ISSN 1392 – 1231. CHEMINĖ TECHNOLOGIJA. 2015. Nr. 1 (66)

Chemical composition of tomatoes depending on the stage of ripening

M. Duma

Department of Chemistry, Faculty of Food Technology, Latvia University of Agriculture, Liela Str. 2, Jelgava Palace, LV-3001 Jelgava, Latvia
E-mail: Mara.Duma@llu.lv

I. Alsina, L. Dubova, I. Erdberga

Institute of Soil and Plant Sciences, Faculty of Agriculture, Latvia University of Agriculture, Liela Str. 2, LV-3001 Jelgava, Latvia

crossref http://dx.doi.org/10.5755/j01.ct.66.1.12053

Received 20 April 2015; Accepted 12 September 2015

Tomatoes are well-known vegetables, grown and eaten around the world due to their nutritional benefits. The aim of this research was to determine the chemical composition (dry matter, soluble solids, titritable acidity, vitamin C, lycopene), the taste index and maturity in three cherry tomato varieties (Sakura, Sunstream, Mathew) grown and collected from greenhouse at different stages of ripening. The output of the analyses showed that there were significant differences in the mean values among the analysed parameters according to the stage of ripening and variety. During ripening, the content of soluble solids increases on average two times in all analyzed varieties; the highest content of vitamin C and lycopene was determined in tomatoes of Sunstream variety in red stage. The highest total acidity expressed as g of citric acid 100 g^{-1} was observed in pink stage (variety Sakura) or a breaker stage (varieties Sunstream and Mathew). The taste index of the variety Sakura was higher at all analyzed ripening stages in comparison with other varieties. This shows that ripening stages have a significant effect on tomato biochemical composition along with their variety.

Key words: tomatoes, ripening, chemical composition, taste index, maturity

Introduction

Tomatoes (*Lycoperssicon esculentum*) are very valuable vegetables due to their nutritional benefits. Tomato fruit quality has been assessed by the content of different chemical compounds such as citric, ascorbic and other organic acids, sugars, minerals, antioxidants and characterized with dry matter, the Brix degree as well as maturity and the taste index [1].

The most important antioxidants in tomatoes are carotenoids, especially lycopene. The content of these compounds and their antioxidant activity vary significantly depending on ripening, maturity, variety and environmental conditions [2].

Tomato fruit colour is one of the important indices of tomato maturity and quality. It is known that the colour of tomato fruits changes during ripening. The green colour of unripe tomato fruits is due to the presence of chlorophyll, but during maturation the degradation of this pigment and synthesis of yellow pigments such as *β*-carotene and xanthophylls happen. The reddish colour occurs due to the accumulation of lycopene. The colour of tomato varieties differs from yellow to orange red depending on the lycopene / *β*-carotene ratio [3]. Researchers [4] reported that tomatoes described as full flavoured were characterized by a low level of titratable acidity, a high content of total sugars and soluble solids.

Tomatoes are usually consumed at full red (or yellow) colour, when they have the highest quality. But taking into account the growing conditions, the variety of tomatoes and other factors, tomato fruits are often harvested at the mature green stage to minimize the damage during the post-harvest period and then may later ripen spontaneously or after treatment with ethylene [5]. The fruits which are harvested green, at the beginning of ripening, often are kept in different conditions for rapid colour development and ripening. This process characterizes with important losses in quality, due to the losses of vitamins, minerals, antioxidants. There are several studies about changes of tomato chemical composition during storage [3, 5–7], but there are less information about tomato chemical composition at different stages of ripening.

The aim of this research was to determine and compare the physico-chemical compounds – dry matter, soluble solids, titratable acidity, vitamin C, lycopene, as well as the taste index and maturity in the three cherry tomato varieties (Sakura, Sunstream, Mathew) collected from a greenhouse at different stages of ripening.

Materials and methods

Investigations were carried out at the Latvia University of Agriculture, Institute of Soil and Plant Sciences.

Three varieties of cherry tomato plants Sunstream, Sakura and Mathew were grown in a greenhouse from 1st of May till 21st of August 2014. The fruits of varieties Sakura and Sunstream are red, but Mathew fruits are orange at the full ripening stage.

