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EVALUATION OF THE BASIC SACCHARIDES CONTENT IN TOMATOES

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ABSTRACT
Saccharides are the basic dry matter components of all fruits and vegetables. The dominant tomatoes saccharides are fructose and glucose, minor ones are sucrose but also arabinose, xylose, and galactose. The objective of this paper is to analyze carbohydrates such as glucose, fructose and sucrose in the selected tomatoes varieties intended for the direct consumption and industrial processing. We used 14 varieties and 3 newly selected tomatoes varieties. The glucose content in the studied varieties was in the range of 4.87 – 15.9 $g.kg^{-1}$, the fructose content was 11.1 – 22.27 $g.kg^{-1}$ and sucrose content was 0.07 – 1.73 $g.kg^{-1}$. The highest fructose and sucrose content was detected in the Tomanova variety, the highest sucrose content was found out in the Bovita variety. When comparing the glucose content it was found out that the higher content on average was achieved in the varieties intended for the industrial processing (10.10 $g.kg^{-1}$) than in the varieties for the direct consumption (7.96 $g.kg^{-1}$). The varieties intended for industrial processing were generally characterized by higher glucose and fructose content than the varieties intended for the direct consumption. When comparing the fructose content, we found a higher average content in the varieties intended for industrial processing (15.70 $g.kg^{-1}$) than in the varieties for the direct consumption (14.40 $g.kg^{-1}$). In most of the studied varieties sucrose was present in low content (<1.0 $g.kg^{-1}$), only in the Tomanova variety sucrose content represented more than 1 $g.kg^{-1}$.

Keywords: tomato; saccharides; glucose; fructose; sucrose

INTRODUCTION
Carbohydrates and organic acids are the dry matter key ingredients with influence on tomatoes quality and the preference of the variety for consumers in terms of taste intensity **(Baldwin et al., 2011; Bastias et al., 2011; Ponce-Valadez et al., 2016; Wang et al., 2016)**. Sugars and organic acids represent more than 60% of tomatoes' dry matter content.

Most studies show that the dominant carbohydrates present in tomatoes are fructose, glucose, and sucrose, and organic acids such as malic, citric, or eventually ascorbic acid are dominant **(Osvald et al., 2001; Fulton et al., 2002; Ruggieri et al., 2014)**. Fructose and glucose levels are low during the growth and development of tomatoes, but their concentration increases rapidly during the tomato maturation time **(Carrari et al., 2006)**.

Thakur et al. (1996) reported that a small percentage of sucrose, raffinose, arabinose, xylose, and galactose are also present in the tomatoes. **Schauer et al. (2005)** detected alcoholic sugars such as galactitol, maltitol and sorbitol in tomatoes. **Kelebek et al. (2017)** determined that sucrose is in the smallest amount present among tomatoes carbohydrates.

The indicators, representing the basic composition of tomatoes such as soluble dry matter content, acid content, carbohydrates content, are often the most important indicators that determine the variety success for both the consumer and processor.

Tijskens and Schouten (2009) reported that consumers firstly perceive the content of sugars and acids in the tomatoes, which they convert to the sweetness and acidity of the tomatoes and finally to the tomatoes flavor attribute, which is crucial for tomatoes success. Also, **Kader (2008)** and **Baldwin et al. (2008)** state that the tastiness of tomatoes is determined by the presence of sugars, organic acids, mineral substances, and volatile substances that contribute to the tomatoes' flavor. The fruit taste and aroma are of decisive importance for the perception of the overall tomato acceptability.

The second most important factor, after genotype determining final tomatoes quality, is the tomatoes harvest at the right maturity level **(Kader, 2008)**. At the time of ripening, the proportion of sugars in tomatoes increases, organic acids are degraded, and volatile substances are intensively synthesized.

The picking of tomatoes at the right degree of maturity also determines the use of the harvested tomatoes, either for the direct consumption without the necessity of storage or for storage or canning processing. The objective of this paper is to analyze the basic carbohydrates, such as glucose, fructose, and sucrose in the selected tomato varieties.

Scientific Hypothesis

Carbohydrates are the basic component of tomato dry matter. The dominant carbohydrates are fructose and glucose. Sucrose is a minor in tomato fruits. The variety has a statistically significant effect on the carbohydrate content.

MATERIAL AND METHODOLOGY

Samples

We used 14 varieties and 3 newly selected tomato varieties. Out of the varieties intended for the industrial processing, we analyzed varieties Uno Rosso F1, Pavlína, Mobil, Zömök, Denár, Bovita, Danuša, Salus. Out of the varieties dedicated for the direct consumption, we analyzed varieties Niki Zel F1, Ady Zel F1, Ambros F1, Žofka, F1, Jerguš F1, Tomanova, and the newly-selected varieties 987/17, 1037/17, and 1018/17. The newly-selected varieties 1037/17 and 1018/17 belonged to the small cherry tomato types.

