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CAROTENOIDS AND LYCOPENE CONTENT IN FRESH AND DRIED TOMATO FRUITS AND TOMATO JUICE

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Abstract

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Important component of the tomato are carotenoid dyes, especially lycopene. The importance of lycopene in the diet of people in recent years has grown mainly for its pharmacological effects due to its ability to reduce the risk of carcinoma diseases and prevention of cardiovascular diseases. The aim of this work was to analyze the content of total carotenoids and lycopene in 8 varieties of tomato and to monitor dynamic changes after their different treatments (heating, drying). The experiment included following tomato varieties: Bambino F1, Darina F1, Diana F1, Denár, Milica F1, Orange F1, Paulína F1, Šejk F1.
We found that processing of tomato fruits into juices and dried slices positively affected the presence of carotenoids and lycopene. Processing leads to an increase in the content of carotenoids that can be attributed to better availability of these components in the human body.

tomato, carotenoids, lycopene, processing, retention

It is well known that a healthy diet is an important element in the prevention of chronic diseases, to improve energy balance and body weight. Many studies have shown a strong correlation dependence between consumption of tomatoes and their products and by reducing the risk in developing of certain types of cancer, neurodegenerative diseases, degenerative diseases, cardiovascular disease and age-related macular degeneration (Giovannucci, 2002; Giovannucci *et al*., 2002; Khachik *et al*., 2002; Muller *et al*., 2002; Sesso *et al*., 2003, 2004; Stahl and Sies, 2005).

The protective effect is attributed mainly to provitamin A and other carotenoids. Carotenoids are the main group of precursors of essential vitamins and antioxidants (Mayne, 1996).

Tomatoes are considered as a major source of carotenoids in the human diet. From a total of about 40 carotenoids present in the human diet in human blood is only 25 carotenoids which are present due to their selective intake of the digestive tract. Of these, the majority of carotenoids are present just in fresh and processed tomatoes. The most important carotenoids for humans include lycopene, lutein, zeaxanthin and β-cryptoxanthin (Shi and Maguer, 2000).

Boček *et al*. (2008) explored the effect of dried organic and organomineral fertilizers on the yield and quality of the bush processing tomatoes variety Proton. Total solids, carotenoids, ascorbic acid and nitrates were analysed in fruits. Fertilizers did not significantly influence total yield and marketable yield. There was not found significant effect of fertilizers on carotenoids.

Lycopene is a lipophilic carotenoid pigment present in tomatoes and other red fruits and vegetables. Higher amounts of lycopene are found in fruits such as of watermelon, guava and pink grapefruit (Shi *et al*., 2002).

Lycopene is considered to be the most effective natural antioxidant. It is reported that it is twice more effective than β-carotene and ten times more effective than α-tocopherol (Di Mascio *et al*., 1989). Shelf life of foods is dependent on many factors,

internal as pH, water activity, nutrient content, occurrence of antimicrobial agents, redox potential, properties of biological structures etc. (Pavelková and Flimelová, 2012). Lycopene is used in the food and pharmaceutical industries. Commercially available lycopene is of natural origin or is produced by chemical synthesis. Natural lycopene produced e.g. as an extract from tomato is nutritionally advantageous to humans. The presence of other phytochemicals, such as β-carotene, phytoene, phytofluene, improves utilization of lycopene and carotenoids (Shixian *et al*., 2005).

In the tomatoes predominant is *all-trans* lycopene form, which is thermodynamically the most stable. It is isomerized by influence of heat, light, and chemical agents (Wang and Chen, 2006).

During processing or storage of tomatoes lycopene may change from trans to cis isomer. In the different types of tomato products, *all-trans* isomer is contained in the range of 36 to 96% of the total lycopene content. 5-cis, 9-cis and 15-cis isomers are present in the products from tomatoes which were analyzed by NMR spectroscopy (Shi and Mauger, 2000).

The aim of this work was to analyze the content of carotenoids and lycopene content in fresh tomato fruits and in various tomato products (juices, dried tomato products…) and to assess the dynamics of changes in the content of carotenoids and lycopene in thermally processed tomato products.