Tomato sampling

For analysis, a bunch of tomato with fruits at different stages of ripening was cut off. The samples selected for experiments were classified into four stages of ripening: green – fruit surface is completely green; breakers – a definite break in colour from green to tannish-yellow; pink – 40 to 70 % of the surface shows a pink or red (yellow) colour; red – more than 80 % of the surface shows a red (orange) colour. Five tomatoes at each stage of maturation were randomly selected for analysis, weighed, hand-rinsed with pure water, shaken to remove water, blotted with a paper towel, then were mixed and homogenized. From this puree, samples were taken on triplicate to measure acidity, the Brix degree, titratable acidity, the content of vitamin C and lycopene.

Chemicals and spectral measurements

All the reagents used were of the analytical grade from Sigma Aldrich, Germany. A spectrophotometer UV-1800 (Shimadzu Corporation, Japan) was used for the absorbance measurements.

Analytical methods

The dry matter content was determined by weighing samples before and after drying at 80 °C for 48 h in a ventilated thermostat.

The soluble solid content was determined using an A. KRÜSS Optronic Digital Handheld Refractometer Dr301-95set at t = 20 °C.

Carotenoids were extracted using tetrahydrofuran (THF). For extraction, a representative portion of a sample (0.5 ± 0.001 g) was accurately weighted in a glass test tube. Then 5 ml of a solvent was added to it, and the test tubes were held for 15 min with occasional shaking at room temperature and finally centrifuged. The carotenoid content was analyzed spectrophotometrically by absorption measurements at 350 to 700 nm and calculated in accordance with Nagata and Yamashita [8].

For determination of titratable acidity, 5 ± 0.001 g of tomato puree was quantitatively transferred into 100 ml tubes with adding 40 ml of pure water thoroughly mixing. After 20 minutes, the solution was filtered through a filter paper No. 89th. For determination, 10 ml of the filtrate was titrated with 0.1 M NaOH solution and expressed as g 100 g^{-1} of citric acid.

The content of vitamin C was determined titrimetrically using 2.6-dichlorphenolindophenol (AOAC, 1990). For determination, 2 ± 0.001 g of tomato puree was quantitatively transferred into 100 ml tubes with adding 50 ml a 1 % HCl and 5 % HPO_3 mixture (1 : 1 v/v), and mixed thoroughly. After 30 minutes the solution was filtered through a filter paper No. 89th. For determination, 10 ml (V_a) of the filtrate was titrated with 0.0005 molar solution of 2.6-dichlorphenolindophenol (V_{titr}).

The content of vitamin C was calculating according to the equation (1):

$$\text{Vitamin C (mg 100 g}^{-1}\text{)} = \frac{V_{titr} \cdot 0.044 \cdot V_{total} \cdot 100}{V_a \cdot weight} \quad (1).$$

A taste index and maturity were calculated using the equation proposed by [9, 10].

The results were analyzed using ANOVA at the significance level of $p = 0.05$. All values are averages of triplicates assay ± standard errors.

Results and discussion

Tomato fruit quality is closely related to the tomato ripening stage. The results obtained in the chemical parameters analyzed in all the samples characterizing different varieties and stages of ripening are shown in Table 1.

Table 1. The physico-chemical parameters of three tomato varieties according to the stage of ripening

Variety	Stage of ripening	Dry matter, mg 100 g^{-1}	Solubles solids (°Brix)	Titratable acidity*	Taste index	Maturity
Sakura	Green	6.75±0.28	4.62±0.13	0.686±0.034	1.02±0.09	6.7±1.9
	Breakers	7.10±0.51	4.64±0.31	0.687±0.041	1.05±0.08	6.8±1.5
	Pink	7.65±0.31	5.26±0.15	0.704±0.003	1.08±0.10	7.5±1.4
	Red	8.21±0.37	6.58±0.22	0.625±0.088	1.15±0.09	10.5±1.4
Sunstream	Green	6.38±0.33	3.62±0.04	0.493±0.004	0.86±0.08	7.3±1.2
	Breakers	6.59±0.18	4.3±0.22	0.545±0.016	0.94±0.09	7.9±1.2
	Pink	7.28±0.35	5.26±0.23	0.490±0.040	1.03±0.07	10.7±1.1
	Red	8.15±0.21	6.28±0.19	0.500±0.014	1.13±0.08	12.6±1.3
Mathew	Green	6.84±0.18	3.86±0.16	0.691±0.004	0.97±0.09	5.6±0.8
	Breakers	6.96±0.24	4.42±0.08	0.741±0.047	1.04±0.09	5.9±0.9
	Pink	7.18±0.29	5.02±0.08	0.671±0.019	1.05±0.08	7.5±1.1
	Red	8.16±0.18	6.22±0.26	0.617±0.063	1.12±0.10	10.1±1.2