Chemicals

To prepare samples, an extraction solution in the composition of demineralized water and ethanol was used (Ethanol ≥99.5%, suitable for HPLC, CAS 64-17-5, Sigma-Aldrich. St Louis, MO, USA) in a ratio of 20:80.

They were used to clarify the samples:

Carrez solution I for determination of sugars and starch (1 L contains: 219 g zinc acetate – dihydrate, 30 g acetic acid min. 99.8 %, water pure, CAS R.9944.1, P-LAB, ČR, Praha

Carrez solution II for determination of sugars and starch (1 L contains 106 g potassium ferrocyanide – trihydrate, water pure, CAS R.9950.1, P-LAB, ČR, Praha)

Calibration curves were prepared from solution:

Glucose (D-(+)-Glucose ≥99.5% (GC), CAS 50-99-7, Sigma-Aldrich. St Louis, MO, USA)

Fructose (D-(−)-Fructose ≥99%, CAS 57-48-7 Sigma-Aldrich. St Louis, MO, USA)

Sucrose (Saccharose ≥99.5% (GC), CAS 57-50-1, Sigma-Aldrich. St Louis, MO, USA).

Biological Material

Samples of cultivars Uno Rosso F1, Pavlína, Mobil, Zömök and Denár were supplied by the Botanical Garden of the Slovak University of Agriculture in Nitra. The location is in a mild climate. The climate is continental with an average annual temperature of 9.5 °C and an average annual rainfall of around 595 mm.

Samples of cultivars Niki Zel F1, Ady Zel F1, Ambros F1, Žofka, F1, Jerguš F1, Tomanova, Bovita, Salus, 987/17, 1037/17 and 1018/17 were supplied by the Zelseed Breeding Station in Horná Potôň. The location is in a mild climate. The climate is continental with an average annual temperature of 9.9 °C and average annual precipitation of about 513 mm.

Instrument

The following instrument was used for the measurement:

Liquid Chromatography Equipment (HPLC) LC-20 AD, Shimadzu Corporation.

Description of the Experiment

Collection of samples for analysis

The tomatoes assigned for the experiment were picked at the stage of technological maturity, which concerned the varieties intended for industrial processing. The varieties targeted for the direct consumption were harvested at the stage of consumer maturity. The ripeness of the tomatoes was characterized by intense deep color, characteristic full tomato flavor and aroma, and a minimum value of soluble dry matter of 4.5 °Brix. Maturity in the field conditions was monitored subjectively by the color intensity of the tomatoes, and also objectively by the soluble dry matter content using a Krüss HR18-01 digital hand refractometer.

Laboratory Methods

Determination of glucose, fructose, and sucrose content in the samples was performed by HPLC-RID (Refractive Index Detector) method **(Sanz and Martínez-Castro, 2007)**. The liquid chromatography was used for the analysis with the Agilent Zorbax column and aminopropyl stationary phase. The mixture of acetonitrile and water at the ratio of 80:20 with the flow rate of 1.6 $mL.min^{-1}$ was used as the mobile phase. The sample preparation consisted of extracting 2 g of homogenized tomato mass in 20 mL of the soluble mixture consisting of ultrapure ethanol and water at a ratio of 4:1 for 1 hour. The clarification of the sample was performed with Carrez reagents in amounts of 2.5 mL Carrez I and 2.5 mL of Carrez II. After the clarification for 15 minutes, the samples were centrifuged and filtered by syringe filters before the analysis. Calibration curves were prepared from a stock solution of glucose, fructose, and sucrose at the concentration of 0.5 – 20 V.

Statistical Analysis

For statistical evaluation of the influence of the variety on the content of the monitored parameters, a one-factor resp. two-way analysis of variance ANOVA at $p < 0.01$. In post-hoc testing, the Tukey HSD multiple comparison test was used to find statistically significant differences at $p < 0.05$. All statistical analyzes were performed using the Statsoft Statistica 12.5 statistical package (Statsoft Inc., Tulsa, USA).

RESULTS AND DISCUSSION

Soluble dry matter

The determination of the soluble dry matter content expressed as °Brix is in practice used as a basic measurable indicator to determine tomato ripeness. A minimum of 4.6 °Brix is required for tomatoes to be processed and, as reported by **Patané and Cosentino (2010)**, the low soluble dry matter content and the high-water content of tomatoes cause a reduction of economic profits during processing. De **Castro Vilas Boas et al. (2017)** also state that at the point of purchase the quality of tomatoes intended for processing is currently determined subjectively by color and measured by the soluble dry matter in °Brix, while other quality characteristics are often overlooked. In addition to the soluble dry matter content, the ratio of carbohydrates to organic acids **(Zhao et al., 2016)** is significant in assessing the quality of ready-to-eat tomatoes.