MATERIAL AND METHODS

The field experiment was established in the Botanical Garden of the Slovak University of Agriculture in Nitra in 2011. Based on the climatic conditions in the area of interest is very warm climate zone, subarea dry with mild winters with longer sunshine. The soil is moderately heavy, with medium-sized content of humus. The experiment included following tomato varieties: Bambino F1, Milica F1, (indeterminate tomato varieties) and Darina F1, Diana F1, Denár, Milica F1, Orange F1, Paulína F1, Šejk F1 (determinate tomato varieties).

Tomato juice was made from the fruits of selected varieties at full technological maturity. The fruits were sorted, washed, crushed, pre-heated and strained. Juice was heated up 95 °C for 3 minutes. The hot fluid was filled in containers and hot stabilized. Prepared tomato juice was analyzed after 7 days.

Drying of tomato fruits was carried out in a laboratory oven, WTC Binder. Fruits were sorted, washed, sliced into 5 mm thick, deposited on the sieve dryer and dried at 45 °C in three eight-hour intervals, with a break of 16 hours.

Methods

The total contents of carotenoids and lycopene were investigated spectrophotometrically at UV-VIS Jenway device according to the methodology given in the Slovak Technical Standard (STN 12136). Measurement of carotenoids in fruits of fresh tomato, in tomato juice and in dried tomato fruits was performed at a wavelength of 445 nm. Determination of lycopene was determined at a wavelength of 472 nm.

Dry matter content of fresh fruits and their processed products was performed gravimetrically. Samples were dried to constant weight at 105 °C. All analyzes were performed in triplicate.

Statistical processing

The results were processed by the Statistica system. Effect of variety, respectively form of the tomato processing on the carotenoid and lycopene content was monitored by one-way analysis of variance and the differences among tomato varieties and their processed forms have been tested by Fisher test.

RESULTS AND DISCUSSION

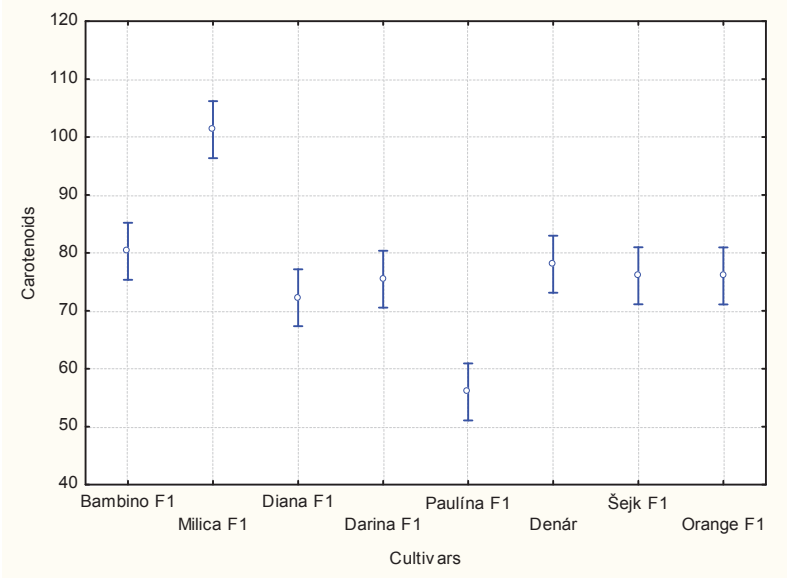
Carotenoid content in fresh fruits of selected varieties ranged from 2.63 to 6.55 mg.100 g^{-1}. The highest content of carotenoids was observed at variety Milica F1 and the lowest in Paulina F1. Carotenoid content decreased in the following order: Milica F1 > Bambino F1 > Diana F1 > Darina F1 > Denár > Šejk F1 > Orange F1 > Paulína F1.

