Mechanical harvesting and processing of tomato varieties

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Abstract. Research in recent years has shown that the physical health of the population depends on the food quality. Concentrated tomato products (tomato paste, ketchup, sauces, etc.) can become a source of antioxidants necessary for the human body. The quantity and quality of the obtained canned food directly depends on the biochemical composition of tomato fruits and, first of all, the soluble dry matter. In a field experiment, six tomato samples of domestic and foreign breeding, suitable for one-time harvesting and processing into concentrated tomato products, were studied. As a result of the studies carried out, it was found that the chemical composition of the fruits changes depending on the weather conditions of the tomato growing season. On average, with an increase or decrease in dry matter content in tomato fruits by 1%, the calculated yield changes by 13.1 t / ha, which gives an increase or decrease in the volume of finished products during processing by 2.5 t / ha. When growing the studied tomato varieties suitable for modern cultivation and harvesting technologies in the soil and climatic conditions of the central zone of Krasnodar region, the highest calculated yield of finished products was obtained from the LG-1181 sample and the F₁ hybrid No. 8504 Heinz.

1 Introduction

Tomato (Solanum lycopersicum L.) is one of the most consumed vegetables in the world and the basis of other food products. It contains important compounds such as sugars, minerals, vitamins, carotenoids and phenols, the levels of which can vary markedly depending on genetic, physiological, agronomic, technological or other factors [1].

According to the Food and Agriculture Organization of the United Nations (FAOSTAT, 2017), tomato production in 2017 exceeded 182 million tons and is widespread worldwide. The popularity of tomatoes depends on whether they can be eaten fresh or in a variety of processed forms, including canned tomatoes, tomato-based foods, and dried tomatoes [2]. Thermal processing, including drying, is a common way to prolong the shelf life of tomatoes, and previous studies have compared nutritional parameters between raw and processed products [3].

Due to population growth and prosperity, food demand is expected to rise in the coming decades, which will put more pressure on the land and require other resources for food production, while climate change will create challenges for agricultural production [4].

Tomato is an important raw material for the canning industry. About 144 thousand tons of tomato concentrates (juices, ketchup, tomato puree, sauces) and other types of canned food are produced in Russia annually. Providing the population of Russia with high-quality food products throughout the year is an important task of the Government, which the "State Program for the Development of Agriculture of the Russian Federation", calculated until 2025, is designed to solve [5].
A number of researchers (Cheng et al., 2017) believe that increased consumption of tomatoes is directly associated with a decrease in the risk of chronic diseases. Tomatoes have a low calorie content, so they are useful for people prone to overweight. The fruits contain very important biologically active substances that lower cholesterol levels, protect against atherosclerosis and promote the formation of hemoglobin. Its consumption helps to reduce the incidence of cancer and helps to minimize the risk of cardiovascular and related diseases [6]. In recent years, in the tomato industry, more and more attention is paid to the quality of tomato fruits, which is influenced by both the genotype and the production system [7,8].

The main criterion for the suitability of tomato fruit for processing is quality. This is a complex trait, including: biochemical composition, which determines the nutritional value of tomato and its taste; fruit resistance to mechanical stress and cracking (cracking reduces the marketability of the crop, and in bulk transportation leads to juice leakage through cracks, which reduces the quality of the transported products and shortens the shelf life of fruits at harvesting points and raw material sites of factories), long shelf life of the commercial quality of fruits on plants in the field, transportability, suitability for processing and storage.

The quantity and quality of the products obtained directly depends on the dry matter content in the fruits and, first of all, on the soluble dry matter. Dry matter in tomatoes consists mainly of sugars and organic acids, making concentration levels of these molecules crucial in the assessment of fruit palatability, as they act as the main compounds responsible for the sweet and sour/acid tastes of these fruits, respectively [9].

The main organic acids of tomatoes are citric, malic and succinic, with citric acid prevailing. Other organic acids can arise from the processing of tomatoes: among these molecules, low levels of aconitic acids are formed as a result of the dehydration of citric acid [10].

The higher the dry matter content is, the less tomato fruit you need to make one kilogram of tomato paste. And the benefit is not only that. The factory will spend less energy on boiling the product. Reducing the cooking time will improve the organoleptic properties of the paste. It will be brighter in color, tastier, more aromatic, more nutrients and vitamins will be retained in it. Based on the obtained scientifically grounded data, it was found that the accumulation of basic chemicals in the fruits of tomatoes grown under the same conditions depends on the variety [11].