The soluble dry matter content in the monitored tomato varieties ranged in the values of 4.5 to 7.5 °Brix. According to the average dry matter content, the varieties were divided into 5 homogeneous groups. The newly selected varieties 987/17 and 1018/17 reached statistical significance ($p < 0.05$) with the lowest values (4.5 °Brix), while the highest content of soluble dry matter was detected in the variety Tomanova (7.5 °Brix) intended for the direct consumption. The varieties Danuša, Bovita, and 1037/17 also showed high dry matter content (6.5 °Brix). According to their way of utilization Danuša and Bovita varieties are classified among the varieties intended for industrial processing with the possible way of use for the direct consumption. The varieties with the soluble dry matter content of 5.0 – 5.2 °Brix represented the largest group of varieties with a balanced dry matter content. This group included the varieties intended for the industrial processing such as Uno Rosso F1, Mobil, Zömök, Salus, as well as the varieties intended for the direct consumption, such as Niki Zel F1, Ady Zel F1, Ambros F1, Žofka F1 or Jerguš F1 (Table 1).

Sun et al. (2012) states that the fruit lycopene content and the total soluble solids content are important factors that determine the quality of tomato fruit.

Anthon et al. (2011) in their publication also monitored the soluble dry matter content. According to their results, the dry matter of tomatoes is mainly composed of simple sugars such as glucose and fructose. The authors monitored the dry matter content of tomatoes intended for industrial processing and found out that the dry matter content ranged from 4.6 to 5.4 °Brix. During the time of storage just before processing they detected an increase of dry matter content up to 5.6 °Brix in most varieties, which was partly due to transpiration and breathing processes that are accompanied by loss of water of tomato pulp, but also by tomato post-harvest ripening and synthesis of the various dry matter components. However, along with the prolonged tomato storage time and during storage at temperatures above 20 °C, there is a risk of tomatoes self-heating and the development of undesirable microorganisms. Therefore, it is not recommended to store tomatoes before processing with the purpose of post-harvest ripening, and thus to increase the dry matter content. If the storage before processing is necessary, the technology should include at least a minimum of cooling.

Patané et al. (2017) analyzed the soluble dry matter content by using the Digital Brix refractometer HI 96801 in the Italian tomato varieties Pizzottello di Montallegro and Locale di Filicudi grown in Italy, Catania. They reported that the content of dry matter was 8.2 °Brix and 8.15 °Brix, which is higher than we found out in our study. Undoubtedly, the climatic conditions of the growing area, in particular, higher average temperatures, higher sums of temperatures during vegetation, and also the intensity of sunlight had the positive effect on the higher dry matter content, as it was documented in the publication of **Patané et al. (2017)**.

The dry matter content of tomatoes grown in the northern Tunisia was monitored by **Ilahy et al. (2016)**. In their paper, they evaluated newly selected tomato varieties with a high content of lycopene HLT-F71 and HLT-F72 and they used Tunisian traditionally grown variety Rio Grande as a reference variety. The Rio Grande variety reached an average dry matter content of 5.8 °Brix, while newly selected varieties achieved the dry matter content up to 6.7 °Brix. These values correspond to our varieties, in which we found a higher content of soluble dry matter, namely variety Danuša, Bovita, and newly selected variety 1037/17.

Radzevičius et al. (2016) evaluated the soluble dry matter content of tomatoes by using the varieties Rutuliai during ripening time. They utilized the classical methods and by using NIR spectrophotometer. The authors recorded that the dry matter content measured by the NIR spectrophotometer was slightly lower than the dry matter content determined by the classical method. The values that were detected by the authors at the stage of tomato ripening were 3.98 – 5.20 °Brix. These values are comparable to our findings.

Domínguez et al. (2016) monitored the content of soluble dry matter in the varieties Delitia and Pitenza. Tomatoes were grown in the greenhouse conditions in Spain and they are picked at the stage of full ripeness. The authors found out a soluble dry matter content of 5.6 °Brix in the variety Delitia right after harvest.

Duma et al. (2017) monitored the soluble dry matter content in varieties Sunstream F1, Sakura F1, Black Cherry F1, Golden Nudget F1, and Rhianna F1 cultivated in Lithuania. The authors detected the highest dry matter content in the variety Golden Nudget F1, represented 7.9 °Brix and the lowest in the variety Sunstream 5.2 °Brix. These values are also comparable with our results.