Mendelová *et al*. (2010) found that the content of carotenoids in fruits of tomatoes for industrial processing varied in the amount of 4.41 to 7.85 mg.100 g^{-1}. The highest content was determined in the varieties of Eskort (7.85 mg.100 g^{-1}) and Premium (7.04 mg.100 g^{-1}). Minimum content was detected in samples of Šampion (4.41 mg.100 g^{-1}) and Žiara (4.67 mg.100 g^{-1}).

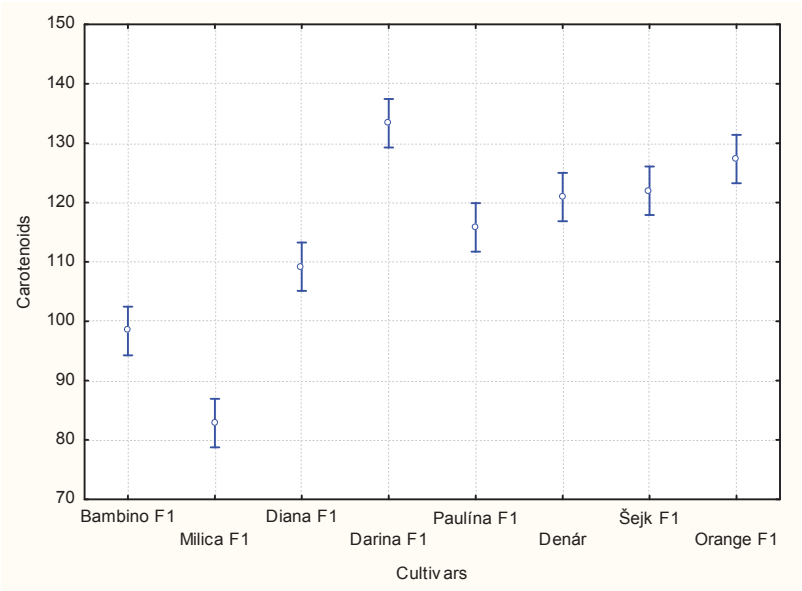
Dry matter content in fruits of tomato ranged from 4.49 to 6.97%. The highest dry matter content was determined in a variety Bambino F1 and the lowest in Orange F1 variety. Carotenoid content after conversion to dry matter content varied from 55.73 to 106.89 mg.100 g^{-1}. The highest content of carotenoids was observed in a variety of Milica F1 and the lowest at Paulína F1 (Fig. 1).

By testing with use of the Fisher's LSD test were observed differences in carotenoid content among varieties. The monitored varieties established 5 homogeneous groups, which differed among themselves in carotenoid content. The most balanced group was a group consisting of varieties Darina F1, Orange F1, Šejk F1 and Denár. Carotenoid content calculated per dry matter in these varieties varied from 75.45 to 78.03 mg.100 g^{-1} and statistically insignificant differences were found. Varieties Paulína F1, Diana F1, Bambino F1 and Milica F1 differed among themselves in carotenoid content.

Martínez-Valverde *et al*. (2002), Kuti and Konuru (2005) and García-Valverde (2013) observed the content of total carotenoids, lycopene and β-carotene and state that the content of these components is significantly affected not only by



1: *Mean carotenoid content [mg.100 g^{-1} dry matter] in fresh tomato fruits*



2: *Mean carotenoid content [mg.100 g^{-1} dry mater] in the dry matter of juice*

