Biochemical and agro-technological evaluation of the assortment of tomatoes to create a functional food

A Yu Medelyaeva¹, A F Bukharov², Yu V Trunov¹, S I Danilin¹, D V Akishin¹ and E I Popova¹

¹Michurinsk State Agrarian University, 101, International st., Michurinsk, 393760, Russia
²Federal Scientific Center for Vegetable Growing, VNIISSOK village, Breeding st., 14, Odintsovo, Moscow Oblast, Russia

E-mail: trunov.yu58@mail.ru

Abstract. Tomatoes are the main vegetable crops in open and protected ground. Currently, a huge number of varieties and hybrids have been created for industrial and amateur vegetable growing, which differ in the type of bush, yield, early maturity, marketability, disease resistance, color, shape, size, mechanical strength, and biochemical composition of fruits (content of dry substances, sugars, vitamins, mineral salts, organic acids and other vital ingredients). Therefore, not all varieties are equally suitable for processing into functional food products. The article considers the assortment of tomatoes for open ground by yield, marketable qualities and the main indicators of the biochemical composition of the fruit: acidity, dry matter content, sugars, vitamin C, the accumulation of nitrates in the fruit, as well as by taste. As a result of a comprehensive assessment of 9 varieties of tomatoes, the varieties Nepryadva, Belkhavsky and Pulsar were identified, which have high yield, marketability, taste qualities of fruits, vitamin value and suitability for processing into functional products. In breeding for use as sources, the main economically valuable traits are of interest: yield and marketability of fruits – Belkowski, Nepryadva, Pulsar, the size of the fruit – Belkowski, Pulsar; the content of dry substances Belkovsky, Bui-Tur, Nepryadva, Pulsar; vitamin C – Belkowski, Bui-Tur, Pulsar; on the accumulation of nitrate – Nepryadva, Shuttle, Beljavsky, Kulon; taste – Belkowski, Nepryadva, Bui-Tur, Pulsar, Yakhont.

1. Introduction

Vegetables are the most important sources of vitamins, trace elements, carbohydrates and phytoncides, so the consumption of vegetables contributes to the supply of the human body with many biologically active substances [1, 2].

A variety of types and forms of fruit, berry and vegetable crops, containing a complex of various biologically active compounds, allows creating products of functional purpose, beneficial to human health [3-5].

The main challenges facing the breeders are the allocation of plant sources of biologically active substances, the creation of varieties of vegetable crops with high nutritional value [6, 7], improved biochemical composition [8].

Tomato or «pomidor» (Latin: Solanum lycopersicum Mill.) is an annual or perennial herbaceous plant, a species of the genus Solanum (Solanum) of the Solanaceae family. Tomatoes the main
vegetable crops, cultivated both in open and protected ground, grown for the edible fruit is a juicy two-
or more sections of berries of various shape, color, size, nutritional value, etc.

Tomatoes contain about 92-95% of water 1-1.5% protein, 0.1% fat, 2-5% carbohydrate, 0.6% fibre, organic acids, vitamins a, C, PP and others [9].

Tomato fruits can be of different colors, which are given by carotenoids: lycopene, carotene, xanthophyll. Yellow-orange fruits contain more carotene, and orange-red fruits contain more lycopene [8].

The aim of the work is to give a comparative assessment of the studied varieties in terms of yield, size and basic biochemical parameters of fruits and to identify varieties that have a complex of economically valuable characteristics and a high content of biologically valuable substances for processing into functional products.

2. Materials and methods

The variety study of vegetable crops was carried out in 2006-2018 at the experimental sites of the Federal State Budgetary Research Institution of the Russian Academy of Sciences, in the Ramenskoye district of the Moscow Region. Agrotechnological assessment of the assortment of vegetable crops was carried out in the OPH "Bykovo" of the Moscow region and on the basis of farms in the Tambov region.

The objects of research are varieties of tomatoes (Solanum lycopersicum Mill.): Argo (Control), Belkhavsky, Buoy Tour, Kulon, Lunny, Nepryadva, Pulsar, Shuttle, Yakhont.

