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Biochemical properties of several genetic resources of the national tomato germplasm

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ABSTRACT

The tomato (*Lycopersicon esculentum* Mill.) is a self-pollinated diploid species with twelve pairs of chromosomes (2n = 24). It belongs to the *Solanaceae* family, along with other frugally important crops such as pepper, eggplant, and potato. Tomatoes are a rich source of vitamins and minerals (Ca, P, and Fe) and are strong antioxidants against cancer and heart disease. It is a leading vegetable crop in our republic and is widely cultivated in open and protected soils. Due to the biologically active substances and essential amino acids contained in the fruit, it is used in the daily diet of people throughout the year in fresh and “processing” form. The tomato plays an important role in the prevention of diseases in humans, and many varieties and hybrids belonging to its different varieties are currently being created by breeders. In our republic, tomato selection work started more than 90 years ago. Various cultivated varieties were created, which are widely cultivated by farmers. During the creation of the variety, great attention was paid to their taste and quality characteristics. The created varieties are of national value, and it is important to preserve them for future generations as well as for cultivation and selection purposes. Given the impact of climate change and varying environmental conditions on the biochemical indicators of tomato fruits, we performed these studies to get more accurate data on the fruits of different varieties of tomatoes under genotype x environment and genotype x year cultivation conditions.

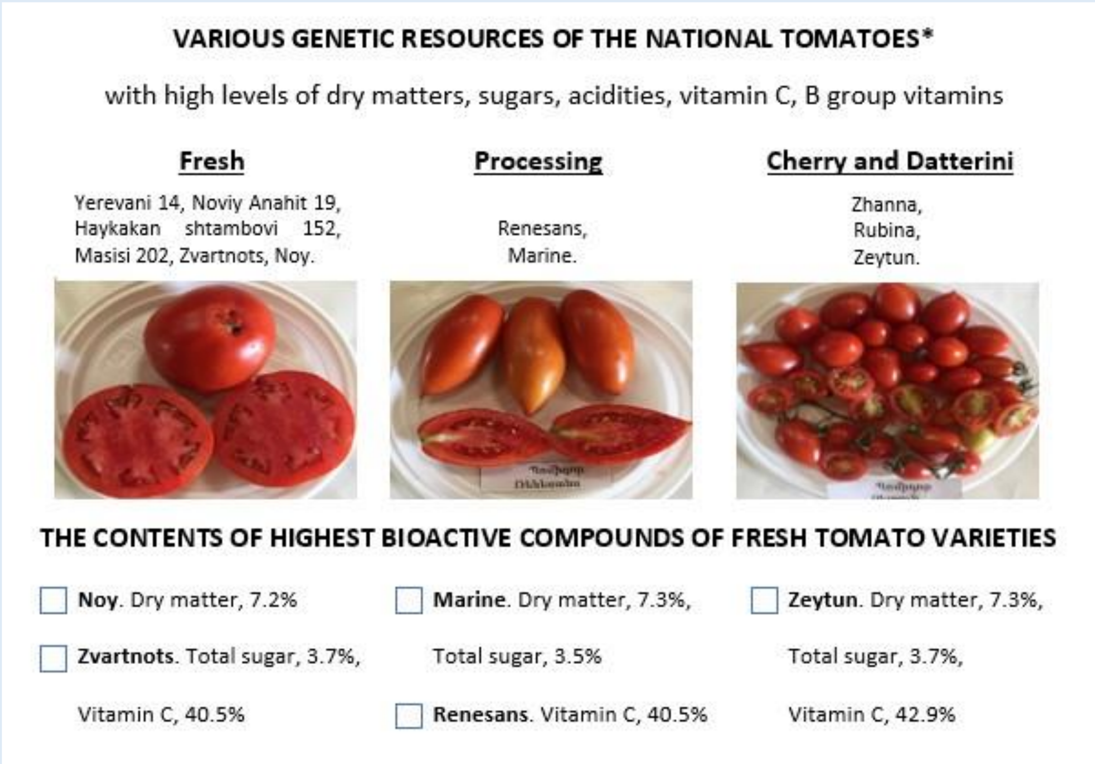
Objective: To evaluate the efficiency of several genetic resources of the national tomato germplasm in terms of the content of bioactive components and qualitative parameters (dry matter, sugars, acidity, vitamin C, B group vitamins.) in tomato fruits.

Methods: Experiments were carried out at v. Darakert, Ararat Marz, Republic of Armenia, in 2021–2022. A block-randomized method was used to set up the experiment in four replications. Experiments were conducted on various genetic resources of the national tomato, including Fresh, “Processing”, Cherry, and Datterini varieties. The study examined bioactive compounds, dry matter, and total sugars in biologically ripened tomato fruits. Ascorbic acid was determined through titration, and B vitamins were quantified using spectrophotometric analysis on a Cary 60 UV-Vis spectrophotometer. The content of vitamin B was calculated using a calibration graph.

Results: The study revealed that tomato fruits contain high levels of dry matter, sugars, acidity, vitamin C, and B group vitamins, with pantothenic acid, nicotinic acid, and inositol being predominant.

Conclusion: Several genetic resources of national tomato: Yerevani 14, Noviy Anahit 19, Haykakan shtambovi 152, Masisi 202, Zvartnots, Noy (fresh tomato varieties), Renesans, Marine (“processing” tomato varieties), Zhanna, Rubina, Zeytun (cherry and datterini tomato varieties) have high levels of dry matter, sugars, acidity, vitamin C, B group vitamins and can be used as functional foods.

