

Biochemical composition of potato tubers of various varieties and the economic efficiency of its cultivation in the conditions of the Middle Urals

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Abstract. The purpose of the research is to study the effect of the feeding area of Gala potato, the use of fungicides on the yield and quality of tubers in the Middle Urals. This research was carried out on the experimental field of the educational and experimental farm "Uralets" of the Ural State Agrarian University, the village "Studencheskiy", during 2016-2018, in the climatic zone of the Middle Urals. The feeding area influenced the mineral and biochemical composition of tubers, especially the content of nitrogen, phosphorus, potassium, dry matter, vitamin C and others. The calculation of the economic efficiency of potato showed that during the years of research, the production cost fluctuated within the range of 4446 - 9446 rubles/ton, the profit from 63 724 to 269 172 rubles/ha and the level of profitability in the range of 24.66-165.43%.

1 Introduction

Potato is the most important agricultural crop for many uses. However, its main importance is food. The varied uses of potatoes are due to their valuable chemical composition. Tubers contain about 25% dry matter, including 10 to 23% starch, 1.4-3.0% high quality proteins, vitamins C, B₁, B₂, B₆, PP and K, which makes it an extremely important product human nutrition. Potato is good food for animals and poultry. 100 kg of tubers contain 25-30 feed units and 2.1 kg of digestible protein, in the tops of 8.5-12 feed units and 1.6 kg of digestible protein. In terms of the digestibility of organic matter (83–97%), it shares the first place with fodder root crops among plant feeds. Potato tubers are raw materials for industrial production of valuable products. From 1 ton of potato tubers with a starch content of 17.5%, you can get 112 liters of alcohol, 55 kg of liquid carbon dioxide or 170 kg of starch and 1000 kg of pulp. Processed products - fresh and dry pulp, bard - are valuable animal feed [16].

Potato is grown in more than 100 countries on a cultivated area of 18.4 million hectares, with a yield of 18.4 t/ha and an annual production of 347 million tons [12]. In fact, more

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potato is produced in developing countries today than in developed countries. Potato consumption has increased by 70% over the past 50 years in both Africa and Asia [17].

The structure of potato use includes: food consumption (fresh) – 15-16 million tons; seeds – 6-7 million tons; for feed – 5-6 million tons; processing – up to 1 million tons; import – 0.7-1.5 million tons; export – 50-70 thousand tons. According to the Ministry of Health and Social Development of Russia, the recommended potato consumption rate is 95-100 kg per person per year [18].

Chemical composition of tubers depends on the variety, growing conditions (climatic, weather, type of soil, fertilizers used, cultivation agrotechnics), maturity of tubers, terms and conditions of storage, etc.[5].

Many authors indicate that the accumulation of vitamin C is most significantly affected by the potato variety. The significant influence of meteorological conditions on the content of ascorbic acid was noted. Dry weather increases it, while wet and cold weather decreases it. As a rule, the content of vitamin C in light soils is higher than in heavy soils. Excessive amount of nitrogen and potassium reduces its content, and phosphorus increases. It was found that the level of vitamin C in tubers depends on the variety by 44.0%, by 0.9% on the year of cultivation and by 52.0% on the combination of these factors [11].

In scientific publications, it is noted that the amount of carotenoids ranges from 50 to 100 mg per 100 g of raw pulp of tubers with white pulp and up to 2000 mg in tubers with dark yellow and orange pulp. Varieties of potatoes with white flesh contain 40-101 mg/100 g of wet weight of carotenoids, yellow - 101-250, bright yellow - 509-795 mg/100 g [8].

The major role of carbohydrates in nutrition is to provide energy. The complex carbohydrates present in potato are important to a healthy diet. Carbohydrates in potato are mostly found in the form of starch. Starch furnishes most of the energy supplied by the potato [1, 10].

The development of potato varieties with altered starch properties, such as a higher amylose/amylopectin ratio and longer amylopectin chain lengths may decrease glycemic index [6].

Potato produces more energy and protein per unit area and unit of time than most other major food crops. It is also rich in several micronutrients and antioxidants, which may play a part in preventing diseases related to ageing, and a source of dietary fiber [4]. The health benefits of potato are influenced by cultivar, cooking method, storage conditions, and other foods consumed [7, 15]. Extensive and accessible genetic resources offer breeders opportunities to add to the nutritional value of potato [3, 9].