Majidi et al. (2011) analyzed the dry matter content of the tomatoes grown in the Iranian region and found out the dry matter content within the range of 5.2 – 6.0 °Brix. The authors decided to evaluate the dynamics of changes in the dry matter content during the cold storage as well as the storage with a regulated atmosphere. It was stated that the dry matter content slightly increased during 90 days of storage in conditions of the cold storage during the first 20 days and later it decreased sharply, while in the storage using regulated atmosphere the dry matter content decreased after 40 days of storage

Glucose, fructose, sucrose

Sugars and organic acids are the key components impacting tomato quality and customer preferences. They account for over 60% of the dry matter, and contribute to soluble solid content and also are essential to the flavor intensity **(Goff and Klee, 2006; Bastias et al., 2011; Sauvage et al., 2014; Zhang et al., 2010; Zhang et al., 2016)**.

In fruit, sugars provide sweetness, which is the most important determinant of fruit quality. The relationship between sugar content, measured as the soluble solids content, and fruit yield has been evaluated in a number of horticultural studies **(Ruggieri et al., 2014; Anthon et al., 2011; Kanayama et al., 2005)**.

Generally known, carbohydrates are the main dry matter components of fruits and vegetables. As we learned from our results, the main carbohydrate in the analyzed tomato varieties was fructose, which was present at the amount of 11.10 – 22.27 g.kg^{-1} in fresh tomatoes. Glucose was present in lower quantity and it reached 4.50 – 15.93 g.kg^{-1} in the individual varieties. The lowest content was represented by sucrose, which was analyzed in amounts of 0.07 – 1.73 g.kg^{-1} in fresh tomatoes (Table 1).

According to the average glucose content by comparing the analyzed varieties, they were divided into 6 homogeneous groups. The statistically significant highest (p <0.05) glucose content was found out in the variety Tomanova (15.93 g.kg^{-1}). Higher values were also detected in the varieties Bovita (15.10 g.kg^{-1}) and Pavlína (14.37 g.kg^{-1}). On the other hand, the statistically significant lowest values were recorded in the varieties intended for the direct consumption, such as Niki Zel F1 (4.5 g.kg^{-1}), Ady Zel F1 (5.0 g.kg^{-1}), 987/17 (5.07 g.kg^{-1}), 1018/17 (5.17 g.kg^{-1}) and also in the variety Salus (4.87 g.kg^{-1})

intended for the industrial processing. In the case of fructose, these varieties were also of low content. Both the variety Salus and newly selected variety 1018/17 had statistically significant (p <0.05) the lowest fructose content (homogeneous group a). In the case of varieties intended for the direct consumption, the low content of simple sugars may cause the less attractive taste to the consumer, and in case of the variety Salus, intended for the industrial processing, a lower sugar content may cause a lower product yield during the tomato purée production.

According to the average fructose content, the varieties were divided into 9 homogeneous groups. The statistically significantly highest (p <0.05) fructose content was analyzed in the variety Bovita (22.27 g.kg^{-1}) and high content was also analyzed in the variety Tomanova (20.83 g.kg^{-1}). Both varieties showed not only significantly higher fructose content but also high glucose content.

The biggest homogeneous group regarding glucose content was the group of 15.9 – 17.0 g.kg^{-1}, which included 6 varieties, such as 4 varieties intended for industrial processing particularly variety Denár (15.93 g.kg^{-1}), Mobile (16.10 g.kg^{-1}), Pavlína (16.83 g.kg^{-1}) and Danuša (17.0 g.kg^{-1}) and 2 varieties intended for the direct consumption, such as newly selected variety 1037/17 and Žofka F1 variety, both had a the comparable average fructose content of 16.53 g.kg^{-1}. Based on the statistical results, it cannot be directly stated that the varieties intended for the direct consumption in comparison with the varieties intended for industrial processing were characterized by a higher or lower content of simple carbohydrates.

Based on the results of the Tukey HSD test of multiple comparisons of the average sucrose content, the varieties were only divided into 2 homogeneous groups. As already mentioned, sucrose is not a dominant carbohydrate present in tomatoes. It is represented in the smallest amount and the majority of the monitored varieties showed in the given parameter lower values below 1 g.kg^{-1} and these varieties formed a separate homogeneous group containing up to 15 varieties. The variety Pavlína with an average sucrose content of 0.83 g.kg^{-1} represented the variety that was not statistically significantly different from the group of varieties with very low sucrose content, but nor from the variety Tomanova (1.73 g.kg^{-1}), which had the statistically significant highest sucrose content.

Bastias et al. (2011) reported the fructose content in mature tomatoes at the level of 1.19 g.100g^{-1} FM and glucose content of 0.91 g.100g^{-1} FM. **Beullens et al. (2006)** monitored the sugar content in tomatoes by using high-performance gas chromatography and found out the fructose content in the range of 1.21 – 1.98 g.100g^{-1} FM, glucose content of 1.17 – 2.16 g.100g^{-1} FM and the lowest one was sucrose content in the range of 0.41 – 0.84 g.100g^{-1} FM.