Keywords: tomato, dry matter, sugars, acidity, vitamin C, B group vitamin



INTRODUCTION

For over a century, tomatoes, members of the Solanaceae (Solanaceae Juss) family, have evolved into a globally renowned crop, gaining popularity among vegetable producers, processors, businessmen, stock breeders, scientists, and collectors. The tomato, which is native to the Andes and cultivated in Mexico, was less accepted until the end of the 19th century, together with mandragora and pelaatonia. Robert Gibbon Johnson opened a new page in the history of vegetable growing by daring to eat tomatoes while standing on the steps of the courthouse in New Jersey (USA) in 1820 [1-2]. Currently the popularity of the tomato and its prevalence everywhere goes hand in hand with big businesses, selection and with gene engineering. The widespread presence of tomatoes in numerous countries worldwide, along with its significant contribution to overall vegetable production, can be attributed to its distinctive characteristics in growth, development, fruit-bearing, high yield, and versatile utilization of its fruits—whether consumed fresh, canned whole, in various concentrations, or incorporated into dietary canned products. Furthermore, the biological richness and high qualitative attributes of tomatoes, including sugar content, vitamins, microelements, and mineral salts, contribute to its appeal. Tomato fruits contain 5-6% of dry substances, 50% of which is soluble sugar (mannose), 0.5% of organic acid, 0.84% of cellulose, 0.19% pectic substances, 0.95% wet protein, 0.2% fats and essential oils, and 0.6% mineral salts [3]. Fruit having such favorable chemical composition made tomatoes highly valuable as a source of dietary food in certain cases [4]. Changes in the content of bioactive components and qualitative parameters (dry matter, sugars, acidity, vitamin C, B group vitamins) of tomato fruits can be greatly influenced by climatic conditions, different cultivation technologies, fertilizers of different organic and chemical composition [5-6]. The cultivation and use of tomatoes in Armenia have a long tradition. Tomato is cited only among the vegetable crops cultivated for "home needs" in the Agricultural Statistical Information of Yerevan province in 1870. Tomato is also cited in Ghevond Alishan's "Armenian vegetables" (1985) book [7].

According to Professor G.P. Grdzelyan tomato was cultivated in Transcaucasia (Georgia) starting from the 70s of the 19th centuries and was famous among the population as Rusuli badrejan (rusul's eggplant) name [7]. For more than 90 years, breeders of different generations in our republic have studied thousands of tomato samples, wild forms, varieties, and hybrids of different ecological and geographical origins [7]. By selecting the most suitable parental forms, they conducted crossbreeding to create valuable varieties and hybrids. These were subsequently cultivated in agricultural production over different years, resulting in a flavorful, high-quality tomato crop that met the demands of the national population. Many varieties were presented at international exhibitions and received medals and diplomas. In our republic, tomato selection work started 90 years ago, various cultivated varieties were created, which are widely cultivated by farmers[7]. A number of scientific publications mention the exceptional usefulness of tomato fruit quality indicators (dry matter, sugars, acidity, vitamin C). Thus, the content of dry matter in tomato fruits according to species and varieties ranges from 6 to 7.5%, sugars from 3 to 4.5%, acidity from 0.30 to 0.55%, vitamin C from 22 to 40 mg% [8]. The higher the dry matter content, the more useful the product is, especially for making tomato paste. Along with the increase of sugars and acidity, the taste and smell of tomato increases, which is determined by the sugar-acid index, which can vary between 5-9% [9]. The increase in juiciness and excellent taste properties is attributed to a high expression of the sugars/acidity ratio[10]. A low acidity percentage in tomato fruits has adverse effects, particularly during the canning of marinades with whole fruits. This results in a low-quality product, and, more critically, the tomato fruits in these cans spoil rapidly, preventing the preservation of the product in containers[11-12]. Considering the aforementioned summary and the future focus on breeding new tomato varieties exclusively for use in functional food, it is essential to recommend the best-performing varieties identified in our study. Our scientific research, conducted to address these considerations, is both current and applicable [13-14]. During the creation of the variety, great attention was paid to their taste and quality characteristics [15]. The created varieties are of national value and it is important to preserve them for future generations, and for the purposes of cultivation and selection [16]. Given the impact of climate change and varying environmental conditions on the biochemical indicators of tomato fruits, we performed these studies to get more accurate data on the fruits of different varieties of tomatoes under genotype x environment and genotype x year cultivation conditions [17]. Tomatoes are rich in vitamins, minerals, antioxidants, and contain biologically active compounds. carotenoids, polyphenols, and large amounts of vitamin C [18]. Polyphenols reduce the probability of cardiovascular and tumor diseases [19]. Vitamin C is a powerful antioxidant that strengthens the immune system. The abundant fiber content of tomatoes satiates for a long time and suppresses the feeling of hunger [20]. Due to the rich content of lycopene, tomatoes protect the body from the effects of free radicals and prevent the occurrence of cancer. As a rule, the redder the tomato, the richer it is in lycopene. It is also effective in the fight against rheumatism and arthritis [21]. Tomatoes in the diet contribute to the strengthening of immunity, the efficiency of the heart muscle, the improvement of metabolism, the overcoming of depression, the regulation of pulse pressure, and the release of toxins from the body [22].

Breeders worldwide have developed varieties and hybrids of various tomato types, which are extensively distributed and thrive in countries and islands across the globe.Tomato is considered the number one vegetable crop in the world from the point of view of its cultivation, distribution, production and use [22]. Currently, the seeds of the ancient forms and cultivated varieties of tomatoes are collected by different countries of the world for future generations, to be preserved in the Svalbard Global Seed Vault. In our republic, we also propagate the seeds of these forms and varieties of tomatoes with the intention of sending them for preservation.From the point of view of scientific interest, we have set a task to study the biochemical indicators in the context of genotype x environment and genotype x year in some of the national genetic resources of tomato.

Objective: The aim of this study was to evaluate the effectiveness of the Several Genetic Resources of National Tomato for content of bioactive components and qualitative parameters (dry matter, sugars, acidity, vitamin C, B group vitamins) in tomato fruits.

MATERIALS AND METHODS

Germplasm material: A total of 10 tomato accessions representing of genetic resources Armenian national tomato germplasm were used.

Experiments were conducted on the several genetic resources of the national tomato: fresh tomato varieties-Yerevani 14, Noviy Anahit 19, Haykakan shtambovi 152, Masisi 202, Zvartnots, Noy (the average weight of the fruits of these varieties ranges from 240-250 g. within limits), "processing" tomato varieties-Renesans, Marine (the average weight of the fruits of these varieties ranges from 70-80 g. within limits), cherry and datterini tomato varieties-Zhanna, Rubina, Zeytun (the average weight of the fruits of these varieties ranges from 15-25 g. within limits). To fulfill the daily vitamin requirements (C, group B), it is recommended that every adult consumes up to 300 grams of fruits and vegetables from the Solanaceae family, including tomatoes, peppers, eggplants, and potatoes.