In connection with the above, the theoretical substantiation of the choice of varieties and their evaluation of suitability for processing into tomato products is an urgent task.

Purpose of the research. The purpose of the research is to evaluate tomato varieties of domestic and foreign breeding, suitable for modern technologies of cultivation, harvesting and complex processing of tomato raw materials into tomato products.

2. Materials and methods

The object of research were six tomato varieties of average ripening period, suitable for mechanized harvesting: varieties bred by FSBSI "Krymsk Experimental Breeding Station VIR" (Pamyatny and Veneta), FSBSI "Volgograd State Agrarian University" (Novichok), F₁ hybrid No. 8504 of the American company "Heinz", hybrid LG-1181, bred by FSBSI "Federal Scientific Rice Centre". The variety Mirage bred by FSBSI "Federal Scientific Rice Centre" was used as a standard.

When laying the experiments and conducting phenological observations and counts, the method of field experiment in vegetable growing was used, edited by Academician S.S. Litvinov [11]. The studies were carried out in the old delta agrolandscape area (central soil and climatic zone of Krasnodar region) in field conditions on the territory of the experimental plot of FSBSI "Federal Scientific Rice Centre". Research method - laboratory and field experiment. The area of the accounting plot is 50 m²; the replication is threefold. To increase the germination of seed material and prevent viral diseases 3 weeks before sowing, the seeds were treated according to the following scheme:

- warming up in a thermostat for two days at a temperature of 50°C;
- warming up in a thermostat for one day at a temperature of 78°C.
Due to the fact that sowing tomato seeds in the ground does not give even seedling vigor, and, consequently, even ripening of the crop, the most progressive modern cultivation method is cassette. Tomato seedlings were grown in plastic cassettes in a greenhouse with a film cover and emergency heating. Due to the fact that the end of March in the Kuban was characterized by cold weather, sowing of seeds in cassettes was carried out on April 8, when the average daily air temperature was above 10°C. Mass seedlings were obtained on April 16-18. Seedlings were planted in open ground at the age of 30 days on May 18. Planting scheme in the field - (90 + 50) / 2x35-40 cm. This provided a planting density of 40.8 thousand pcs / ha. The work on the care of plants in the experimental area (hilling, cultivation, pest and disease control, etc.) was carried out in the optimal agrotechnical terms in accordance with the recommendations for growing tomato [12]. For irrigation, we used Netafim drip systems. Harvesting was carried out at three times as the studied samples matured, when ripe fruits on the plants were at least 75% of the total. Employees of the agrochemical laboratory of the FSBSI "Federal Scientific Rice Centre" carried out analyzes to determine dry matter content, total sugar, mono- and disaccharides, acidity, ascorbic acid, carotene in tomato fruits of studied varieties and hybrids.

Statistical processing of the research results was carried out according to A.Kh. Sheudzhen [13].

3. Results and discussion
Analysis of the Russian market shows that the range of canned vegetables is the narrowest in relation to canned tomatoes. Therefore, first of all, it is necessary to diversify the assortment and increase the volumes of concentrated tomato products with a high content of nutrients produced by the canning industry. The majority of tomatoes were consumed as tomato puree, paste, or sauce [14].

It is known that the quality of tomato fruits is determined by the content of sugars, acids, vitamins, pectin substances, etc. For the canning industry, the amount of dry matter in fruits and their acidity are the main indicators. Some overexposure of ripe fruits on the plant is usually inevitable during combine harvesting, which leads to a decrease in the content of dry matter and acids in them, and sometimes to seed germination in fruits, and, consequently, to an increase in waste and product rejects during processing. Therefore, when evaluating varieties, it is necessary to strictly monitor the content of not only dry matter in fruits, but also acids, vitamins and other valuable compounds.