Kelebek et al. (2017) monitored the glucose, fructose and sucrose content of the variety Shasta in tomatoes grown in Turkey. Tomatoes were intended for the industrial processing, and similarly to our research, the authors found out the lowest content of sucrose of 1.75 – 1.81 mg.100g^{-1}. They also detected that the highest content of carbohydrates showed fructose, representing 14.44 – 14.73 mg.100g^{-1}, which was similar to our results. The authors also monitored the changes in carbohydrates that occur during the tomato processing and found out that the content of all monitored carbohydrates increased gradually during the individual processing stages, while the mutual ratios between the individual carbohydrates remained the same.

Ayvaz et al. (2016) monitored glucose and fructose content in 66 tomato varieties that were not specified in detail according to the method of tomato identification. The authors determined the soluble dry matter content in the range of 3.9 to 6.3 °Brix. Glucose content of 2.7 – 18.1 g.dm^{-3} was recorded, as well as a fructose content of 3.8 – 14.5 g.dm^{-3}. Especially in the case of fructose, these values differ from our findings because in our results we found out the fructose content more than 11 g.dm^{-3}.

Wilkerson et al. (2013) analyzed the glucose and fructose content of the tomato varieties intended for processing, but

Table 1 Average values of soluble dry matter content, content of glucose, fructose and sucrose and homogenous groups based on multiple Tukey HSD test results.

Variety	dry matter (°Brix)	glucose (g.kg^{-1})	fructose (g.kg^{-1})	sucrose (g.kg^{-1})
Uno Rosso F1	5.2 b	10.13 ±0.06 cd	13.43 ±0.23 de	0.07 ±0.02 a
Pavlína	5.5 c	14.37 ±0.35 ef	16.83 ±0.56 g	0.83 ±0.05 ab
Mobil	5.0 b	9.90 ±0.20 cd	16.10 ±0.36 g	0.77±0.15 a
Zömök	5.0 b	6.33 ±0.41 b	12.60 ±0.17 cd	0.17 ±0.01 a
Denár	5.0 b	9.93 ±0.21 cd	15.93 ±0.23 g	0.33 ±0.02 a
Bovita	6.5 d	15.10 ±0.10 ef	22.27 ±0.38 i	0.53 ±0.12 a
Salus	5.0 b	4.87 ±0.38 a	11.43 ±0.06 a	0.60 ±0.20 a
Danuša	6.5 d	10.27 ±0.12 d	17.00 ±0.17 g	0.67 ±0.15 a
Niki Zel F1	5.0 b	4.50 ±0.13 a	11.93 ±0.25 abc	0.27 ±0.06 a
Tomanova	7.5 e	15.93 ±0.12 f	20.83 ±0.15 h	1.73 ±0.32 b
Ady Zel F1	5.0 b	5.00 ±0.11 a	12.57 ±0.12 bcd	0.10 ±0.00 a
Ambros F1	5.0 b	9.10 ±0.22 c	14.57 ±0.12 f	0.63 ±0.06 a
Žofka F1	5.0 b	9.10 ±0.36 c	16.53 ±0.06 g	0.33 ±0.03 a
Jerguš F1	5.0 b	6.80 ±0.10 b	14.13 ±0.21 ef	0.17 ±0.01 a
987/17	4.5 a	5.07 ±0.25 a	11.47 ±0.12 ab	0.37 ±0.11 a
1037/17	6.5 d	10.93 ±0.2 e	16.53 ±0.21 g	0.17 ±0.06 a
1018/17	4.5 a	5.17 ±0.40 a	11.10 ±0.10 a	0.20 ±0.10 a

Note: average value in fresh matter; ±standard deviation, different letters at averages represent statistically significant differences among varieties (p <0.05).

they do not specify the name of varieties. Tomatoes were grown in field conditions in the different areas of California. The authors found out the results related to glucose content 10.0 – 21.4 $g.dm^{-3}$ and fructose content 11.0 – 20.6 $g.dm^{-3}$, which are results that are comparable with our measurements.

Pinela et al. (2012) evaluated the content of individual carbohydrates in tomato commercial varieties grown in Portugal. In the study they used the varieties Amarelo, Batateiro, Comprido and Coração and found out that sucrose had the smallest content, almost zero, regarding to the studied carbohydrates and among individual varieties they indicate the content of 0.0 – 0.02 $g.100g^{-1}$. The glucose content ranged from 2.15 to 3.42 $g.100g^{-1}$ in the evaluated varieties. The highest values of the monitored carbohydrates were achieved by fructose, which was present in the samples in the quantity of 2.15 – 3.42 $g.100g^{-1}$. When comparing the varieties, the highest content of carbohydrates was present in the Amarelo variety and the lowest content in the Comprido variety.

