2016–2018) in the climatic zone of the Middle Urals. For the object of research in the experiment, we took a potato variety for table purpose, medium early, high-yielding Gala, bred by German breeders, originator Norika (Germany). In the experiment, two fungicides were studied: “Shirlan” and “Infinito”.

The soil of the experimental site is podzolized chernozem, according to its granulometric composition, it is heavy loamy with a humus content of 4.5 %, the reaction of the soil is weakly acidic, the availability of mobile phosphorus is low, exchangeable potassium is average. The depth of the arable layer is 25 cm, the availability of the available forms N, P and K is very low. Agrochemical parameters of soil: pH, saline = 5.4; N = 185.9 mg/kg of soil; P₂O₅ = 238.9 mg/kg; K₂O = 268.5 mg/kg.

The experiment (two-factor) consists of 15 variants and 4 replications. The area of one plot is 20 m² (width = 2.5 m and length = 8 m), a total of 60 test plots, the total area of the experiment is 1200 m². The placement of plots in the experiment is systematic. The row spacing is 70 cm, and the distance between plants in a row is from 20 to 40 cm. Influence of the feeding area (factor A) and the use of fungicides (factor B) on the yield and economic efficiency of potato cultivation in the Middle Urals.

Biochemical analyzes of potato tubers were carried out in the analytical laboratory of the Ural Scientific Research Institute of Agriculture, a branch of the Ural Scientific Research Center of the Russian Academy of Sciences with the following methods: moisture (gravimetric method); mass fraction of nitrogen (crude protein) (Kjeldahl method); fat (extraction method); raw ash (gravimetric); carotene (extraction); acidity, vitamin C (titrimetric method); sugar (ebullioscopic method); nitrates (ionometric); phosphorus (photometric method); potassium (flame photometric method) and fiber (method of removing acid-alkali-soluble substances from the product). For biochemical analyzes in each variant, 1 kg of potato tubers were taken during harvesting. The Agrotechnology of potato cultivation in the experiment was generally accepted for the Middle Urals.

Results

The results of the 2016–2018 studies have shown that the food area influenced the biochemical parameters of potato tubers of the Gala variety.

Indicators of mineral elements in potato tubers grown at different food areas are presented in table 1.

From the analysis of the data in table 1, it can be seen that the total nitrogen content changed from 0.25 to 0.37 % and did not depend on the feeding area. The phosphorus content varied from 0.034 to 0.063 % and depended on the feeding area, i. e. the less often the plantings were, the more phosphorus was contained. Potassium content fluctuated over the years. In 2017 (wet and cool) potassium was higher in tubers with a smaller feeding area, and in 2018, which was characterized

by drier and warmer weather, on the contrary, more potassium was contained in tubers when they were rarely planted.

The biochemical parameters of potato tubers were also studied in table 2.

The experimental data obtained by us on the quality of tubers showed that the dry matter content depended both on the weather conditions over the years and on the planting density. Moreover, the larger the area of plant nutrition, the higher the dry matter content. There was a tendency to an increase in sugar content depending on an increase in the feeding area.

The content of vitamin C in cool, humid weather decreased with an increase in the feeding area, and, on the contrary, increased in warm, humid weather.

A strong reaction to changes in weather conditions was identified by the content of nitrates. In 2018, in warm, humid weather, the tubers contained 3.16 times more nitrates than in 2017 (dry and cool) with small feeding areas, and with large feeding areas, the differences increased up to 5 times.

The starch content was stable and did not depend on weather conditions and feeding area and ranged from 11.3 to 15.4 %.

The biochemical and mineral composition of tubers during storage, depending on the feeding area and the use of fungicides, are presented in table 3.

Analysis of the data in table 3 makes it possible to judge that the dry matter content in the variant with the "Shirlan" treatment and the 70 × 35 cm planting scheme was higher than in the control and amounted to 19.17 %. When calculated per hectare, the dry matter yield in the control was 4500 kg, and with the use of "Shirlan" = 7016 kg/ha, or 55 % more. Vita-

Table 1
Mineral composition of potato tubers depending on feeding area, 2017–2018

Landing scheme, cm	Feeding area, cm ²	Nitrogen, %		Phosphorus, %		Potassium, %	
		2017	2018	2017	2018	2017	2018
70 × 20	1400	0.35	0.26	0.053	0.034	0.640	0.98
70 × 25	1750	0.33	0.31	0.060	0.045	0.662	1.23
70 × 30 (c)	2100 (c)	0.27	0.25	0.052	0.038	0.605	1.21
70 × 35	2450	0.31	0.33	0.063	0.043	0.660	1.19
70 × 40	2800	0.37	0.30	0.062	0.053	0.690	2.00
<i>r</i>	–	0.08	0.47	0.65	0.79	0.49	0.81

Table 2
Biochemical parameters of potato tubers depending on feeding area, 2017–2018

Landing scheme, cm	Feeding area, cm ²	Dry matter, %		Sugar, %		Vitamin C, mg %		Nitrates, mg/kg		Starch, %	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
70 × 20	1400	19.9	17.80	1.70	0.16	24.2	33.4	67.0	131.0	14.3	14.3
70 × 25	1750	20.8	17.20	2.00	0.19	25.5	29.9	20.4	146.0	12.3	12.3
70 × 30 (c)	2100 (c)	20.0	17.70	2.28	0.17	23.8	33.9	22.5	138.0	11.3	12.3
70 × 35	2450	21.2	17.60	2.42	0.24	23.3	31.2	20.9	137.0	11.8	11.8
70 × 40	2800	21.6	18.60	2.10	0.21	24.2	33.0	30.2	133.0	12.3	15.4
<i>r</i>		0.81	0.62	0.70	0.74	–0.43	0.05	–0.58	–0.14	–0.62	0.17