We studied the indicators of the yield of varieties, the content of dry substances, sugars, vitamin C (ascorbic acid), and nitrates in the fruits. Definition of yield, marketability and average weight of fruit and vegetable plants was carried out according to the method VIR (1986); dry matter content was determined by drying according to GOST 28561-90; the content of sugars – according to Bertrand and GOST 8756.13-87; the content of ascorbic acid – using fluorimetric method; nitrate – colorimetric method.

To determine the relationship between the indicators of the biochemical composition of fruits, the indices were calculated:

The sugar-acid index $K_{SA}$, expressed as the ratio of the content of sugars in the fruit to the acidity of the fruit, according to the formula:

$$K_{SA} = \frac{S}{A},$$

where $S$ is the content of sugars in the fruit; $A$ is the acidity of the fruit.

The biological meaning of the sugar-acid index is that the higher the index, the sweeter and tastier the fruit. The standard indicator of the sugar-acid index for tomatoes is at least 7 [10].

The vitamin-nitrate index of the $K_{VN}$, expressed as the ratio of the content of vitamin C in fruits to the content of nitrates, according to the formula:

$$K_{VN} = \frac{V}{N},$$

where $V$ is the content of vitamin C in the fruit; $N$ is the content of nitrates.

The biological meaning of the vitamin-nitrate index – the higher the index, the higher the vitamin value and environmental safety of the product.

Sugar vitamin the $K_{SV}$ index, expressed as the ratio of the content of sugars in the fruit the content of vitamin C, according to the formula:

$$K_{SV} = \frac{S}{V},$$

where $S$ is the content of sugars in fruits and $V$-vitamin C.

The biological meaning of the sugar-vitamin index – the lower the index, the higher the vitamin value and dietary usefulness of the product.

The integral score of the complex of quality indicators of $K_{int}$ varieties was determined as the sum of the indicators reduced to a common denominator, according to the formula:

$$K_{int} = \frac{(b_1 + b_2 + b_3 + b_4)}{n},$$

where $b$ is the score of specific indicators, $n$ is the number of indicators.

We bring the score of specific indicators to a common denominator, taking the maximum value of each specific indicator as the highest score (5 points). At the same time, the significance of individual
indicators is leveled (not taken into account), so this assessment is valid only within the limits of a specific experience.

Symbols:
1 - yield of varieties;
2 - marketability of fruits;
3 - acidity of the fruit;
4 - dry matter content;
5 - sugar content;
6 - vitamin C content;
7 - content of nitrates;
8 - sugar-acid index;
9 - vitamin-nitrate index.

The dispersion analysis of the experimental material was carried out according to B. A. Dospekho (1985).

3. Results and discussion
Table 1 shows data on the yield, marketability, average weight of fruits and acidity of fruits of 9 varieties of tomatoes, where the control variety was the Argo variety.

Table 1. Yield, marketability and acidity of fruits in tomato varieties (Solánum lycopérsicum Mill.), on average for 3 years

| Varieties, hybrids | Yield, t / ha | Yield increase, % | Fruit marketability, % | Average fruit weight, g | Fruit acidity, % |
|--------------------|---------------|-------------------|------------------------|-------------------------|-----------------|
| Argo (K)           | 37.0          | -                 | 89.2                   | 80                      | 0.59            |
| Belkhavsky         | 51.2          | 38.4              | 95.2                   | 100                     | 0.49            |
| Buoy Tour          | 44.3          | 19.7              | 90.4                   | 70                      | 0.42            |
| Kulon              | 42.8          | 15.7              | 92.1                   | 60                      | 0.52            |
| Lunny              | 46.3          | 25.1              | 91.7                   | 60                      | 0.57            |
| Nepryadva          | 49.4          | 33.5              | 95.0                   | 80                      | 0.40            |
| Pulsar             | 57.6          | 55.7              | 94.5                   | 100                     | 0.51            |
| Shuttle 4          | 44.1          | 19.2              | 91.6                   | 70                      | 0.42            |
| Yakhont            | 38.7          | 4.6               | 89.1                   | 120                     | 0.51            |
| LSD<sub>05</sub>   | 9.8           | -                 | 5.3                    | -                       | 0.08            |