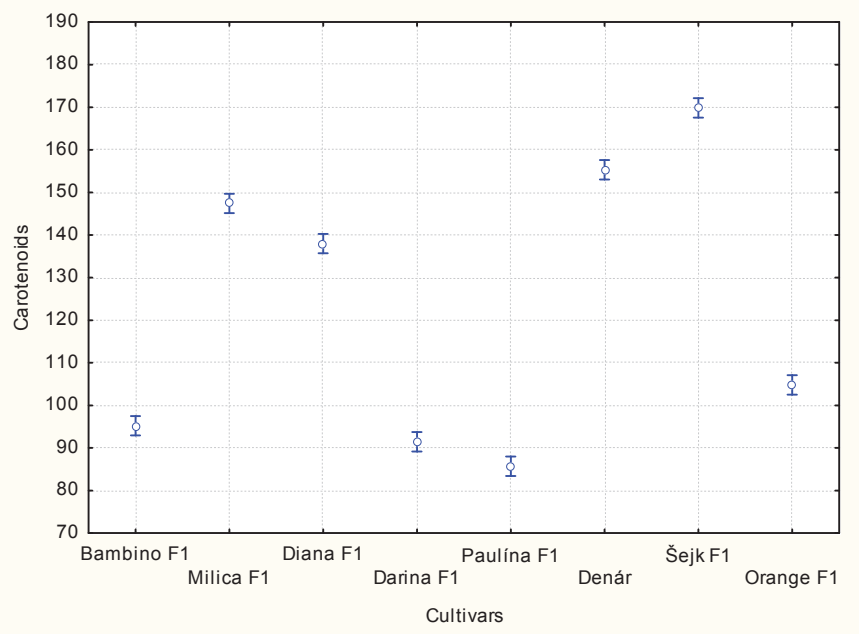
the degree of maturity but also by the variety and growing location.

The content of carotenoids in tomato juice samples ranged from 3.99 mg.100 g^{-1} in a variety Milica to 6.39 mg.100 g^{-1} in a variety Šejk F1. The content of carotenoids in tomato juice decreased in the order: Šejk F1 > Bambino F1 > Darina F1 > Diana F1 > Paulína F1 > Denár > Orange F1 > Milica F1.

Dry matter content of tomato juice was found to be from 3.63% in Orange F1 variety to 5.71% in variety Bambino F1. Mendelová and Andrejiová (2011) in their work indicate that the content of total carotenoids after heat treatment in tomato juice varied in the amount at variety Danuša 4.92 to 8.07 mg.100 g^{-1} in a variety Šampión. Furthermore, they also reported that heat treatment caused a slight reduction in total carotenoids in tomato juice.

Carotenoid content expressed in dry matter of tomato juice ranged from 80.42 mg.100 g^{-1} in a variety Milica F1 to 133.2 mg.100 g^{-1} in a variety Darina F1 (Fig. 2). The content of carotenoids in tomato juice decreased after calculating per dry matter in the following order: Darina F1 > Orange F1 > Šejk F1 > Denár > Paulína F1 > Diana F1 > Bambino F1 > Milica F1.

We can conclude that an increase in the content of carotenoids after processing was observed at all the varieties except of Milica F1, in which a decrease of 18.4 mg.100 g^{-1} was found. The most significant increase was determined at varieties Paulína F1 of 59.80 mg.100 g^{-1} and F1 Darina at 57.92 mg.100 g^{-1}.



3: *Mean carotenoid content [mg.100 g^{-1} dry matter] in dried tomato fruits*

In dried tomatoes the content of carotenoids ranged from 65.65 mg.100 g^{-1} to 133.21 mg.100 g^{-1}. The highest content of carotenoids in dried tomatoes was determined in a variety Šejk F1 and the lowest content at Paulína F1 variety. The content of carotenoids in dried tomatoes decreased in the order: Šejk F1 > Denár > Milica F1 > Diana F1 > Orange F1 > Bambino F1 > Darina F1 > Paulína F1.

Dry matter content of dried tomatoes ranged from 77.46% to 78.84%. The lowest carotenoid content (Fig. 3) was measured in a variety Paulína F1 (85.71 mg.100 g^{-1}) and the highest in variety Šejk (169.85 mg.100 g^{-1}). After drying, we observed in all varieties higher levels of carotenoids than in fresh matter.

The content of lycopene in the tomato fruits after harvest ranged from 1.16 to 5.57 mg.100 g^{-1} of fresh matter. O'Neill *et al.* (2001) found that the tomato is a source of β-carotene present in the average of 0.61 mg.100 g^{-1}, the amount of lutein is 0.077 mg.100 g^{-1} and lycopene is present in the amount of 2.718 mg.100 g^{-1}, this declared content of lycopene is comparable with our results. Clinton (1999) states that the content of lycopene in tomato fruits is in the range of 0.88 to 4.2 mg.100 g^{-1}, which is slightly lower than we found in our work.