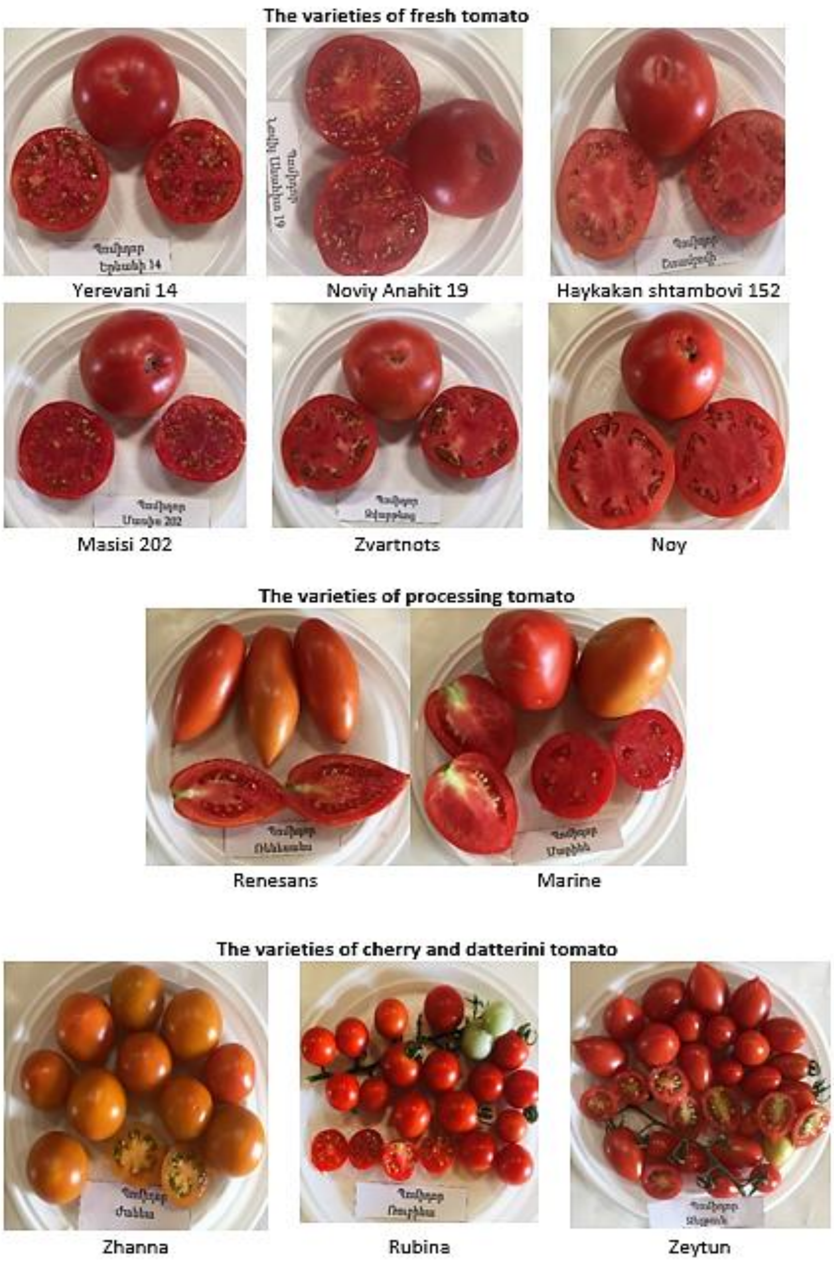
The studied varieties were bred in Armenia, at our scientific center, and have been used in food by our population for many years. These varieties are high-yielding, adaptive, endowed with valuable biological and economic properties. Due to having the best features, they are the best donors in selection. Local tomato varieties Nver is of the varieties of fresh tomato, Erza is of the varieties of "processing" tomato, Deghnaktuts is of the varieties of cherry and datterini tomato served as controls in the experimental works.

Experimental design: Experiments were conducted in 2021-2022 in v. Darakert, Ararat Marz of Armenia.The experiment was set up by a block-randomized method in 4 replications [23].

Seed germination, transplanting, and plant growth: Tomato seeds were sown in spring, in mid-March, and seedlings were planted in the open field in mid-May. Seedlings were planted in a 90x70x20 planting scheme. In the field, all required agrotechnical measures for plant care were carried out: irrigation, nutrition, fertilization, mulching, use of pesticides against common diseases and pests, harvesting. Tomato fruits reached biological maturity from mid-July, and mass ripening began in August depending on varietal characteristics. At that time, ripe tomato fruits were collected from the plants and biochemical analyses were performed in laboratory conditions, the results of which were included in this scientific article.

Fruit compositional quality: The content of bioactive compounds, dry matter, and total sugars in tomato fruits was studied in biological ripened fruits in all experimental variants. Ascorbic acid was determined by titration. Quantitative analysis of B vitamins was done at the Laboratory of Biochemistry. For the quantitative analysis of water-soluble B group vitamins (thiamine - B1, pyridoxine - B6, pantothenic acid - B5, nicotinic acid - PP, inositol), spectrophotometric methods were employed using a Cary 60 UV-Vis spectrophotometer from Agilent Technologies, USA. The method is based on the determination of reduced and oxidized riboflavin at a wavelength of 445 nm in relation to a solvent (0.1N HCl solution). The content of vitamin B was calculated using a calibration graph. The content of dry matter in fruits was determined by the refractometric method, total sugars were determined according to Bertrand [24-25].

Statistical analyses: The experimental data was subjected to statistical processing using the Analysis of Variance (ANOVA).