The yield of tomato varieties varied greatly in the range of 37.0-57.6 t / ha. 37.0 t / ha of fruits and were collected on the control Argo variety. The yield of all the studied tomato varieties exceeded the yield of the control variety. However, the highest yield was formed on the varieties Nepryadva (49.4 t/ha), Belkhavsky (51.2 t/ha) and Pulsar (57.6 t/ha). The excess of yield over the control level in these varieties was significant at the 05% level of significance and amounted to 33.5, 38.4 and 55.7%, respectively. It is characteristic that the marketability of tomato fruits in these varieties was also the highest 95.0, 95.2 and 94.5%, respectively, which is significantly higher than the marketability of fruits in the control variety (89.2). In general, the marketability of fruits in all varieties of tomatoes was at a fairly high level.

The average fruit weight of tomato varieties was weakly correlated with the yield and depended primarily on the genotypic characteristics of the varieties. The largest fruits were formed in the varieties Belkhavsky, Pulsar (100 g) and Yakhont (120 g). The smallest fruits were in the varieties Kulon and Lunny (60 g). Other varieties studied, like the control variety Argo, formed medium-sized fruits.

The acidity of fruits in tomato varieties was generally low and varied in the range of 0.40-0.59%. This indicator was highest in the control variety Argo (0.59%) and in the variety Lunny (0.57%). At
the same time, the acidity of fruits in 6 varieties out of 9 studied was significantly lower than the control (0.40-0.51%), which probably indicates a better taste of fruits in these varieties. Table 2 shows the results of the biochemical and tasting evaluation of 9 tomato varieties.

**Table 2. Biochemical composition and quality indices of fruits in tomato varieties (Solanum lycopersicum Mill.), on average for 3 years**

| Varieties, hybrids | Content | Fruit quality indices | Tasting score, | dry substances, % | sugar, % | vitamin C, mg% | nitrates, mg% | sugar-acid | vitamin-nitrate | sugar-vitamin |
|-------------------|---------|-----------------------|----------------|------------------|----------|----------------|--------------|------------|-----------------|--------------|
| Argo (K)          | 5.4     | 2.6                   | 27.7           | 3.2              | 4.4      | 8.7            | 0.09         | 4.2        |                  |              |
| Belkhavsky        | 6.0     | 3.7                   | 41.2           | 2.0              | 7.6      | 20.6           | 0.09         | 5.0        |                  |              |
| Buoy Tour         | 6.2     | 3.0                   | 38.8           | 2.3              | 7.1      | 16.9           | 0.08         | 4.9        |                  |              |
| Kulon             | 5.5     | 2.9                   | 36.3           | 2.0              | 5.6      | 18.2           | 0.08         | 4.2        |                  |              |
| Lunny             | 5.8     | 2.8                   | 29.5           | 2.8              | 4.9      | 10.5           | 0.09         | 4.4        |                  |              |
| Nepryadva         | 6.0     | 3.1                   | 36.4           | 1.9              | 7.1      | 24.3           | 0.09         | 4.7        |                  |              |
| Pulsar            | 6.1     | 3.6                   | 40.9           | 2.1              | 7.1      | 19.5           | 0.09         | 4.9        |                  |              |
| Shuttle           | 5.6     | 3.0                   | 32.3           | 1.9              | 7.1      | 17.0           | 0.09         | 4.8        |                  |              |
| Yakhont           | 5.7     | 3.6                   | 37.2           | 3.2              | 7.1      | 11.6           | 0.10         | 5.0        |                  |              |
| LSD05             | 0.5     | 0.6                   | 7.2            | 0.6              | 1.3      | 3.0            | 0.02         | 0.5        |                  |              |

In accordance with the requirements for tomato varieties for industrial processing, the dry matter content in the fruit should be at the level of 5.0% or higher. The content of dry substances in the fruits of all the studied tomato varieties exceeded this indicator by 0.4% in the control variety, by 1.0% in the varieties Nepryadva, Belkhavsky, by 1.1% in the Pulsar variety and by 1.2% in the Buoy Tour variety. The excess of this indicator over the control level in the listed varieties was significant and amounted to 11.1-14.8%.