Lycopene content in tomato varieties varied from 33.75 to 87.74% of the total carotenoids. The lowest proportion of lycopene showed a variety Orange F1. The highest content of lycopene contained Bambino F1 variety.

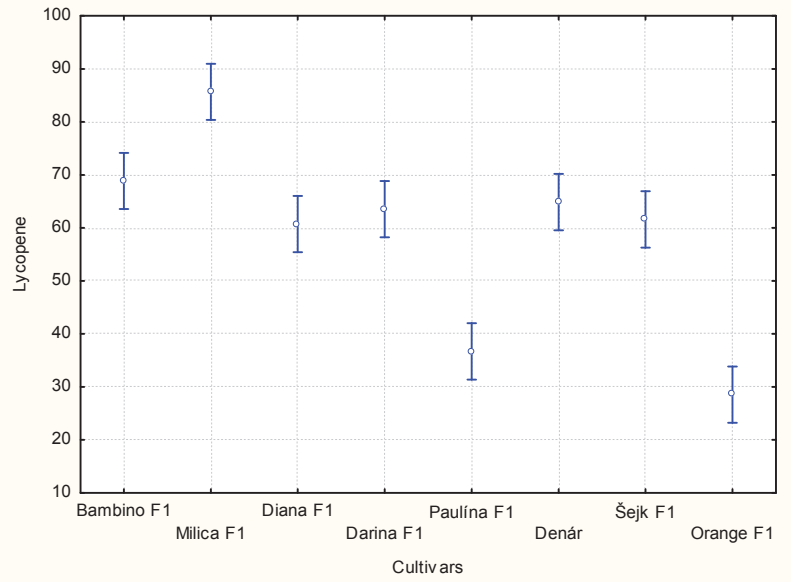
Content of lycopene after a conversion per dry matter content ranged from 25.85 to 90.87 mg.100 g^{-1}. The highest lycopene content in dry matter was determined in variety Milica F1, which accounted for 85.02% of the total carotenoid content. The lowest lycopene content in dry matter was found at Orange F1 variety (Fig. 4). In this variety lycopene represents 33.75% of the total carotenoids.

Zelená *et al.* (2009) in their work monitored the content of lycopene in different varieties of tomato and after different variants of fertilization. They found that supplemental nutrition by increased sulfur content was manifested by higher lycopene content in fruits by 44.5% for a variety Proton and 32.15% for variety Šejk. They also noted a strong correlation relationship between lycopene content and colorimetrically measure of the intensity of red fruits. Statistically we observed relative differences among varieties by Fisher LSD test. Varieties developed six homogeneous groups that differed in lycopene content.

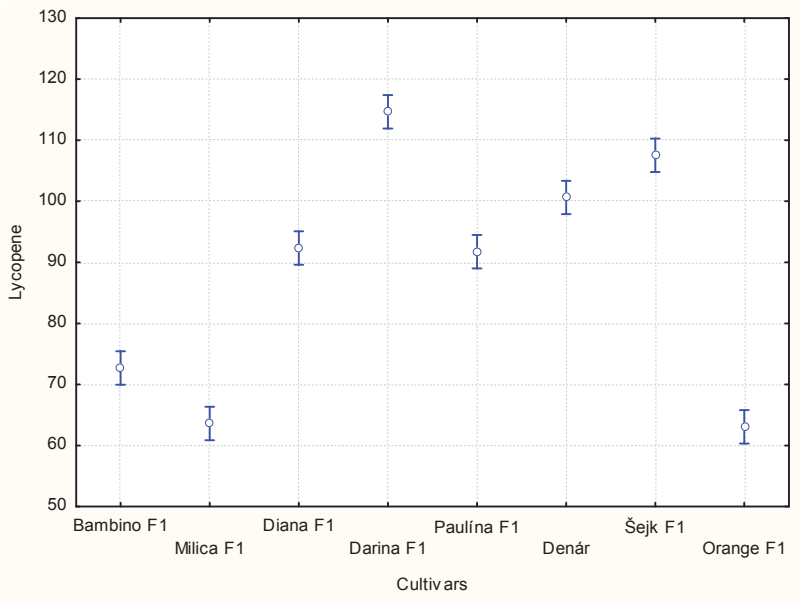
The most balanced group was the group consisted of varieties Šejk F1, Darina F1 and Denár. Lycopene content in this group after conversion to 100% dry matter ranged from 61.60 to 64.86 mg.100 g^{-1}. Orange F1, Paulina F1, Diana F1, Bambino F1, Milica F1 differed in lycopene content among themselves as well as between the group of varieties.