RESULTS AND DISCUSSION

Fruit quality characterization: The results of qualitative parameters of the content of dry matter in the fresh tomato varieties, Yerevani 14, Noviy Anahit 19, Haykakan Shtambovi 152, Masisi 202, Zvartnots and Noy were respectively 6.8; 6.7; 6.9; 7.0; 7.1; 7.2%, in the varieties of "processing" tomato Renesans and Marine, respectively 7.2; 7.3%, in the varieties of cherry and datterini tomato Zhanna, Rubina, Zeytun were respectively 7.0; 7.1; 7.3% (Fig. 1) (P<0.05).

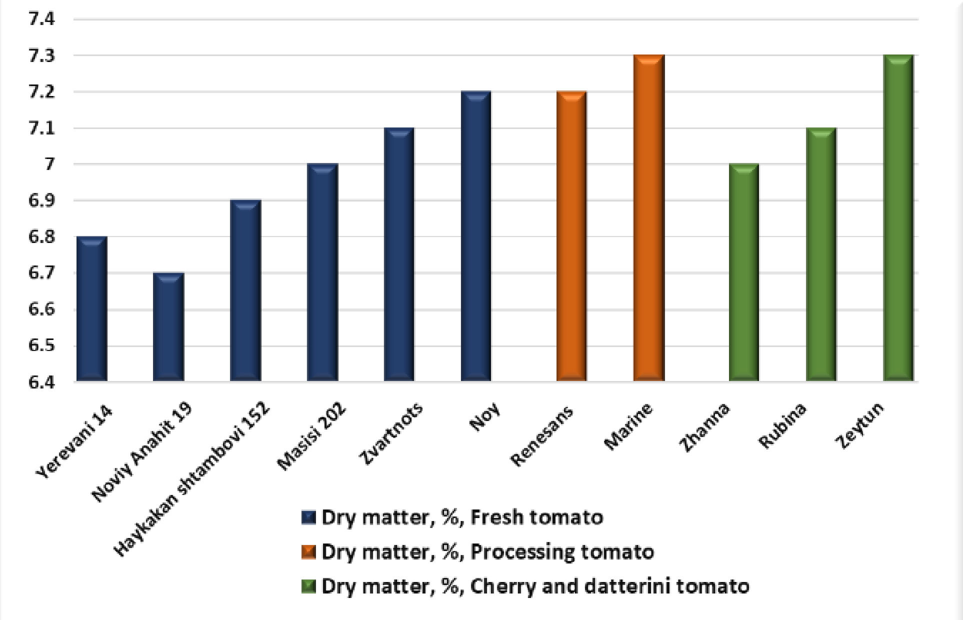


Fig. 1. The content of dry matter in the varieties of tomato

The content of sugar matter in the varieties of fresh tomato was respectively 3.5; 3.6; 3.6; 3.5; 3.7; 3.6%, the varieties of "processing" tomato - 3.4; 3.5% and the varieties of cherry and datterini tomato - 3.4; 3.6; 3.7% (Fig. 2) (P<0.05).

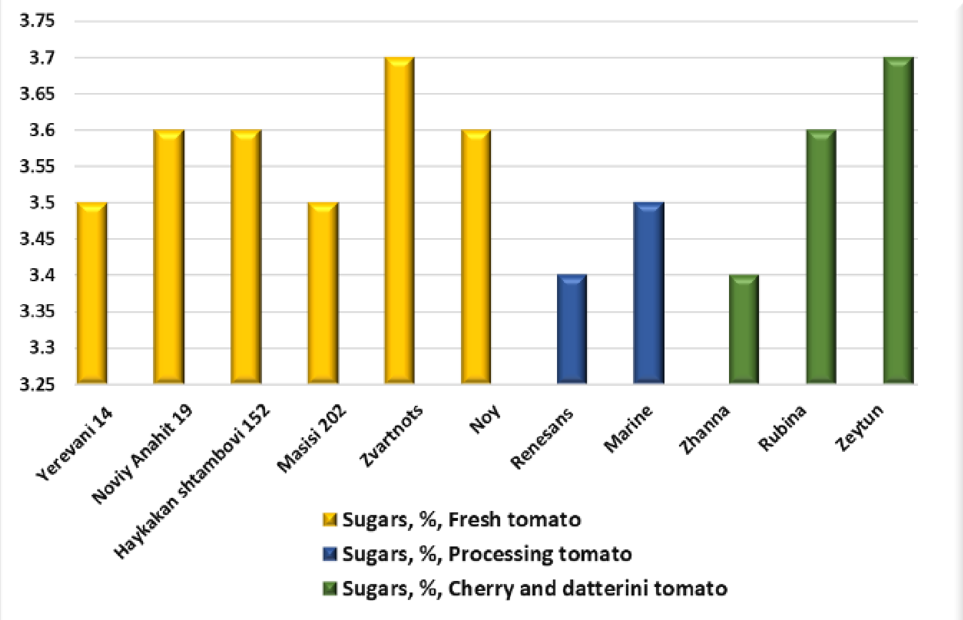


Fig. 2. The content of sugars in the varieties of tomato

The content of acidity in the varieties of fresh tomato was respectively 0.45; 0.47; 0.4.5; 0.48; 0.47; 0.50%, in the varieties of "processing" tomato - 0.46; 0.47%; and in the varieties of cherry and datterini tomato - 0.49; 0.45; 0.42% (Fig. 3) (P<0.05).