Sugar content was highest in the cultivars Belkhavsky (3.7%), the Pulsar and the Yakhont (3.6 percent). These indicators significantly (by 38.4-42.3%) exceeded the control (2.6%). In other varieties, this indicator was at the control level (2.6-3.1%).

The content of ascorbic acid in tomato fruits was quite high and varied in the range of 27.7-41.2 mg% (this is 3-4 times more than that in apples). The highest content of vitamin C, significantly exceeding this indicator of the control variety Argo (27.7 mg%), was in 6 of the 9 studied varieties: Kulon (36.3 mg%), Nepryadva (36.4 mg%), Yakhont (37.2 mg%), Buoy Tour (38.8 mg%), Pulsar (40.9 mg%) and Belkhavsky (41.2 mg%), in other two studied varieties – at the control level.

The accumulation of nitrates in fruits is a negative indicator. The maximum permissible concentration (MPC) of nitrates in tomato fruits is 15.0 mg% [11, 12]. Over the years of research, a fairly low content of nitrates in tomatoes has been noted, in general. Their amount in the fruits of the studied varieties was in the range of 1.5-3.2 mg%. At the same time, the fruits of the control variety accumulated the largest amount of nitrates (3.2 mg%). Of the 9 studied varieties, 6 accumulated significantly less nitrates (by 28.1-53.1%) than in the control variety. The most environmentally friendly variety in this respect was the Nepryadva variety, in the fruits of which there was only 1.5 mg% of nitrates. In the varieties Lunny and Yakhont, the accumulation of nitrates in the fruits was at the level of control.

The ratio of the sugar content to the acid largely determines the taste of the fruit. With high acidity or low sugar content, the sugar-acid index of tomatoes is less than 7, while the fruits are usually of low taste qualities [8]. Varieties of tomatoes with fruits of high taste qualities usually have a sugar-acid index greater than 7. Among the studied varieties, the lowest sugar-acid index was observed in the control variety Argo (4.4). In the varieties Kulon and Lunny, it was slightly higher than the control indicator, but slightly. A significant increase in the sugar-acid index in comparison with control was observed in varieties Dropship, Bui-Tur, Pulsar, Yakhont (7.1), Beljavsky (7.6), Nepryadva (7.8).
Characteristically, these indicators are not only consistent with literature data (sugar-acid index greater than 7), but are confirmed by tasting assessment of fruit from which it is seen that these varieties had the highest tasting score.

Calculations of the vitamin-nitrate index in tomato varieties showed that this indicator was very high in our experiments. The highest level was found in the varieties Nepryadva (24.3) Belkhavsky (20.6), Pulsar (19.5), 2.8, 2.4 and 2.2 times higher than the control, respectively, which indicates a high vitamin value and environmental safety of the products of these varieties. The control Argo variety had the lowest vitamin-nitrate index (8.7).

The sugar-vitamin index of all tomato varieties was very low and varied in the range of 0.08-0.10, which characterizes the products of these varieties as highly dietary. There were no significant differences between the varieties in this indicator.

Table 3 shows the data on the integral score assessment of the complex of indicators of tomato varieties.

| Varieties, hybrids | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | K<sub>int</sub> |
|-------------------|----|----|----|----|----|----|----|----|----|-------------|
| Nepryadva         | 4.3| 5.0| 5.0| 4.8| 4.2| 4.4| 5.0| 5.0| 5.0| 4.74       |
| Belkhavsky        | 4.4| 5.0| 4.1| 4.8| 5.0| 5.0| 3.8| 4.9| 4.2| 4.58       |
| Pulsar            | 5.0| 5.0| 3.9| 4.9| 4.9| 5.0| 3.6| 4.6| 4.0| 4.54       |
| Buoy Tour         | 3.8| 4.7| 4.8| 5.0| 4.1| 4.7| 3.3| 4.6| 3.5| 4.28       |
| Shuttle           | 3.8| 4.8| 4.8| 4.5| 4.1| 3.9| 3.9| 4.6| 3.5| 4.21       |
| Kulon             | 3.7| 4.8| 3.8| 4.4| 3.9| 4.4| 3.8| 3.6| 3.7| 4.01       |
| Yakhont           | 3.4| 4.7| 3.9| 4.6| 4.9| 4.5| 2.3| 4.6| 2.4| 3.92       |
| Lunny             | 4.0| 4.8| 3.5| 4.7| 3.8| 3.6| 2.7| 3.1| 2.2| 3.60       |
| Argo (K)          | 3.2| 4.7| 3.4| 4.3| 3.5| 3.4| 2.3| 2.8| 1.8| 3.27       |