Lycopene content in the heat-treated tomato juice ranged from 2.25 mg.100 g^{-1} to 5.62 mg.100 g^{-1}. The highest content of lycopene was found in the juice prepared from a variety Šejk F1 and the lowest lycopene content was determined in Orange F1 variety. Andrejiová and Mendelová (2012) determined content of lycopene in tomato juice in varieties of Báb, Žiara PK, Šampión, Roti PK. The lycopene content ranged from 4.69 mg.100 g^{-1} in a variety of Báb to 6.75 mg.100 g^{-1} in a variety Roti PK, whose content was higher than we found in our measurements.

Lycopene content in the juices (Fig. 5) after a dry matter conversion decreased in the order: Darina F1 (114.66 mg.100 g^{-1}) > Šejk F1 > Denár > Diana F1



4: *Mean content of lycopene [mg.100 g^{-1} dry matter] in fresh tomato fruits*



5: *Mean content of lycopene [mg.100 g^{-1} dry matter] in tomato juice*

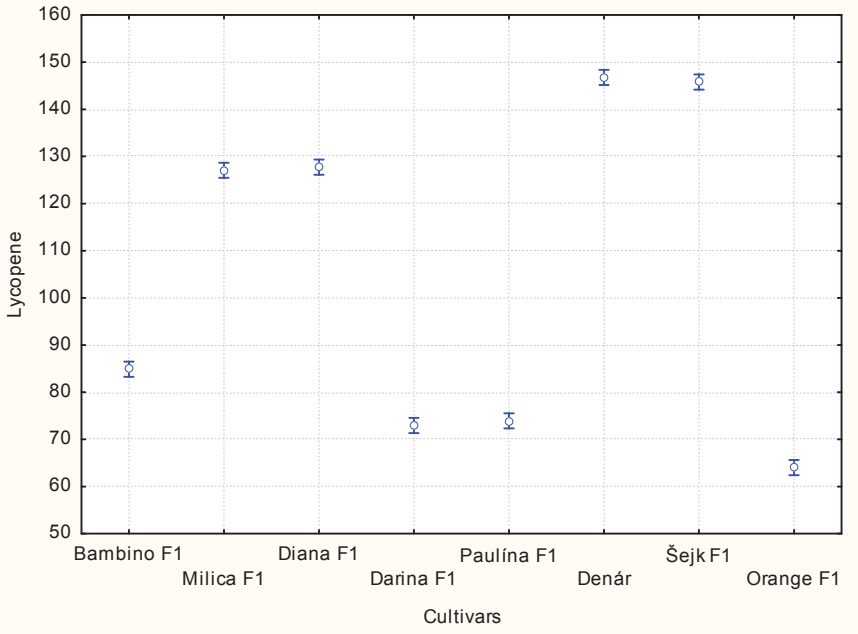
> Paulína F1 > Bambino F1 > Milica F1 > Orange F1 (63.05 mg.100 g^{-1}).

Changes found in the lycopene content in tomato juice were the same as in the case of carotenoids. In all varieties, except of Milica F1, increased lycopene content was determined. The average decrease in lycopene content in variety Milica F1 was 25.7%.