Table 3
Biochemical and mineral composition of potato tubers depending on the feeding area and the use of fungicides, 2016–2018

Variation	Dry matter, %	N _{total} %	Phosphorus, %	Potassium, %	Cellulose, %	Sugar, %	Vitamin C, mg %	Nitrates, mg/kg	Starch, %
Control	16.13	0.31	0.055	0.430	0.295	1.94	25.5	45.4	8.70
"Shirlan"	19.17	0.26	0.062	0.503	0.368	1.79	27.7	57.0	8.70

Table 4
Tasting assessment of potato varieties, 2016–2018

Name of samples	Appearance (color, tuber shape)	Tuber boiling time, in minutes	Soft color	Consistency softness	Digestibility	Taste, score	Total assessment, score
Gala + "Shirlan"	White, rounded	25	Yellow	Rough	Weak	4.5	4.5
Gala (control)	White, rounded	23	Yellow	Rough	Weak	5.0	5.0
Irbit	Brown, rounded	25	Dark	Tender	Medium	3.8	3.8
Mayak	Pink, oval	14	White	Tender	Medium	4.0	4.0
Zekura	Grey, rounded	22	Yellow	Rough	Indigestible	4.0	4.0
Luks	Red, rounded	30	White	Tender	Medium	4.5	4.5

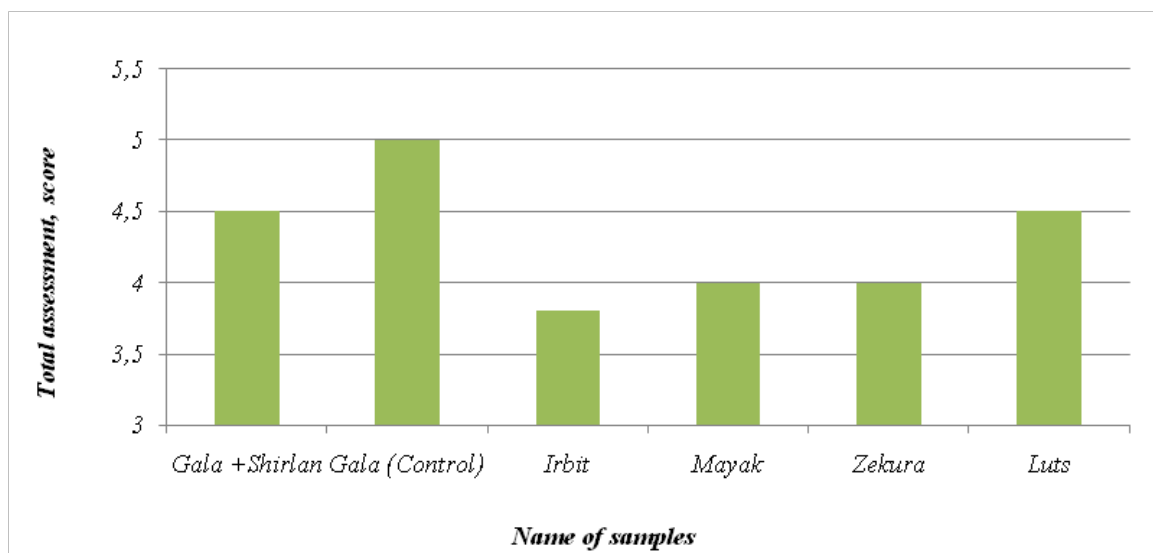


Fig. 1. Tasting assessment of potato varieties, 2016–2018

min C from 1 hectare in the control was 7114 kg, and in the variant with the use of "Shirlan" – 10 138 kg or 42 % more. In the tubers of the control variant, the content of nitrates was 45.4 mg/kg, and when using "Shirlan" = 57.0 mg/kg. For other indicators, the differences were insignificant.

The quality of the products can also be judged by the results of the tasting, which showed that the studied potato variety Gala has high taste (table 4).

Of the five varieties, the most delicious variety was Gala in the control variant without fungicide treatment. It is interesting to note that the use of fungicides negatively affected the taste of the tuber. This happened, apparently, because the use of fungicides changed the concentration of cell sap, electrical conductivity, specific gravity of tuber, nitrate content and temperature of the tuber. Since the indicated indicators changed under the influence of the feeding area, then, apparently, the taste of potato tubers changed. The boiling time of tubers, depending on the variety, varied from 14 to 30 minutes.

Thus, from the studies carried out, it can be concluded that according to the taste assessment of Gala tubers, the control

variant was the best variant; it was evaluated with 5 points. The variant with the use of the fungicide "Shirlan" was evaluated with 4.5 points, i. e. for 0.5 points less than control.

Discussion and Conclusion

Researches have shown that the food area influenced the quality of products, their mineral and biochemical composition, especially the content of nitrogen, phosphorus, potassium, dry matter, vitamin C and others.

The conducted studies allowed us to conclude that, according to the taste assessment of Gala tubers, the control option was the best, it was rated 5 points. The variant with the use of the fungicide "Shirlan" was evaluated with 4.5 points, i. e. for 0.5 points less than control.

With the use of the fungicide "Shirlan", the dry matter content was 7016 kg/ha, which is 55 % more than the control. Vitamin C from 1 hectare in the control was 7114 kg, and in the variant with the use of "Shirlan" = 10138 kg or 42 % more. The nitrate content was 45.4 mg/kg, and when "Shirlan" was used, it was 57.0 mg/kg. For the rest of the indicators, the differences were insignificant.

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