The quality of fresh tomato fruits harvested and supplied for whole-fruit canning, production of juices and concentrated tomato products is evaluated according to GOST 1725-85 "Fresh Tomatoes. Technical conditions " and is determined by the content of dry matter, sugars, vitamins and mineral salts in tomato fruits. According to the requirements of the canning industry, tomato fruits suitable for processing into concentrated tomato products (ketchup, tomato paste) must have biochemical parameters: dry matter content under irrigation conditions - at least 5%, sugars - 3%, total acidity - no more than 0.44 %. The chemical composition of the fruits of the studied tomato samples used as raw materials for the canning industry are presented in Table 1.

| Variety, hybrid | Dry matter, % | Total sugar, % | Mono sugar, % | Di-sugar, % | Acidity, % | Ascorbic acid, mg % | Sugar-acid coefficient |
|----------------|---------------|----------------|---------------|-------------|------------|---------------------|-----------------------|
| Mirage         | 5.62          | 2.67           | 2.60          | 0.07        | 0.32       | 22.74               | 8.3                   |
| Veneta         | 4.06          | 1.82           | 1.78          | 0.04        | 0.22       | 19.90               | 8.3                   |
| Pamyatny       | 4.64          | 2.18           | 2.11          | 0.07        | 0.27       | 24.44               | 8.1                   |
| Novichok       | 5.10          | 2.43           | 2.33          | 0.10        | 0.34       | 17.06               | 7.1                   |
| LG-1181        | 5.43          | 2.74           | 2.70          | 0.04        | 0.37       | 21.60               | 7.4                   |
| F1 hybrid №8504| 6.15          | 2.74           | 2.72          | 0.02        | 0.42       | 27.86               | 6.5                   |
| Heinz          |               |                |               |             |            |                     |                       |
Analysis of Table 1 shows that in the fruits of the varietal samples, the content of ascorbic acid was in the range from 17.06 to 27.86 mg%. Its highest content was in the fruits of F₁ hybrid No. 8504 Heinz and amounted to 27.86 mg%. The total acidity of tomato fruits met the requirements of the canning industry and amounted to 0.22% - 0.42%.

In the process of ripening, tomato fruits undergo a number of food, biochemical and physiological modifications that affect their functional and approximate quality characteristics [15].

The quality of the fruit depends not least on the dry matter content. A feature of varieties and hybrids of tomato, suitable for one-time combine harvesting, is the increased content of soluble dry substances and fiber in fruits. In almost all of the presented varieties, this indicator ranged from 5.1% to 6.2%, which indicates the suitability of fruits for processing into tomato products. The highest dry matter content is observed in F₁ hybrid No. 8504 Heinz - 6.2%. The exceptions were varieties Veneta and Pamyatny, in which the dry matter content in fruits was less than the optimal level of 4.1% and 4.6%, respectively.

As you know, the accumulation of sugars in fruits depends on the weather and climatic conditions of growing and on the tomato variety. Tomato belongs to thermophilic crops. The most optimal temperature for filling, ripening and accumulating sugars is from 23 to 27 °C. This temperature contributes to rapid and simultaneous ripening, the accumulation of a large amount of dry matter, which is very important when processing tomatoes, since there is no loss of nutrients due to overripe. In 2019, in the second half of summer (the time of filling and ripening of fruits), a decrease in temperature below the optimum was observed. The sugar content in all samples, due to the weather conditions of tomato vegetation, was less than the optimal level and was in the range of 1.82% - 2.74%. The highest sugar content in fruits was noted in the F₁ hybrid No. 8504 Heinz and the promising variety LG-1181 (2.74%), the lowest in the variety Veneta (1.82%). Sugar - acid coefficient for all presented varieties and hybrid was in the range of 6.5 - 8.3, which indicates the harmonious taste of the fruit.

The concentration of tomato juice in the production of tomato paste and ketchup is carried out by partial evaporation of water, which is contained in the juice up to 30% of dry matter. This operation is performed on installations of continuous double or triple thermal action. Therefore, it is very important to have a high dry matter content in tomato fruits, since not only the time of juice boiling, but also the volume of the finished product output depends on this.

In this regard, it is advisable to conduct a more detailed evaluation of the yield of the compared varieties. The basis in each group of varieties is the amount of soluble dry matter in the fruits of the standard variety. According to the yield and dry matter content in the fruits of the varieties and the standard, the yield of all varieties is recalculated by an amount proportional to the basic indicator. The yield of each variety (P) is calculated by the formula:

\[ P = Y + \left( \frac{D}{B} - 1 \right) * Y \]

Where:
- \( Y \) - actual yield of the variety, t/ha,
- \( B \) - basic dry matter content (standard fruits),
- \( D \) - dry matter content in the fruits of studied varieties.