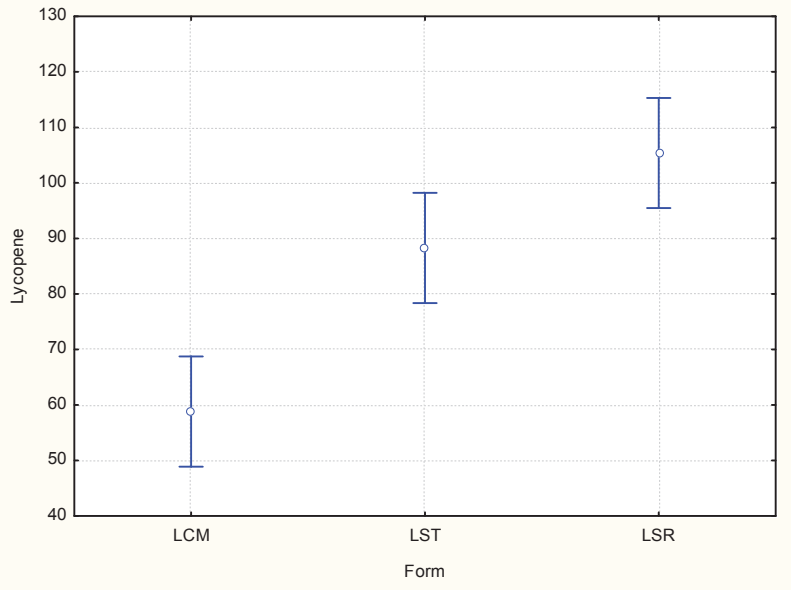
Huang *et al.* (2010) observed content of lycopene and β-carotene in tomato sauce and ketchup. Samples showed higher levels of lycopene, that was also described as the dominant carotenoid in tomato and tomato products. The content of lycopene in tomato sauce was 184.7 mg. 100 g^{-1}of dry matter and 395.84 mg.100 g^{-1} of dry matter.

As it is reported by several authors, after heat treatment an increase in the content and also improvement in bioavailability of lycopene occured. Shi *et al.* (2005) state that at the heat treatment of tomato pulp at a temperature up to 100 °C slow degradation of lycopene is observed. This is due to that some macromolecules such as pectin, may protect lycopene against degradation.

In the dried products from tomatoes, the lycopene content ranged from 64.01 mg.100 g^{-1} to 146.74 mg.100 g^{-1} (Fig. 6). The lowest content in case of dried tomatoes was found in a variety of Orange F1 and the highest showed variety Denár. The content of lycopene after dry matter conversion decreased in the order: Denár > Šejk F1 > Diana F1 > Milica F1



6: *Mean content of lycopene [mg.100 g^{-1} dry matter] in dried tomatoes*



7: *Mean contents of lycopene [mg.100 g^{-1} dry matter] in different processed tomatoes*
LCM – fresh fruits
LST – tomato juice
LSR – dried tomatoes

> Bambino F1 > Darina F1 > Paulína F1 > Orange F1. After drying, increased lycopene content in all varieties was determined.

Kerkhofs *et al.* (2005) monitored content of lycopene in dried tomatoes at 42 °C. They used varieties Aranka, Encore and Flavourine. The studied varieties showed to contain 45.6 mg.100 g^{-1} of lycopene in variety Flavourine, 47.4 mg.100 g^{-1} in variety Encore and 59.2 mg. 100 g^{-1} in a variety Aranka. In case of varieties Encore and Flavourine it is a 24% increase compared to the fresh matter content and at variety Aranka up to 55% increase. In case of our samples comparable increase in lycopene content after drying was found at variety Bambino F1 and Milica F1, greater than 55% increase in the varieties of Diana F1, Paulína F1, Šejk F1, Denár and Orange F1, an increase of 14% was observed in variety Darina F1.