Hernández-Suárez et al. (2008) monitored the glucose and fructose content of the varieties Dorothy, Boludo, Thomas, Dominique, and Dunkan grown in Tenerife and claimed that tomatoes had lower glucose content than fructose, although the differences between the varieties were not as significant as in our case. The highest content of glucose and fructose was found out in the variety Dominique, such as 1.16% of glucose and 1.24% of fructose.

CONCLUSION

By evaluating the carbohydrate content we detected that glucose and fructose were the dominant carbohydrates present in the analyzed tomatoes. Their content of glucose ranged of 4.87 – 15.9 $g.kg^{-1}$ and in the case of fructose of 11.10 – 22.27 $g.kg^{-1}$. According to the obtained results sucrose can be considered as a minor tomato carbohydrate. The sucrose content in tomatoes was in the range of 0.07 – 1.73 $g.kg^{-1}$. When comparing the glucose content it was found out that the higher content on average was achieved in the varieties intended for the industrial processing (10.10 $g.kg^{-1}$) than in the varieties for the direct consumption (7.96 $g.kg^{-1}$). In both groups of varieties, there were exceptions for which the statement for the glucose content cannot be applied. Low glucose values were detected in the group of varieties intended for the industrial processing, such as the varieties Salus and Zömök, and on the other hand, significantly higher glucose content was found out in the group of the varieties intended for the direct consumption, especially in the variety Tomanova. When comparing the fructose content, we found a higher average content in the varieties intended for industrial processing (15.70 $g.kg^{-1}$) than in the varieties for the direct consumption (14.40 $g.kg^{-1}$). Significantly higher fructose content was recorded in the varieties Bovita (22.27 $g.kg^{-1}$) and Tomanova (20.83 $g.kg^{-1}$). Only the minimal differences between the varieties regarding the content of minor saccharide sucrose were registered by using the statistical data testing and multiple comparisons of average values of sucrose content by Tukey test. In most varieties, we found out statistically insignificant (p >0.05) differences in sucrose content. The exception was the variety Tomanova (1.73 $g.kg^{-1}$) with the highest sucrose content.

REFERENCES

Anthon, G. E., Le Strangeb, M., Barretta, D. M. 2011. Changes in pH, acids, sugars and other quality parameters during extended vine holding of ripe processing tomatoes. In *Journal Science Food Agriculture*, vol. 91, no. 7, p. 1175-1181. https://doi.org/10.1002/jsfa.4312

Ayvaz, H., Sierra-Cadavid, A., Aykas, D. P., Mulqueeney, B., Sullivan, S., Rodriguez-Saona. L. E. 2016. Monitoring multicomponent quality traits in tomato juice using portable mid-infrared (MIR) spectroscopy and multivariate analysis. *Food Control*, vol. 66, p. 79-86. http://doi.org/10.1016/j.foodcont.2016.01.031

Baldwin, E. A., Goodner, K., Plotto, A. 2008. Interaction of volatiles, sugars, and acids on perception of tomato aroma and flavor descriptors. *Journal of Food Science*, vol. 73, no. 6, p. 294-307. https://doi.org/10.1111/j.1750-3841.2008.00825.x

Baldwin, E. A., Plotto, A., Narciso, J., Bai, J. 2011. Effect of 1-methylcyclopropene on tomato flavor components, shelf life and decay as influenced by harvest maturity and storage temperature. *Journal of the Science of Food and Agriculture*, vol. 91, no. 6, p. 969-980. https://doi.org/10.1002/jsfa.4281

Bastias, A., Lopez-Climent, M., Valcarcel, M, Rosello, S., Gomez-Cadenas, A., Casaretto, J. A. 2011. Modulation of organic acids and sugar content in tomato fruits by an abscisic acid-regulated transcription factor. *Physiologia Plantarum*, vol. 141, no. 3, p. 215-226. https://doi.org/10.1111/j.1399-3054.2010.01435.x

Beullens, K., Kirsanov, D., Irudayaraj, J., Rudnitskaya, A., Legin, A., Nicolaï, B. M., Lammertyn, J. 2006. The electronic tongue and ATR-FTIR for rapid detection of sugars and acids in tomatoes. *Sensors and Actuators B: Chemical*, vol. 116, no. 1-2, p. 107-115. https://doi.org/10.1016/j.snb.2005.11.084

Carrari, F., Baxter, C., Usadel, B., Urbanczyk-Wochniak, E, Zanor, M. I., Nunes-Nesi, A., Nikiforova, V., Centero, D., Ratzka, A., Pauly, M., Sweetlove, L. J., Fernie, A. R. 2006. Integrated analysis of metabolite and transcript levels reveals the metabolic shifts that underlie tomato fruit development and highlight regulatory aspects of metabolic network behavior. *Plant Physiology*, vol. 142, no. 4, p. 1380-1396. https://doi.org/10.1104/pp.106.088534