Many factors affect the purchase and consumption of potatoes, including taste, cost, preparation time, convenience, familiarity, eye appeal, name recognition, and production conditions, such as locally grown or organic [2].

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 actually.

The aim of this research is to study influence of the feeding area of Gala variety potato, the use of fungicides on the yield and quality of tubers in the conditions of the Middle Urals.

The objectives of the research is to determine the biochemical parameters and tasting assessment of Gala tubers and other potato varieties, calculate the economic and energy efficiency for different feeding areas and the use of fungicides.

2 Materials and Methods

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 of "Studencheskiy", for three years (2016-2018) in the climatic zone of the Middle Urals.

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

Soil and climatic conditions of the Middle Urals in 2016-2018 were favorable for the cultivation of the Gala variety. This made it possible to more fully study the influence of agrotechnical methods on the yield and quality of potato tubers of the Gala variety.

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 using 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 (ebuliosstatic 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, samples of 1 kg of potato tubers were taken in each variant during harvesting.

3 Results and its discussion

Results of the 2016-2018 studies have shown that feeding area influenced the biochemical parameters and tasting assessment of Gala tubers and other potato varieties.

Indicators of mineral elements in potato tubers grown in different feeding areas are presented in Table 1.

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
70x20	1400	0,35	0,26	0,053	0,034	0,640	0,98
70x25	1750	0,33	0,31	0,060	0,045	0,662	1,23
70x30 (c)	2100 (c)	0,27	0,25	0,052	0,038	0,605	1,21
70x35	2450	0,31	0,33	0,063	0,043	0,660	1,19
70x40	2800	0,37	0,30	0,062	0,053	0,690	2,00
r=	-	0,08	0,47	0,65	0,79	0,49	0,81

From the table 1, we observe 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 with a rare planting.

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

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 %		Nitrate, mg/kg		Starch, %	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
70x20	1400	19,9	17,80	1,70	0,16	24,2	33,4	67,0	131,0	14,3	14,3
70x25	1750	20,8	17,20	2,00	0,19	25,5	29,9	20,4	146,0	12,3	12,3
70x30 (c)	2100 (c)	20,0	17,70	2,28	0,17	23,8	33,9	22,5	138,0	11,3	12,3
70x35	2450	21,2	17,60	2,42	0,24	23,3	31,2	20,9	137,0	11,8	11,8
70x40	2800	21,6	18,60	2,10	0,21	24,2	33,0	30,2	133,0	12,3	15,4
r		0,81	0,62	0,70	0,74	-0,43	0,05	-0,58	-0,14	-0,62	0,17

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 increasing 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, 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.

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

Variant	Dry matter, %	Nitrogen, %	Phosphorus, %	Potassium, %	Cellulose, %	Sugar, %	Vitamin «C», mg %	Nitrate, 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

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 70x35 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. 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. 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 the rest of the 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).

Table 4. Tasting assessment of potato varieties, 2016-2018

Name of samples	Appearance (color, tuber shape)	Time boiling, minutes	Soft color	Consistency softness	Digestibility	Taste, score	Overall 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
Irbitsky	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
Luxe	red rounded	30	white	tender	medium	4,5	4,5

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 the tuber, nitrate content and tuber temperature. Since the indicated indicators changed under the influence of the feeding area, then, apparently, the taste of potato tubers changed. The cooking 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 option was the best, it was rated 5 points. The variant with the use of the fungicide shirlan yielded to him by 0.5 points. It is important to note that the taste rating for both varieties (Mayak and Zekura) was 4.0 points, while for the Luxe variety it was 4.5 points. In the experiments, the lowest taste score was obtained for the Irbitsky variety - 3.8 points.