Kerkhofs *et al.* (2005) state an increase of lycopene content at drying at 42 °C due to the release of lycopene bound from the tissues. Zanoni *et al.* (1999), Shi *et al.* (1999) and Laveli *et al.* (1999)

I: *The statistical significance of the impact of tomato processing on the carotenoid and lycopene content by one-way analysis of variance*

Source of variability	Parameter	Sum of Squares	Df	Mean Square	F
Tomato form	carotenoids	2.90997	2		38.13*
Error	carotenoids	2.63279	69	0.0381564	
Total	carotenoids	5.54277	71		
Tomato form	lycopene	4.43853	2	2.21926	23.75*
Error	lycopene	6.44861	69	0.093458	
Total	lycopene	10.8871	71		

* statistically significant at $\alpha < 0,05$; df - degree of freedom; n = 72

performed their experiments with dried tomatoes at temperatures from 55 to 110 °C and they observed decrease of lycopene content. Shi *et al.* (1999) state that the color changes and nutritional quality are found to be lower in reducing the temperature from 90 to 55 °C.

One-way analysis of variance confirmed that the form of tomato - fresh fruits, tomato juice and dried tomatoes showed a statistically significant impact on the content of carotenoids and lycopene (Tab. I). Another testing by Fisher LSD test after logarithmic transformation of the input data, showed differences in carotenoid content and lycopene in various forms of tomato. We found a clear difference in the content of the monitored components among fresh fruit and tomato products after heat treatment. Tomato products did not show any statistical significant difference.

CONCLUSION

The aim of this work was to analyze the presence of carotenoids and lycopene, and to assess the dynamics of changes in different varieties of tomato and after different treatments of processing.

The highest content of carotenoids was observed in varieties Milica F1 and Šejk F1. In the variety of Milica F1 we observed the highest carotenoid content in fresh fruit of tomato. In a variety Šejk F1 was found the highest content of carotenoids in tomato juice and dried tomatoes. The highest content of lycopene in fresh fruit variety was determined at Milica F1, in tomato juice in variety Šejk F1, and in dried tomatoes at variety Denár. The lowest lycopene content in all forms of processing has been confirmed in a variety Orange F1.

Assessing the dynamics of carotenoids and lycopene content after heat treatment, we found that in case of varieties Šejk F1, Diana F1, Darina F1, Paulína F1, Orange F1, Bambino F1, Denár, the increased contents of the studied compounds was found. In variety of Milica F1, decreased content of total carotenoids and lycopene after processing into juice was detected. After drying at 45 °C, the content of carotenoids and lycopene in a variety Milica F1 showed an increase.

Based on the results obtained, we can conclude that at the varieties studied, we found statistically significant differences in the content of the monitored components. We have also recorded significant increased content of both components after heat treatment of the fruit at using temperatures of 45 and 95 °C.

SUMMARY

The aim of this work was to evaluate the content of carotenoids and lycopene in fresh tomato fruits and to observe dynamic changes after heat treatment of tomatoes in tomato products, such as the tomato juice and dried tomato slices. The experiment included varieties Bambino F1, Darina F1, Diana F1, Denár, Milica F1, Orange F1, Paulina F1, Šejk F1. Prepared juice from fresh fruits was subjected to heat treatment at 95 °C for 3 minutes, slices tomatoes were dried at 45 °C for 16 hours. Carotenoid and lycopene content were analyzed spectrophotometrically. Carotenoid content in fresh tomato fruits was detected from 55.73 to 106.89 mg.100 g^{-1} of dry matter. The highest content of carotenoids was observed in variety Milica F1, and variety Paulína F1 showed the lowest content. The content of carotenoids in tomato juice ranged from 80.42 mg.100 g^{-1} dry matter in variety Milica F1 to 133.2 mg.100 g^{-1} dry matter at variety Darina F1. At dried tomatoes was found to be 85.71 mg.100g^{-1} dry matter in variety Paulina F1 to 169.85 mg.100 g^{-1} dry matter in variety Šejk F1.

Lycopene content in tomato varieties varied from 33.75 to 87.74% of the total carotenoids. After drying, increased lycopene content in all varieties was determined.

By monitoring of the dynamics changes in the content of carotenoids and lycopene we found that heat treatment has a positive influence on the content of monitored components. Positive statistically significant difference was confirmed in the content of the monitored components between fresh fruit and the products after their heat treatment. Tomato products observed did not differ statistically significantly among each other.

Acknowledgment

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