*Titratable acidity expressed as g 100 g^{-1} of citric acid

The stage of ripening has a statistically significant influence ($p < 0.05$) on the mean values for all analyzed parameters. There were no statistical differences ($p > 0.05$) among varieties for dry matter comparing this parameter at different stages of ripening. The content of dry matter at the green stage in analyzed tomatoes is on average 6.66 mg 100 g^{-1} and it increases during ripening, reaching 8.17 mg 100 g^{-1}. These mean values were inside the usual range for tomatoes reported in literature [11, 12]. Comparing changes of dry matter at different stages of maturity, the smallest increases were observed comparing green and breakers stages: 1.7 % (variety Mathew), 3.1 % (variety Sunstream) or 4.9 % (variety Sakaura), but the highest increase was observed for varieties Sunstream and Mathew – about 12 %, comparing dry matter content in pink and red stages.

Total soluble solids is one of the most important quality factor for most fruits, and within the range of 4.8–8.8 the Brix degree indicates the highest quality of tomato. It is known that during maturation and ripening of tomato fruits the content of soluble solids changes. Moreover, this content increases from the mature green stage to the red stage [6]. The results of research showed that the obtained soluble solids content was within the levels reported for tomatoes at different stages of ripening [1, 3, 6, 12, 13].

When comparing the mean values among the varieties, it can be observed that the Sunstream variety had the highest changes of soluble solids (3.62 to 6.28 of the Brix degree). In contrast another variety of red tomato, Sakura, showed the lowest mean values. Analyzing the dynamics of the soluble solids content, the highest increase was observed comparing pink and red (orange) stages for all analyzed varieties.

Acidity tends to decrease with the maturity of the fruits [14]. It was found that no significant differences ($p > 0.05$) among varieties and stage of maturity were observed for the mean values of titratable acidity expressed as g 100 g^{-1} of citric acid. A little increase was recognized at the breakers stage (varieties Sunstream and Mathew) or at the pink stage (variety Sakura). The obtained results showed that the mean values of acidity were similar or slightly higher than the data published by other authors [1, 12, 13], but differed from data presented in [6].

The taste index and maturity are calculated using the values of the Brix degree and total acidity for characterizing the quality and taste of tomatoes. When using these data, the mean values of the taste index in all the analyzed tomato varieties at all stages of ripening were higher than 0.85. Maturity is a better predictor of the acid flavour impact than the Brix degree or acidity alone [15]. Due to the increase of soluble solid content during ripening, the maturity also increases and reaches the highest value at the red stage (Table 1). It has been noted that the variety of tomato and the stage of ripening have a significant influence on the value of maturity. The variety Mathew had the mean value of maturity (5.6 ± 0.8) lower than those values determined for the Sakura (6.7 ± 1.9) and Sunstream (7.3 ± 1.2) varieties in the beginning of ripening (green stage). Comparing maturity at the red stage, it was increased from 1.57 times (variety Sakura) to 1.8 times (variety Mathew).

Vitamin C (ascorbic acid) is one of the major natural antioxidants. Its biological significance is based on the ability to participate in different enzymatic, hydroxylation oxidation – reduction reactions and processes. The content of vitamin C in vegetables may vary depending on the environmental and stress factors such as light intensity, temperature, humidity conditions, air pollution, etc. [16].