Even a small decrease in the dry matter content of tomato fruits can significantly reduce the estimated yield of the variety and vice versa (Table 2).

| Variety, hybrid | Dry matter | Yield | Estimated output of finished products, t/ha |
|----------------|------------|-------|-----------------------------------------|
|                |            |       |                                         |
Exceeding the standard, % of dry matter, t / ha
Exceeding the actual yield, taking into account dry matter, t / ha
Exceeding the standard, taking into account dry matter, t / ha

| Variety         | Content, % | Exceeding the standard, % | Actual, t / ha | Calculated taking into account the % of dry matter, t / ha | Exceeding the actual yield, taking into account dry matter, t / ha | Exceeding the standard, taking into account dry matter, t / ha |
|-----------------|------------|---------------------------|----------------|----------------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------------|
| Mirage          | 5,6        | -                         | 73,8           | 73,8                                                     | -                                                              | -                                                           |
| Veneta          | 4,0        | -                         | 87,5           | 63,2                                                     | -24,3                                                          | -10,6                                                       |
| Pamyatny        | 4,6        | -                         | 89,5           | 73,9                                                     | -15,6                                                          | +0,1                                                        |
| Novichok        | 5,1        | -                         | 88,4           | 80,2                                                     | -8,2                                                           | +6,4                                                        |
| LG-1181         | 5,5        | -                         | 86,6           | 84,9                                                     | -1,7                                                           | +1,1                                                        |
| F₁ hybrid №8504 | 6,1        | +9,4                      | 76,9           | 84,1                                                     | +7,2                                                           | +10,3                                                       |
| Heinz           | 5          |                           |                |                                                          |                                                                 |                                                              |
| LSD₀₅            | 2,9        |                           |                |                                                          |                                                                 |                                                              |

From the data in the table it can be seen that the varieties Veneta, Pamyatny and Novichok showed a decrease in the dry matter content compared to the standard by 9.3% - 27.8%. This contributed to a decrease in yield compared with the baseline by 8.2 - 24.3 t / ha. The excess of the percentage of dry matter by 9.4% in F₁ hybrid No. 8504 Heinz contributed to an increase in yield, compared with the actual one, by 7.2 t / ha, and in comparison with the standard by 10.3 t / ha.

In general, for the samples, the estimated yield ranges from 63.2 t / ha to 84.9 t / ha, depending on the actual yield and the percentage of dry matter in the fruits. Despite the fact that the yield of the variety Veneta exceeded the standard by 13.7 t / ha, the estimated yield turned out to be less than the standard by 10.6 t / ha, and, consequently, the yield of finished products will decrease. The highest estimated yield was observed for hybrid F₁ hybrid No. 8504 Heinz (Heinz) and promising variety LG-1181 (81.1 t / ha and 84.9 t / ha, respectively). Varieties Novichok and Pamyatny, despite the fact that the actual yield exceeded the standard by 14.6 t / ha and 15.7 t / ha, respectively, had an estimated yield within the parameters of the standard variety Mirage, slightly exceeding it. On average, with an increase or decrease in dry matter by 1%, the yield changes by 13.1 t / ha, which gives an increase or decrease in the volume of finished products by 2.5 t / ha. Consequently, the volume of finished products obtained by processing tomato fruits from 1 hectare depends both on the yield of the variety and on the dry matter content in the fruits. When growing the studied tomato varieties suitable for modern cultivation and harvesting technologies, in the soil and climatic conditions of the central zone of Krasnodar region, the highest calculated yield of finished products was obtained from samples LG-1181 and F₁ hybrid No. 8504 Heinz (15.9 - 15.7 t / ha, respectively).

4. Conclusions

The results of evaluation of six tomato varieties of domestic and foreign breeding, suitable for modern cultivation and harvesting technologies, showed that all the samples under study are suitable for the complex processing of tomato raw materials into tomato products.

The chemical composition of the fruit varies depending on the weather conditions during the growing season of the tomato.

On average, with an increase or decrease in dry matter in tomato fruits by 1%, the calculated yield changes by 13.1 t / ha, which gives an increase or decrease in the volume of finished products during processing by 2.5 t / ha.
When growing the studied tomato varieties suitable for modern cultivation and harvesting technologies in the soil and climatic conditions of the central zone of Krasnodar region, the highest calculated yield of finished products was obtained from samples LG-1181 and F1 hybrid No. 8504 Heinz.

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