De Castro Vilas Boas, A. A., Page, D., Giovinazzo, R., Bertin, N., Fanciullino, A. L. 2017. Combined Effects of Irrigation Regime, Genotype, and Harvest Stage Determine Tomato Fruit Quality and Aptitude for Processing into Puree. *Frontiers in Plant Science*, vol. 8, p. 1725. https://doi.org/10.3389/fpls.2017.01725

Domínguez, I., Lafuente, M. T., Hernández-Muñoz, P., Gavara, R. 2016. Influence of modified atmosphere and ethylene levels on quality attributes of fresh tomatoes (*Lycopersicon esculentum* Mill.). *Food Chemistry*, vol. 209, no. 15, p. 211-219. http://doi.org/10.1016/j.foodchem.2016.04.049

Duma, M., Alsina, I., Dubova, L., Erdberga, I. 2017. Quality of tomatoes during storage. *FoodBalt 2017*. University of Agriculture : Latvia. p. 130-133. https://doi.org/10.22616/foodbalt.2017.030

Fulton, T. M., Bucheli, P., Voirol, E., López, J., Pétiard, V., Tanksley, S. D. 2002. Quantitative trait loci (QTL) affecting sugars, organic acids and other biochemical properties possibly contributing to flavor, identified in four advanced backcross populations of tomato. *Euphytica*, vol. 127, no. 2, p. 163-177. https://doi.org/10.1023/A:1020209930031

Goff, S. A., Klee, H. J. 2006. Plant volatile compounds: sensory cues for health and nutritional value? *Science*,vol. 311, p. 815-819. https://doi.org/10.1126/science.1112614

Hernández-Suárez, M. H., Rodríguez, E. R., Romero, C. D. 2008. Analysis of organic acid content in cultivars of tomato harvested in Tenerife. *Europen Food Research and Technology*, vol. 226, no. 3, p. 423-435. https://doi.org/10.1007/s00217-006-0553-0.

Ilahy, R., Siddiqui, M. W., Tlili, I., Piro, G, Lenucci, M. S. - Hdider, Ch. 2016. Functional Quality and Colour Attributes of Two High-Lycopene Tomato Breeding Lines Grown under Greenhouse Conditions. *Turkish Journal of Agriculture - Food Science and Technology*, vol. 4, no. 5, p. 365-373. https://doi.org/10.24925/turjaf.v4i5.365-373.620

Kader, A. A. 2008. Flavor quality of fruits and vegetables. *Journal of the Science of Food and Agriculture*, vol. 88, no. 44, p. 1863-1868. https://doi.org/10.1002/jsfa.3293

Kanayama, Y., Kogawa, M., Yamaguchi, M., Kanahama, K. 2005. Fructose content and the activity of fructose-related enzymes in the fruit of eating-quality peach cultivars and native-type peach cultivars. *Journal of the Japanese Society for Horticultural Science*, vol.7, no 6, p. 431-436. https://doi.org/10.2503/jjshs.74.431

Kelebek, H., Selli, S., Kadiroglu, P., Kola, O., Kesen, S., Uçar, B., Çetiner, B. 2017. Bioactive compounds and antioxidant potential in tomato pastes as affected by hot and cold break process. *Food Chemistry*, vol. 220, p. 31-41. http://doi.org/10.1016/j.foodchem.2016.09.190

Majidi, H., Minaei, S., Almasi, M., Mostofi, Y. 2011. Total Soluble Solids, Titratable Acidity and Repining Index of Tomato Various Storage Conditions. *Australian Journal of Basic and Applied Sciences*, vol. 5, no. 12, p. 1723-1726.

Osvald, J., Petrovic, N., Demsar, J. 2001. Sugar and organic acid content of tomato fruits (*Lycopersicon lycopersicum* Mill.) grown on aeroponics at different plant density. *Acta Alimentaria*, vol. 30, p. 53-61. https://doi.org/10.1556/aalim.30.2001.1.6

Patané, C., Cosentino, S. L. 2010. Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. *Agricultural Water Management*, vol. 97, no. 1, p. 131-138. https://doi.org/10.1016/j.agwat.2009.08.021

Patané, C., Pellegrino, A., Saita, A., Siracusa, L., Ruberto, G., Barbagallo, R. 2017. Mediterranean long storage tomato as a source of novel products for the agrifood industry: Nutritional and technological traits. *LWT - Food Science and Technology*, vol. 85, p. 445-448. http://doi.org/10.1016/j.lwt.2016.12.011

Pinela, J., Barros, L., Carvalho, A. M., Ferreira, I. C. F. R. 2012. Nutritional composition and antioxidant activity of four tomato (*Lycopersicon esculentum* L.) farmer' varieties in Northeastern Portugal homegardens. *Food and Chemical Toxicology*, vol. 50, no. 3-4, p. 829-834. https://doi.org/10.1016/j.fct.2011.11.045