From the data in Table 3, it can be seen that the highest integral score for the complex of indicators was obtained for the varieties Nepryadva, Belkhavsky and Pulsar.

4. Conclusion

As a result of a comprehensive study of 9 varieties of tomatoes, the varieties Nepryadva, Belkhavsky and Pulsar were identified with high yield, marketability, taste and vitamin value, suitable for processing into functional products.

When conducting breeding work with tomatoes, the following varieties are recommended as sources of economically valuable traits:
- yield and commodity quality of the fruit – Belkowski, Nepryadva, Pulsar;
- largest fruit – Belkowski, Pulsar;
- according to the content of dry substances-Belkhavsky, Buoy Tour, Nepryadva, Pulsar - when selecting for an increase in the content of dry substances;
- according to the content of vitamin C-Belkhavsky, Bui-Tur, Pulsar-when selecting for vitamin value;
- accumulation of nitrate – Nepryadva, Shuttle, Belkovsky Kulon;
- in taste – Belkowski, Nepryadva, Bui-Tur, Pulsar, Yakhont.

References

[1] Kulikov I and Minakov I 2018 A socio-economic study of the food sector: The supply side European Research Studies Journal 21(4) 174-185
[2] Minakov I A and Nikitin A V 2019 Agricultural market development: Trends and prospects International Journal of Innovative Technology and Exploring Engineering 9(1) 3842-3847
[3] Shevyakova L V, Makhova N N, Bessonov V V, Akimov M Yu, Savelyev N I, Akimova O M, Makarov V N, Zhidekhina T V and Akishin D V 2014 Macro-and microelement composition of fruits and berries of the Russian selection *Food industry* 3 44-46

[4] Kirina I B, Belosokhov F G, Titova L V, Suraykina I A and Pulpitow V F 2020 Biochemical assessment of berry crops as a source of production of functional food products *IOP Conference Series: Earth and Environmental Science* 548(8) 082068

[5] Shcherbakov S Y, Babushkin V A, Krivolapov I P, Lazin P S and Korotkov A A 2020 Determination of the energy efficiency of drying hawthorn fruit in a drum dryer with a paddle mixing device *IOP Conference Series: Materials Science and Engineering* 919(3) 032009

[6] Borisov A V, Litvinov S S and Romanova A V 2003 *Quality and storability of vegetables* (Moscow) 616 p

[7] Vinnitskaya V F, Akishin D V, Neuymin D S and Vetrov M Yu 2015 New food products of functional purpose from the Sunberry nightshade *Conference proceedings* pp 169-174

[8] Trunov Yu V, Medelyaeva A Yu and Medvedev A G 2019 The content of ascorbic acid and sugars in black currant berries under the influence of non-root fertilizing with fertilizers and trace elements *Bulletin of the Michurinsky SAU* 2 10-13

[9] Kondratiev I Yu 2008 Determinantal varieties of tomato for open ground, resistant to ecostream *Vegetable growing in Russia* 1-2 70-71

[10] Lichko N M 2004 *Standardization and certification of crop production* (Moscow: Yurayt-Izdat.) 596 p

[11] Machulkina V A, Sannikova T A, Gulin A V and Antipenko N I 2020 The use of the sugar-acid index for assessing the quality of tomato fruits *Vestnik KrasSAU* 5 168-172

[12]Perfilova O V, Akishin D V, Vinnitskaya V F, Danilin S I and Olikainen O V 2020 Use of vegetable and fruit powder in the production technology of functional food snacks *IOP Conference Series: Earth and Environmental Science* 548(8) 082071