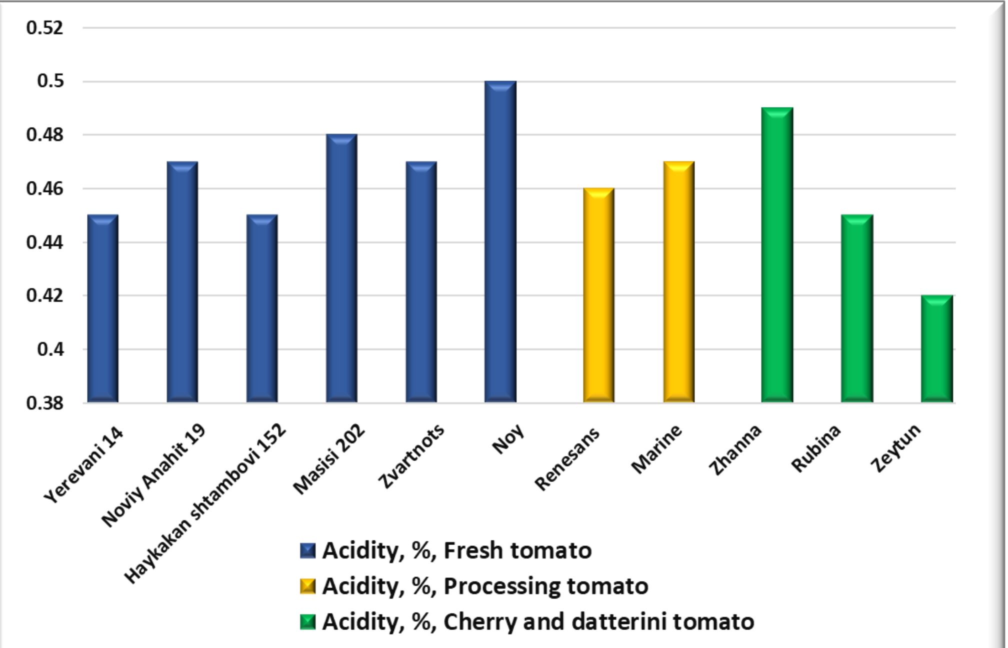


Fig. 3. The content of acidity in the varieties of tomato

The content of vitamin C in the varieties of fresh tomato, respectively; 28.25; 29.56; 34.65; 32.75; 40.55; 35.26 mg%, the varieties of "processing" tomato – 42.25; 41.65 mg%, the varieties of cherry and datterini tomato - 35.84; 36.65; 42.95 mg% (Fig.4) (P<0.05).

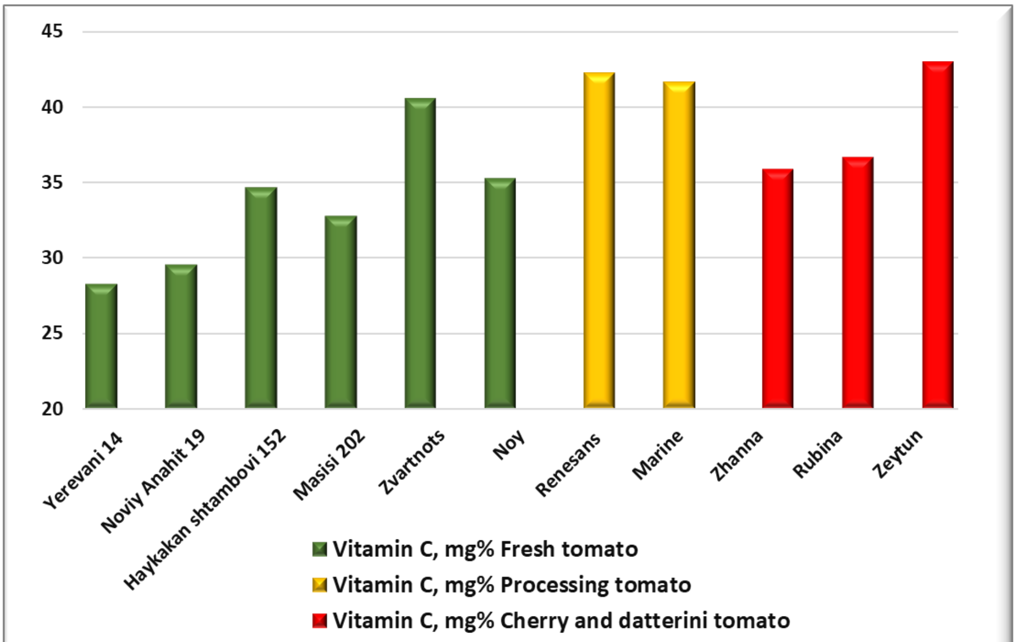


Fig. 4. The content of vitamin C in the varieties of tomato

The content of thiamine (B1) in fresh tomato varieties was 5.27, 4.36, 4.65, 4.95, 4.37, and 5.15 µg/ml, respectively, in "processing" tomato varieties - 4.65 and 4.79 µg/ml. For cherry and datterini tomato varieties, the content was 4.35, 5.16, and 5.35 µg/ml (Fig. 5) (P<0.05).

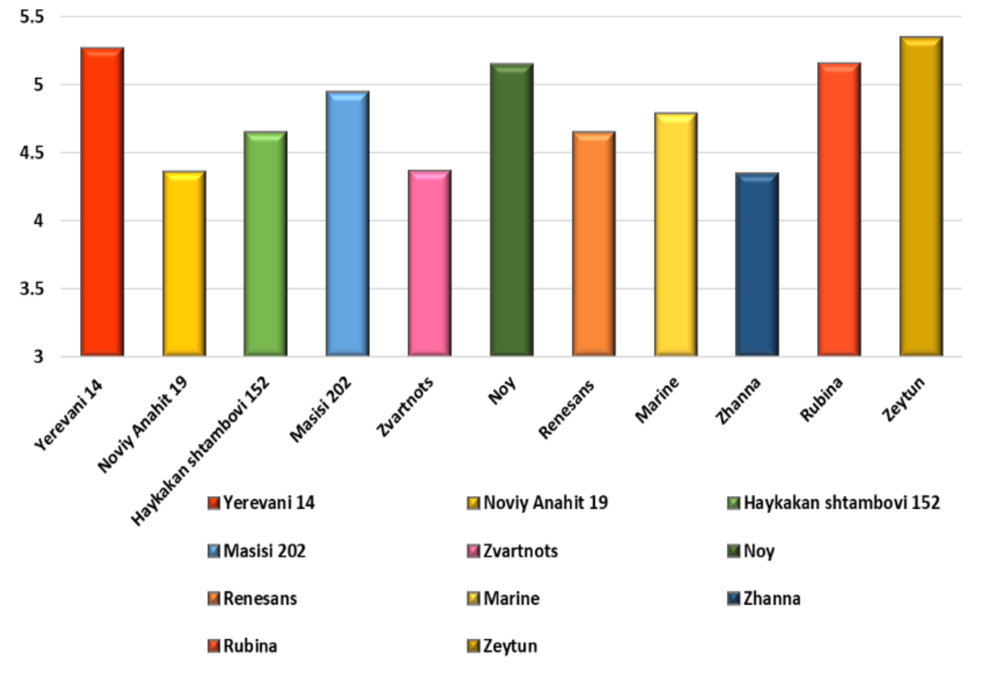


Fig. 5. The content of vitamin of group B - Thiamine (B1) mkg/ml in the varieties tomato