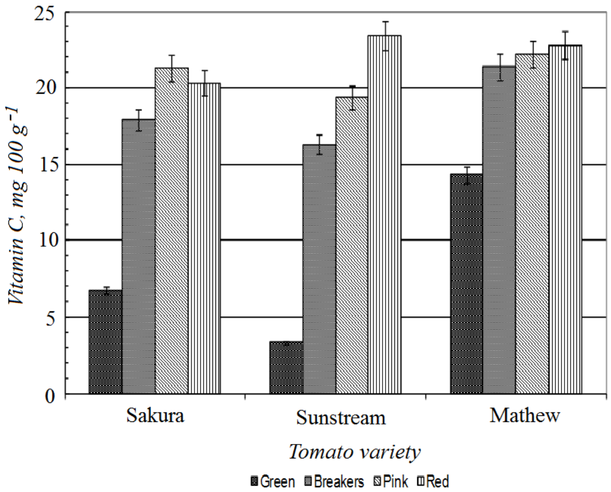

Fig. 1. Content of vitamin C in tomatoes depending on the stage of ripening

The mean values for ascorbic acid observed in this research showed that the stage of maturation had a significant influence. The variety Mathew in the green stage of ripening presented the highest content of vitamin C (14.3 ± 1.1) with significant differences from the concentrations of the Sunstream (3.3 ± 0.5) and the Sakura (6.73 ± 0.35) varieties. The obtained results showed that the content of vitamin C was highest at the pink stage independently of variety – on average 20.96 mg 100 g^{-1}, but the variety Sunstream showed the largest increase in vitamin C content comparing green and breakers stages (from 3.3 to 16.3 mg 100 g^{-1}). The values found in this study were similar to or slightly higher than the ones reported by other researchers [13, 15, 17, 18].

The colour of tomatoes is an important quality parameter for consumer. The synthesis of pigments in tomatoes is related to the ripening, and the red color of tomatoes results from the accumulation of lycopene [19]. Therefore, the content of lycopene has been suggested as a good indicator of the level of ripening. Lycopene is considered to be the predominant carotenoid of tomato fruit (80–90 %), followed by β-carotene (5–10 %) [20].

Data in Fig. 2 present the content of lycopene in the analyzed tomato varieties Sakura and Sunstream. The content of lycopene in the Mathew tomato variety was within the range of 0.007 to 0.98 mg 100 g^{-1} due to the yellow or orange colour of tomato fruits.

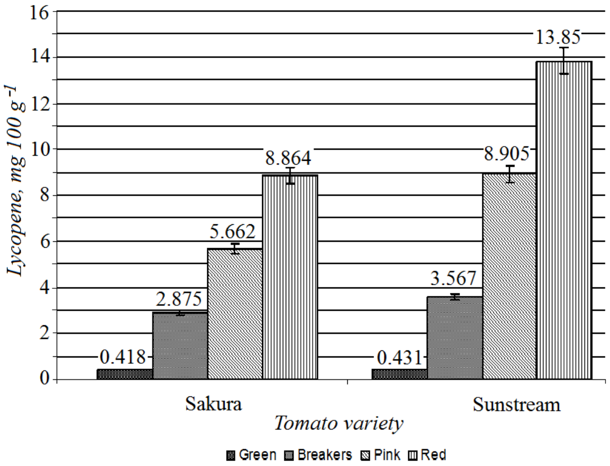

Fig. 2. Content of lycopene in tomatoes depending on the stage of ripening

The obtained results has showed that the content of lycopene in all analyzed samples significantly increases during ripening. Comparing both red tomato varieties, it could be see that the content of lycopene was similar in the green stage (on average 0.42 mg 100 g^{-1}), but significantly differed in the red stage. The highest concentration of lycopene (13.85 ± 0.12 mg 100 g^{-1}) was determined in the fully ripened Sunstream variety tomatoes. The lycopene content can range from 4.3 to 116.7 mg kg^{-1} on a fresh weight basis, with cherry tomato types having the highest lycopene content [21]. The obtained experimental results were similar to results reported in [22], but were lower than reported in [21].

Conclusions

The stage of ripening has the statistically significant influence ($p < 0.05$) on the mean values for all analyzed parameters. During ripening, the content of soluble solids increases on average two times in all analyzed varieties. The highest content of vitamin C and lycopene was determined in tomatoes of the variety Sunstream in the red stage. The highest total acidity expressed as g of citric acid 100 g^{-1} was observed in the pink (variety Sakura) or the breaker stage (varieties Sunstream and Mathew). The taste index of the variety Sakura was higher at all analyzed ripening stages in comparison with other varieties. Comparing maturity at green and red stages, it was increased from 1.57 times (variety Sakura) to 1.8 times (variety Mathew). The maturity of all analyzed tomato varieties at the end of ripening was more than 10.

Acknowledgements

This work was supported by the Latvian Council of Science, project Nr.519/2012.