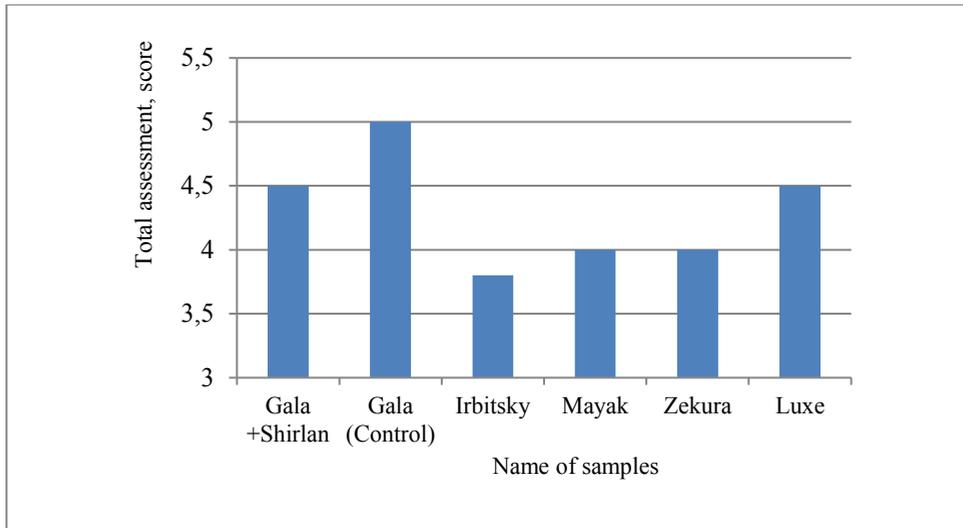


Fig. 1. Tasting assessment of potato varieties, 2016-2018

Irbitsky variety:

Irbitsky potato was created by breeders from the Ural Research Institute of Agriculture. It is included in the State Register of the Russian Federation for the Volgo-Vyatka and West Siberian regions. It is considered a good variety for home breeding. The variety is medium early; the bush is medium, semi-erect. The leaf is medium, dark green. The corolla of the flower is red-violet. The shape of the tuber is round, the depth of the eyes is shallow, the color of the peel is red, the color of the flesh is light yellow. The period from planting to harvest is 65-70 days. The potential yield is 42-50 t/ha, at home they get 25-35 t/ha. The average tuber weight is 120-200 g, the number of tubers in the bush is 5-10 pieces. The starch content is 12.2-14.1%, the digestibility is weak, the taste is good. The protein content is 2.90-3.18%, the vitamin C content is 16.5 = 23.2 mg%. The rest period is average. The variety is resistant to such a parasite as a nematode. Has an average resistance to late blight. Included in the State Register of Breeding Achievements in 2012, approved for cultivation in 4, 9, 10 regions of the Russian Federation [13, 14].

Luxe Variety:

The originator of the "Luxe" potato variety is the Ural Scientific Research Institute of Agriculture of the Russian Agricultural Academy, the Agrofirma "KRiMM" and LLC "Potato" (Sverdlovsk Region). The variety is early. The purpose of the variety is table. The period from planting to harvest is 65-70 days. The bush is medium, erect. The leaf is medium, dark green. The corolla of the flower is light purple. The shape of the tuber is elongated-oval, the depth of the eyes is shallow, the color of the peel is red, the color of the flesh is light yellow. The potential yield is 56-63 t/ha, the number of tubers in the bush is 12-16 pieces, the average tuber weight is 100-130 g, the starch content is 12.0-17.0. The protein content is 2.62-3.31%. The vitamin C content is 19.2-24.0 mg%. The taste is good, the digestibility is low. The shelf life is good. The variety is included in the State Register of Breeding Achievements in 2016. Regions of tolerance: 4, 10. Disease resistance: the variety is resistant to potato cancer, golden cyst nematode, wrinkled and banded mosaic. Moderately susceptible to tops and tuber susceptible to late blight. Resistance to heat and drought is average [13, 14].

Mayak variety:

Medium early variety of table potato. Bred by employees of the Ural Scientific Research Institute of Agriculture. From full sprouting to harvest, 75-85 days pass. Shrub - medium to high, semi-erect. The leaf is medium, dark green. The corolla of the flower is red-violet. The shape of the tuber is oval, the depth of the eyes is very shallow, the color of the peel is raspberry, the color of the pulp is light yellow. Potential yield - 55-58 t/ha, commodity yield - 12-39 t/ha, keeping quality - 95%, number of tubers in a bush - 16-18 pieces, average tuber weight - 97-153 g, starch content - 14.6 -17.3%. The taste is good, the digestibility is moderate. The rest period is long. The variety is included in the State Register of Breeding Achievements in 2013. A region of tolerance is 4. The variety is relatively insensitive to golden nematode, nightshade crayfish and potato mosaic. Mayak also has an average resistance to late blight; Rhizoctonia, common scab and plant rot [14].