The content of pyridoxine (B6) in fresh tomato varieties was 9.68, 9.53, 10.95, 9.54, 9.85, and 9.16 µg/ml, respectively, in "processing" tomato varieties - 10.35 and 10.68 µg/ml, in cherry and datterini tomato varieties- 9.65, 10.75, and 10.96 µg/ml (Fig. 6) ($P<0.05$).

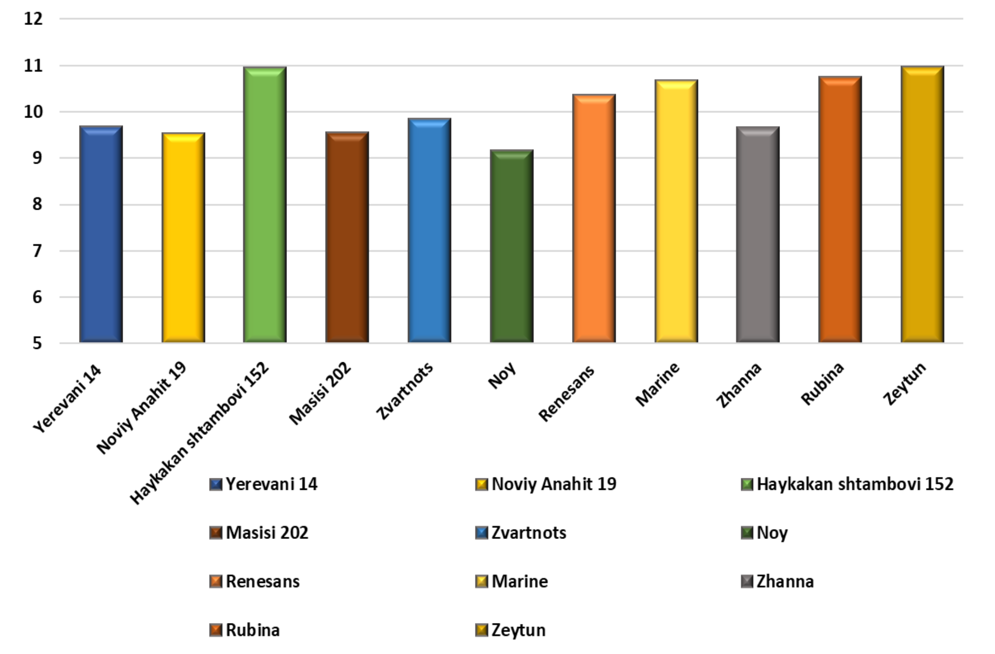


Fig. 6. The content of vitamin of group B - Piridoxine (B6) mkg/ml in the varieties tomato

The content of pantothenic acid (B5) in fresh tomato varieties were as follows: 115.52, 112.64, 116.32, 109.25, 115.68, and 113.45 µg/ml, respectively, in "processing" tomato varieties- 109.52 and 110.28 µg/ml, in cherry and datterini tomato varieties- 110.56, 114.38, and 116.54 µg/ml (Fig. 7) ($P<0.05$).

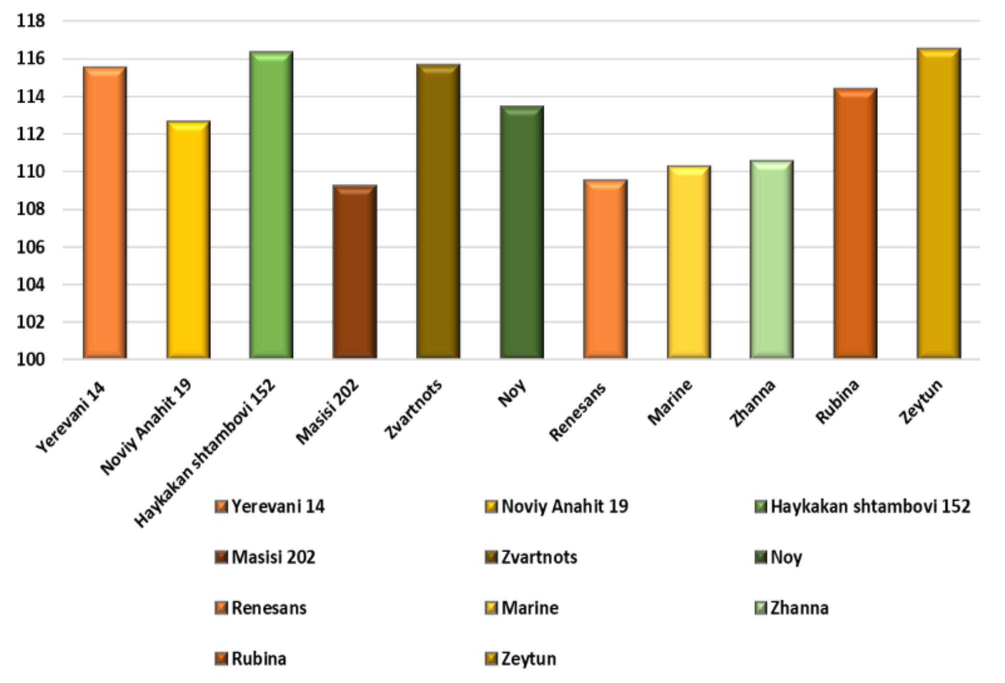


Fig. 7. The content of vitamin of group B - Panothenic (B5) mkg/ml in the varieties tomato

The levels of nicotinic acid (PP) in fresh tomato varieties were recorded as follows: 67.85, 67.25, 70.36, 68.45, 68.95, and 69.21 µg/ml, in "processing" tomato varieties, the levels were 70.96 and 69.53 µg/ml, For cherry and datterini tomato varieties- 68.29, 70.65, and 70.95 µg/ml (Fig.8) (P<0.05).