References

1. **Thybo A. K., Edelenbos M., Christensen L. P., Sorensen J. N., Thorup-Kristensen K.** Effect of organic growing systems on sensory quality and chemical composition of tomatoes // LWT - Food Science and Technology. 2006. Vol. 39. N 8. P. 835–843. http://dx.doi.org/10.1016/j.lwt.2005.09.010
2. **Brandt S., Pek Z., Barna E.** Lycopene content and colour of ripening tomatoes as affected by environmental conditions // Journal of the Science of Food and Agriculture. 2006. Vol. 86. N 4. P. 568–572. http://dx.doi.org/10.1002/jsfa.2390
3. **De Sousa F. A., Neves A. N., de Queiroz M. E. L. R., Heleno F. F., Teofilo R. F., de Pinho G. P.** Influence of ripening stages of tomatoes in the analysis of pesticides by gas chromatography // Journal of the Brazilian Chemical Society. 2014. Vol. 25. N 8. P. 1431–1438. http://dx.doi.org/10.5935/0103-5053.20140125
4. **Tando K. S., Baldwin E. A., Scott J. W., Shewfelt R. L.** Linking sensory descriptors to volatile and nonvolatile components of fresh tomato flavor // Journal of Food Science. 2003. Vol. 68. N 7. P. 2366–2371. http://dx.doi.org/10.1111/j.1365-2621.2003.tb05774.x
5. **Wills R. B. H., Ku V. V. V.** Use of 1-MCP to extend the time to ripen of green tomatoes and postharvest life of ripe tomatoes // Postharvest Biology and Technology. 2002. Vol. 26. N 1. P. 85–90. http://dx.doi.org/10.1016/S0925-5214(01)00201-0
6. **Moneruzzaman K. M., Hossain A. B. M. S., Sani W., Saifuddin M.** Effect of stages of maturity and ripening conditions on the biochemical characteristics of tomato // American Journal of Biochemistry and Biotechnology. 2008. Vol. 4. N 4. P. 329–335. http://dx.doi.org/10.3844/ajbbsp.2008.329.335
7. **Maul E., Sargent S. A., Sims C. A., Baldwin E. A., Balaban M. O., Huber D. J.** Tomato flavor and aroma quality as affected by storage temperature // Journal of Food Science. 2000. Vol. 85. N 7. P. 1228–1237. http://dx.doi.org/10.1111/j.1365-2621.2000.tb10270.x
8. **Nagata M., Yamashita I.** Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit // J. Japan Soc Food Sci. Technol (Nippon Shokuhin Kogyo Gakkaishi). 1992. Vol. 39. N 10. P. 925–928. http://dx.doi.org/10.3136/nskkk1962.39.925
9. **Narvez B., Letard M., Graselly D., Jost M.** Les criteres de qualite de la tomate // Infos-Ctifl. 1999. Vol. 155. P. 41–47.
10. **Nielsen S.** Food analysis (3rd ed.). New-York, Kluwer Academic/Plenum Publishers, 2003. 534 p.
11. **Guil-Guerrero J. L., Rebolloso-Fuentes M. M.** Nutrient composition and antioxidant activity of eight tomato (*Lycopersicon esculentum*) varieties // Journal of Food Composition and Analysis. 2009. Vol. 22. N 2. P. 123–129. http://dx.doi.org/10.1016/j.jfca.2008.10.012
12. **Suarez H. M., Rodriguez R. E. M., Romero D. C.** Chemical composition of tomato (*Lycopersicon esculentum*) from Tenerife, the Canary Islands // Food Chemistry. 2008. Vol. 106. N 3. P. 1046–1056. http://dx.doi.org/10.1016/j.foodchem.2007.07.025
13. **Oliveira A. B., Moura C. F. H., Gomes-Filho E., Marco C. A., Urban L., Miranda M. R. A.** The impact of organic farming on quality of tomatoes is associated to increased oxidative stress during fruit development // PLoS ONE. 2013. Vol. 8. N 2. e56354. http://dx.doi.org/10.1371/journal.pone.0056354
14. **Raffo A., Leonardi C., Fogliano V., Ambrosino P., Salucci M., Gennaro L.** Nutritional value of cherry tomatoes (*Lycopersicon esculentum* cv. Naomi F1) harvested at different ripening stages // Journal of Agriculture and Food Chemistry. 2002. Vol. 50. N 22. P. 6550–6556. http://dx.doi.org/10.1021/jf020315t