Ponce-Valadez, M., Escalona-Buendía, H. B., Villa-Hernández, J. M., Díaz De León-Sánchez, F., Rivera-Cabrera, F., Alia-Tejacal, I., Pérez-Flores, L. J. 2016. Effect of refrigerated storage on tomato (*Solanum lycopersicum*) fruit flavor: A biochemical and sensory analysis. *Postharvest Biology and Technology*, vol. 111, p. 6-14. http://doi.org/10.1016/j.postharvbio.2015.07.010

Radzevičius, A., Viškelis, J., Karklelienė, R., Uškevičienė, D., Viškelis, P. 2016. Determination of tomato quality attributes using near infrared spectroscopy and reference analysis. *Zemdirbyste-Agriculture*, vol. 103, no. 1, p. 91-98. https://doi.org/10.13080/z-a.2016.103.012

Ruggieri, V., Francese, G., Sacco, A., D'Alessandro, A., Rigano, M. M., Parisi, M., Milone, M., Cardi, T., Mennella, G., Barone, A. 2014. An association mapping approach to identify favourable alleles for tomato fruit quality breeding. *BMC Plant Biology*, no 14, p. 337. https://doi.org/10.1186/s12870-014-0337-9

Sanz, M. L., Martínez-Castro, I. 2007. Recent developments in sample preparation for chromatographic analysis of carbohydrates. *Journal of Chromatography A*, vol. 1153, no. 1-2, p. 74-89. https://doi.org/10.1016/j.chroma.2007.01.028

Schauer, N., Zamir, D., Fernie, A. R. 2005. Metabolic profiling of leaves and fruit of wild species tomato: a survey of the *Solanum Lycopersicum* Complex. *Journal of Experimental Botany*, vol. 56, no. 410, p. 297-307. https://doi.org/10.1093/jxb/eri057

Sauvage, C., Segura, V., Bauchet, G., Stevens, R., Do, P. T., Nikoloski, Z, Fernie, A., Cause, M. 2014. Genome-wide association in tomato reveals 44 candidate loci for fruit metabolic traits. *Plant Physiology*, vol. 165, p. 1120-1132. https://doi.org/10.1104/pp.114.241521

Sun, Y. D., Liang, Y., Wu, J. M., Li, Y. Z., Cui, X., Qin, L. 2012. Dynamic QTL analysis for fruit lycopene content and total soluble solid content in a Solanum lycopersicum × S. pimpinellifolium cross. *Genetics and Molecular Research*, vol. 11, no. 4, p. 3696-3710 http://doi.org/10.4238/2012

Thakur, B. R., Singh, R. K., Nelson, P. E. 1996. Quality attributes of processed tomato products: A review. *Food Reviews International*, vol. 12, no. 3, p. 375-401. https://doi.org/10.1080/87559129609541085

Tijskens, L. M. M., Schouten, R. E. 2009. Modeling quality attributes and quality properties. In Florkowski, W., Shewfelt, R., Prussia, S., Banks, N., Prussia, S., Shewfelt, R., Brueckner, B. *Postharvest Handling: A Systems Approach*. 2nd ed. Cambridge, USA : Academic Press, 640 p. ISBN 978-0-12-374112-7.

Wang, L., Baldwin, E. A., Bai, J. 2016. Recent Advance in Aromatic Volatile Research in Tomato Fruit: The Metabolisms and Regulations. *Food and Bioprocess Technology*, vol. 9, no. 2, p. 203-216. https://doi.org/10.1007/s11947-015-1638-1.

Wilkerson, E. D., Anthon, G. E., Barrett, D. M., Sayajon, G. F. G., Santos, A. M., Rodriguez-Saona, L. E. 2013. Rapid assessment of quality parameters in processing tomatoes using hand-held and benchtop infrared spectrometers and multivariate analysis. *Journal of Agricultural and Food Chemistry*, vol. 61, no. 9, p. 2088-2095. https://doi.org/10.1021/jf304968f

Zhang, Y., Li, P., Cheng, L. 2010. Developmental changes of carbohydrates, organic acids, amino acids, and phenolic compounds in 'Honeycrisp' apple flesh. *Food Chemistry*, vol. 123, p. 1013-1018. https://doi.org/10.1016/j.foodchem.2010.05.053

Zhang, J., Zhao, J., Liang, Y., Zou, Z. 2016. Genome-wide association-mapping for fruit quality traits in tomato. *Euphytica*, vol. 207, p. 439–451. https://doi.org/10.1007/s10681-015-1567-0

Zhao, J., Xu, Y., Ding, Q., Huang, X., Zhang, Y., Zou, Z., Li, M., Cui, L., Zhang, J. 2016. Association mapping of main tomato fruit sugars and organic acids. *Frontiers in Plant Science*, vol. 7, p. 1286. https://doi.org/10.3389/fpls.2016.01286

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