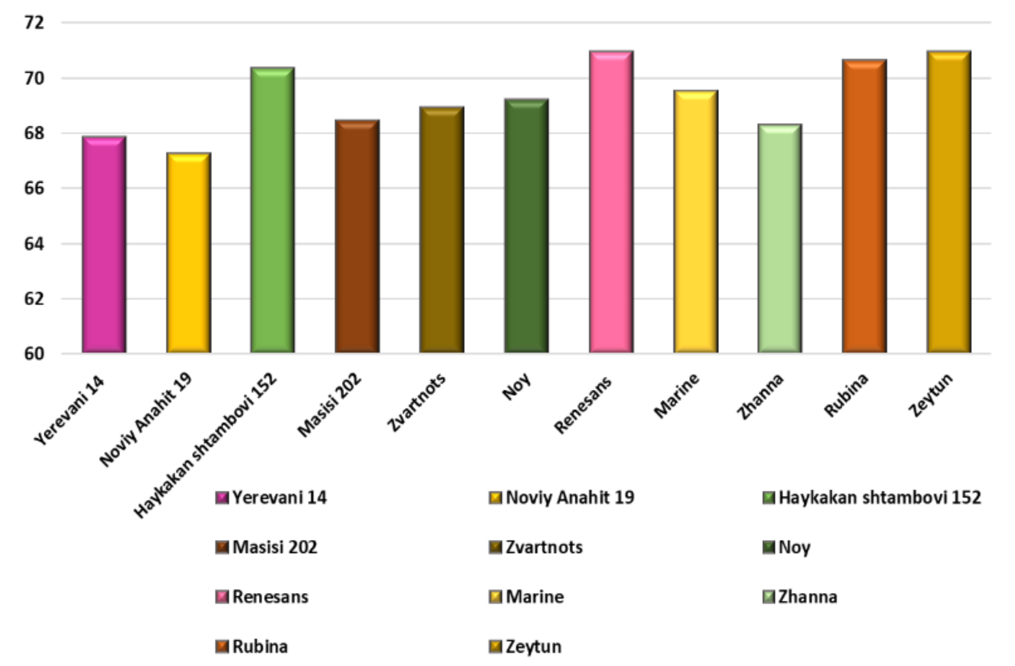


Fig. 8. The content of vitamin of group B - Nicotinic (PP) mkg/ml in the varieties tomato

Inositol (B8) in the varieties of fresh tomato was respectively 3645.8; 3665.2; 3755.8; 3664.3; 3785.2; 3695.8 µg/ml, in the varieties of "processing" tomato - 3683.5; 3752.9 µg/ml, in the varieties of cherry and datterini tomato - 3641.5; 3763.8; 3795.6 µg/ml (Fig. 9) (P<0.05).

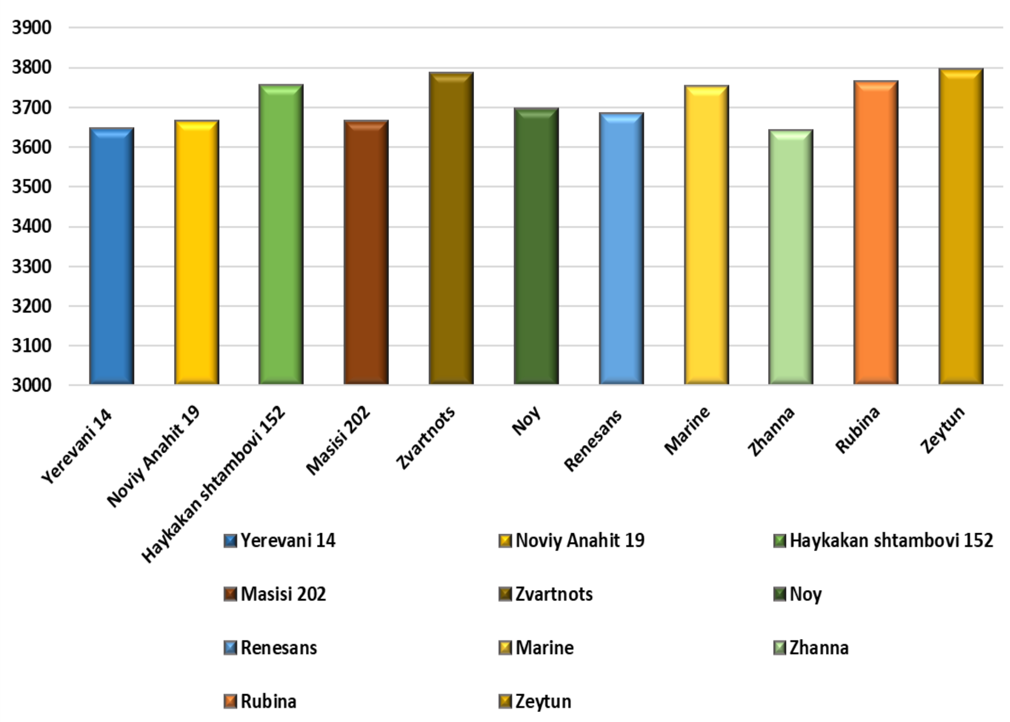


Fig. 9. The content of vitamin of group B -Inositol (B8) mkg/ml in the varieties tomato

The scientific literature provides numerous data on functional food made from plant fruits [27-30]. A number of studies have revealed that the high composition of bioactive properties contributes to the treatment of a number of diseases in the human body [31-32]. The number of bioactive properties in the fruits of plants increases due to the breeding of new selection varieties and hybrids, when varieties rich in these indicators are selected as parental forms during cross-breeding. In the vegetative organs of plants, exclusively in leaves and fruits, high rates of bioactive properties were also recorded in the case of using different doses of fertilizers [33-35]. Tomatoes are a valuable source of biologically active substances (vitamin C, lycopene, lutein, macro- and microelements) and can be used to produce functional foods [36]. A number of scientists have expressed the opinion that chemically synthesized drugs, processed products of fruits, berries and vegetables, including tomatoes, can serve as a source of biologically active substances [37-41].