Zekura variety:

German table potato variety, developed by the employees of Solana GmbH & CO KG in the early 90s. It was included in the state register of breeding achievements of the Russian Federation in 1997. Zoned in 6 regions: Volgo-Vyatka, Central Black Earth, North Caucasian, Middle Volga, West Siberian, Far East. Zekura potato belongs to medium early ripening varieties and at the same time they have rather high keeping characteristics. The variety is medium early. The period from planting to harvest is 90-100 days. Zekura potato bush is compact, slightly spreading, low - up to 35 cm. Leaves are simple, open, light green. The flowers are red-violet in color, collected in small corollas. The base of the sprout is also reddish-purple in color. The tuber shape is oval, oblong. The peel is smooth, yellow in color. The pulp is yellow. The eyes are small. Productivity - 35-37 t/ha, the number of tubers in a bush - 15-20 pieces, the average mass of a tuber - 60-135 g. Starch content - up to 18%, poorly boiled. The marketability of tubers is 79-96%. Keeping quality is 98%. The variety is resistant to cancer and golden cyst nematodes, slightly susceptible to leaf curling, very rarely affected by viruses A and Y, common scab, glandular spot, late blight of tops and tubers.

The economic efficiency allows you to determine the effectiveness of the results obtained and choose the most optimal variant.

Economic indicators of research results are presented in table 5

Table 5. Economic efficiency of the area of nutrition and the use of fungicides in the cultivation of potato of the Gala variety, 2016-2018.

Feeding area, cm ²	Productivity, t/ha	Sales proceeds per hectare, rubles	Expenses		Profit per hectare, rubles	Cost of 1 ton, rub.	Profitability level, %
			per 1 ha, thousand rubles	incl. for seeds, %			
control (untreated, factor A)							
1400	27,3	322 140	258,4	78,40	63 724	9 466	24,66
1750	27,9	329 220	212,6	76,34	116 596	7 621	54,84
2100 (c)	27,0	318 600	175,3	74,25	143 280	6 493	81,73
2450	24,9	293 820	160,2	72,57	133 589	6 435	83,37
2800	22,7	267 860	143,8	70,87	124 021	6 336	86,22
shirlan treatment (factor B)							

1400	33,2	391 760	260,7	78,40	130 960	7 855	50,21
1750	35,4	417 720	215,0	76,34	202 686	6 074	94,26
2100 (c)	34,0	401 200	182,2	74,25	218 904	5 362	120,08
2450	36,6	431 880	162,7	72,57	269 172	4 446	165,43
2800	32,9	388 220	146,2	70,87	241 930	4 447	165,37
treatment infinito							
1400	34,0	401 200	280,0	78,40	121 123	8 238	43,25
1750	33,9	400 020	231,0	76,34	169 018	6 814	73,17
2100 (c)	26,9	317 420	197,0	74,25	120 340	7 327	61,06
2450	26,2	309 160	173,0	72,57	136 078	6 606	78,62
2800	19,1	225 380	154,9	70,87	70 405	8 114	45,43

The economic efficiency of the research carried out made it possible to characterize the influence of the feeding area and the use of fungicides on the cost, profit and profitability of products.

The calculation of the economic efficiency of potato showed that during the years of research, the production cost fluctuated within the range of 4446 - 9446 rubles/ton, the profit from 63 724 to 269 172 rubles/ha and the level of profitability in the range of 24.66-165.43%.

4 Conclusion

To increase the yield and the level of profitability of the production of Gala potatoes, depending on the feeding area and the use of fungicides in the Middle Urals, we recommend using the option with a feeding area of 2450 cm² (70x35 cm) and the use of the fungicide shirlan at a dose of 0.3-0.4 l/ha before closing the rows and then every 7-10 days. At the same time, the yield amounted to 36.6 t / ha, which is 31.1% higher than the control (factor A). At the same time, the prime cost amounted to 4,446 rubles/ton, profit - 269,172 rubles/ha, and profitability - 165.43%.

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