15. **Suarez H. M., Rodriguez R.E., Romero D. C.** Analysis of organic acid content in cultivars of tomato harvested in Tenerife // European Food Research and Technology. 2008. Vol. 226. N 3. P. 423–435. http://dx.doi.org/10.1007/s00217-006-0553-0
16. **Singh D. P., Beloy J., Mclnerney J. K., Day L.** Impact of boron, calcium and genetic factors on vitamin C, carotenoids, phenolic acids, anthocyanins and antioxidant capacity of carrots (*Daucus carota*) // Food Chemistry. 2012. Vol. 132. N 3. P. 1161–1170. http://dx.doi.org/10.1016/j.foodchem.2011.11.045
17. **Ilahy R., Hider C., Lenucci M. S, Tlili I., Dalessandro G.** Phytochemicalcomposition and antioxidant activity of high-lycopene tomato (*Solanum lycopersicum* L.) cultivars grown in Southern Italy // Scientia Horticulturae. 2011. Vol. 127. N 3. P. 255–261. http://dx.doi.org/10.1016/j.scienta.2010.10.001
18. **Kotkov Z., Lachman J., Hejtmnkov A., Hejtmnkov K.** Determination of antioxidant activity and antioxidant content in tomato varieties and evaluation of mutual interactions between antioxidants // LWT - Journal of Food Science and Technology. 2011. Vol. 44. N 8. P. 1703–1710. http://dx.doi.org/10.1016/j.lwt.2011.03.015
19. **Helyes L., Pék Z.** Tomato fruit quality and content depend on stage of maturity // HortSciece. 2006. Vol. 41. N 6. P. 1400–1401.
20. **Lenucci M. S., Cadinu D., Taurino M., Piro G., Dalessandro G**. Antioxidant composition in cherry and high-pigment tomato cultivars // Journal of the Agriculture and Food Chemistry. 2006. Vol. 54. N 7. P. 2606–2613. http://dx.doi.org/10.1021/jf052920c
21. **Kuti J. O., Konuru H. B.** Effects of genotype and cultivation environment olycopene content in red-ripe tomatoes // Journal of the Science of Food and Agriculture. 2005. Vol. 85. N 12. P. 2021–2026. http://dx.doi.org/10.1002/jsfa.2205
22. **Radzevičius A., Karkleliene R., Viškelis P., Bobinas C., Bobinaite R., Sakalauskiene S.** Tomato (*Lycopersicon esculentum* Mill.) fruit quality and physiological parameters at different ripening stages of Lithuanian cultivars // Agronomy Research. 2009. Vol. 7. N 2. P. 712–718.

M. Duma, I. Alsina, L. Dubova, I. Erdberga

POMIDORŲ CHEMINĖ SUDĖTIS ATSIŽVELGIANT Į SUNOKIMO FAZĘ

Santrauka

Pomidorai dėl savo vaistinės vertės yra gerai žinomos daržovės. Jos auginamos ir vartojamos daugelyje pasaulio šalių. Šio tyrimo tikslas – nustatyti trijų rūšių pomidorų (‘Sakura’, ‘Sunstream’, ‘Mathew’), užaugintų šiltnamiuose ir surinktų skirtingomis sunokimo fazėmis, cheminę sudėtį (sausąsias medžiagas, tirpiąsias nuosėdas, titruojamąjį rūgštingumą, vitaminą C, likopeną), skonio indeksą ir subrendimą. Tyrimų rezultatai parodė, kad buvo reikšmingas skirtumas tarp analizuojamų parametrų rezultatų atsižvelgiant į sunokimo fazę ir rūšį. Visose tirtų pomidorų rūšių tirpiųjų nuosėdų kiekis brendimo proceso metu padidėjo vidutiniškai du kartus. Didžiausias vitamino C ir likopeno kiekis buvo nustatytas pomidoruose ‘Sunstream’ raudonumo (*red*) fazėje. Didžiausias bendras rūgštingumas, išreikštas gramais 100 g citrinos rūgšties, buvo nustatytas rausvumo (*pink*) fazėje (‘Sakura’) ir pereinamojoje (*breaker*) fazėje (‘Sunstream’ ir ‘Mathew’). ‘Sakura’ rūšies pomidorų skonio indeksas buvo didžiausias visose analizuojamosiose nokimo fazėse, palyginti su kitomis rūšimis. Buvo patvirtinta, kad sunokimo fazė, nepaisant pomidoro rūšies, turi reikšmingą poveikį pomidoro biocheminei sudėčiai.