In our experiments, compared to tomato controls Nver (fresh tomato), Eraz ("processing" tomato), and Deghnaktuts (cherry and datterini tomato varieties), high amounts of dry matter, sugars, vitamin C, and group B vitamins were recorded in the studied varieties.

The research findings indicated that the fresh tomato varieties Yerevan 14, Novi Anahit 19, Haykakan Shtambovi 152, Masisi 202, Zvartnots, and Noi had a dry matter content that was 0.7% higher than the control, which was 6.5%. On the other hand, in the "processing" tomato varieties Renesans and Marine, the dry matter content was 0.3% higher than the control, which was 7.0%.

In the varieties of cherry and datterini tomato; Zhanna, Rubina, Zeytun was 0.5 % higher than the control, which is 6.8%. The sugar content differs among various types of tomatoes. Specifically, it is 0.2% higher than the control (which is 3.3%) in the fresh tomato varieties. In the "processing" tomato varieties, the sugar content is 0.3% higher than the control (which is 3.2%), in the cherry and datterini tomato varieties, the sugar content is 0.5% higher than the control (which is 3.1%).

The acidity in the fresh tomato variation ranged from 0.45% to 0.50%. For the "processing" voraety tomato, acidity ranged from 0.46% to 0.47%. In the variation of cherry and datterini tomatoes, acidity was recorded at 0.42% to 0.49%. Finally, in the control, acidity levels were observed at 0.45%, 0.46%, and 0.48%, respectively. The vitamin C content in fresh tomato varieties increased by 4.2%, in "processing" tomato varieties by 9.5%, and in cherry and datterini tomato varieties by 12.5% compared to the control. The respective values were 26.1 mg%, 32.7 mg%, and 30.45 mg%. The content of B group vitamin thiamine (B1) in fresh tomato varieties is 0.8% higher than the control, with a value of 4.33 µg/ml. In "processing" tomato varieties, it is 0.7% higher than the control, with a value of 4.54 µg/ml. The varieties of cherry and datterini tomatoes show a 1.5% increase compared to the control, with a value of 3.95 µg/ml. The pyridoxine (B6) content in fresh tomato varieties is 0.9% higher than the control, with a value of 8.27 µg/ml. In "processing" tomato varieties, it is 0.7% higher than the control, with a value of 10.28 µg/ml. The varieties of cherry and datterini tomatoes exhibit a 1.6% increase compared to the control, with a value of 9.15 µg/ml. The pantothenic acid (B5) content in fresh tomato varieties is 0.5% higher than the control, with a value of 110.45 µg/ml. In "processing" tomato varieties, it is 0.3% higher than the control, with a value of 108.61 µg/ml. The varieties of cherry and datterini tomatoes exhibit a 0.8% increase compared to the control, with a value of 108.47 µg/ml. The nicotinic acid (PP) content in fresh tomato varieties is 0.3% higher than the control, with a value of 67.52 µg/ml. In "processing" tomato varieties, it is 0.2% higher than the control, with a value of 70.95 µg/ml. The varieties of cherry and datterini tomatoes show a 0.6% increase compared to the control, with a value of 65.24 µg/ml. The inositol (B8) content in fresh tomato varieties is 1.2% higher than the control, with a value of 3685.2 µg/ml. In "processing" tomato varieties, it is 1.3% higher than the control, with a value of 3624.8 µg/ml. The varieties of cherry and datterini tomatoes exhibit a 1.5% increase compared to the control, with a value of 3605.6 µg/ml. The results showed that the high content of vitamins of group B in tomato fruits was recorded in varieties, and pantothenic acid (B5), nicotinic acid (PP), and inositol (B8) predominated.

The data from our studies indicates that to meet the daily vitamin requirements, each person should consume 1.5-2 fruits of tomato varieties such as Yerevani 14, Noviy Anahit 19, Haykakan Shtambovi 152, Masisi 202, Zvartnots, and Noy. Additionally, 4-5 fruits of Renesans and Marine varieties, as well as 15-20 fruits of Zhanna, Rubina, and Zeytun varieties, are recommended.

CONCLUSION

Several genetic resources of the national tomato Yerevani 14, Noviy Anahit 19, Haykakan Shtambovi 152, Masisi 202, Zvartnots, Noy (fresh tomato varieties), Renesans, Marine ("processing" tomato varieties) Zhanna, Rubina, Zeytun (cherry and datterinii tomato varieties) have high levels of dry matter, sugars, acidity, vitamin C, and B-group vitamins and can be used as functional foods. The scientific novelty of the research lies in the fact that the content of indicators of bioactive properties studied in different varieties allows us to recommend them as the best parental forms in selection for use in hybrids. The information we have obtained can significantly contribute to the development of new high-quality varieties.The newly cultivated varieties are expected to possess a high content of bioactive substances. This characteristic will facilitate the production of various types of functional food using the fruits obtained from the cultivation of these varieties.These varieties should be handed over to the Svalbard Global Seed Vault for use by future generations. The results of our research will help the scientific community develop new food recipes from tomato fruits that will contribute to the improvement of human health.

Author Contributions: K.S. designed the research. K.S. provided a variety Renesans, Marine, Zhanna, Rubina, Zeytun, Yerevani 14, Noviy Anahit 19, Haykakan shtambovi 152, Masisi 202, Zvartnots, Noy for research. G.K., G.Sh. performed biochemical analysis. K.S., G.K. performed statistical analyses. K.S. and M.G. wrote the manuscript. M.Z. edited the article and worked on graphical abstract designs. All authors read and approved the final version of the manuscript.

List of Abbreviations: BOLD - Biodiversity for Opportunities, Livelihoods and Development.

Competing Interests: There are no conflicts of interest to declare.

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