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Tomato (*Lycopersicon esculentum* Mill.) fruit quality and physiological parameters at different ripening stages of; Lithuanian cultivars

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Abstract. Four cultivars (‘Neris’, ‘Svara’, ‘Vytėnų didieji’, ‘Jurgiai’) and one hybrid (‘Vaisa’) of tomato *(Lycopersicon esculentum* Mill.) were investigated at the Lithuanian Institute of Horticulture from 2007–2008.

During this investigation fruit quality and physiological parameters were evaluated: the lycopene and β-carotene contents, colour indices (CIE L*a*) and hue angle (h°) with chroma (C) at four different fruit ripening stages (I stage – green, II stage – beginning of ripening, III – not fully ripened, IV – fully ripened)

A significant increase in lycopene and β-carotene content at each successive ripening stage of tomato fruit was recorded. Tomato fruit colour became darker and the ratio of red to green colour increased during the ripening process. Chroma value increased with a change of tomato colour from green to light red, and subsequently declined at the red fruit stage, but chroma of the hybrid ‘Vaisa’ increased at all ripening stages.

External colour was expressed in terms of hue angle. All the analyzed tomato cultivars developed a similar colour when mature, with average hue angles generally being close to 40 degrees, but the cultivar ‘Neris’ had lower hue value (32 degrees).

Key words: carotenoids, colour, lycopene, *Lycopersicon esculentum*, ripening, tomato

INTRODUCTION

Tomatoes (*Lycopersicon esculentum* Mill.) are widely consumed either fresh or processed. Tomatoes are known as health stimulating fruit because of the antioxidant properties of their main compounds. Antioxidants are important in disease prevention in plants as well as in animals and humans. Their activity is based on inhibiting or delaying the oxidation of biomolecules by preventing the initiation or propagation of oxidizing chain reactions. The most important antioxidants in tomatoes are carotenes (Clinton, 1998). Among the carotenes, lycopene dominates, and its content varies significantly depending on ripening, variety and environment (Brandt et al., 2006). Lycopene appears to be relatively stable during food processing and cooking. Epidemiological studies have suggested a possible role for lycopene in the protection against some types of cancer and in the prevention of cardiovascular disease (Clinton, 1998). The second most important carotenoid is β-carotene, which represents about 7% of the total carotenoid content (Gould, 1974). The amount of carotenes as well as their antioxidant activity is significantly influenced by tomato variety and maturity (Arias et al., 2000). Tomato fruit colour is one of the most important and complex attributes of fruit quality. The complexity of tomato colour is due to the presence of a diverse carotenoid pigment system with appearance conditioned by pigment types and concentrations, and it is subject to both genetic and environmental regulation (Arias et al., 2000; Lopez & Gomez 2004). Tomatoes are usually consumed at their maximum organoleptic quality, which takes place when they reach the full red colour stage but before excessive softening. This means that colour in tomato is the most important external characteristic to assess ripeness and postharvest life and is a major factor in the consumer's purchase decision. Red colour is the result of chlorophyll degradation as well as synthesis of lycopene and other carotenoids, as chloroplasts are converted into chromoplasts.

Since humans are unable to synthesise carotenoids themselves, we obtain them exclusively from the diet. At least 85% of our dietary lycopene comes from tomato fruit and tomato-based products, the remainder being obtained from watermelon, pink grapefruit, guava and papaya (Clinton, 1998).

MATERIALS AND METHODS

Four cultivars ('Neris', 'Svara', 'Vytėnų didieji', 'Jurgiai') and one hybrid ('Vaisa') of edible tomato *(Lycopersicon esculentum* Mill.) were investigated in 2007–2008. The tomatoes were cultivated at the Lithuanian Institute of Horticulture, in an unheated greenhouse covered with polymeric film.

During the investigation, fruit quality and physiological parameters were evaluated: lycopene and β-carotene contents, colour indices (CIE L*a*b*) and calculated hue angle (h°) with chroma (C) at four different stages of fruit ripening (I stage – green, II stage – beginning of ripening, III – not fully ripened, IV – fully ripened).

In order to establish the lycopene and β-carotene contents, the tomatoes were homogenized by a Bosch Easy Mixx crusher (type CNHR6, Robert Bosch GmbH, Stuttgart, Germany). Lycopene and β-carotene was identified spectrophotometrically (Ermakov, 1987; Scott, 2001). Colour indices were measured with the spectrophotometer MiniScan XE Plus (Hunter Associates Laboratory, Inc., Reston, Virginia, USA). Regarding light reflection, the parameters L*, a* and b* (correspondingly lightness, indices of redness and yellowness according to scale CIE L*a*b*) were measured and chroma ($C = (a^{*2}+b^{*2})^{1/2}$) and hue angle ($h° = \arctan(b^*/a^*)$) were calculated. The volumes L*, C, a* and b* are measured in NBS units, hue angle h^o – in degrees from 0 to 360°. NBS unit is a unit of the USA National Standard Bureau and corresponds to one threshold of colour distinction power, i.e. the least distinction in colour, which the trained human eye can notice (McGuiere, 1992; HunterLab, 1996).

Before each series of measurements the spectrophotometer was calibrated with a light catcher and standard white colour, the colour coordinates XYZ which in colour space are X = 81.3; Y = 86,2; Z = 92.7.

Value L* indicates the ratio of white to black colour, value a* – the ratio of red to green colour, value b* – the ratio of yellow to blue colour.

The data are presented are the means of three measurements. Colour indices were processed by the Universal Software V.4–10 programme. Statisticalprograms SAS and ANOVA were used for the evaluation of data (Tarakanovas & Raudonius, 2003).

RESULTS

The results of our investigation (Fig. 1) established that the content of lycopene in all the investigated tomatoes during fruit ripening significantly increased. The lowest concentration of lycopene (0.25 mg 100 g^{-1}) was recorded in the green fruits of the hybrid ‘Vaisa’, and the highest concentration of this carotenoid (1.42 mg 100 g^{-1}) was found in the green fruits of the cultivar ‘Svara’. The highest concentration of lycopene (12.51 mg 100 g^{-1}) was measured in completely ripened tomatoes of the cultivar ‘Neris’ and only slightly lower concentrations of this carotenoid were found in the ripened fruits of the cultivar ‘Jurgiai’ and the hybrid ‘Vaisa’.

The analyses of β-carotene in tomato fruits of different ripeness (Fig. 2) showed that during ripening the content of this carotenoid increased. The decrease of β-carotene content after the fourth measurement was observed only in fruits of the cultivar ‘Svara’, but this difference was not significant. A very small increase, between third and fourth ripening stages, was established in the fruits of the hybrid ‘Vaisa’. Tomatoes of the cultivar ‘Jurgiai’ had the highest concentration of β-carotene (over 2 mg 100 g^{-1}) in ripened fruits and the lowest concentration (0.17 mg 100 g^{-1}) was recorded in the green fruit of the hybrid ‘Vaisa’.

During fruit ripening, not only the content of lycopene and β-carotene in tomatoes increased, but also the ratio of these carotenoids (Fig. 3). The highest ratio of lycopene to β-carotene (7/1) was recorded in the ripened tomatoes of the cultivar ‘Vytėnų didieji’. The concentration of lycopene in the ripened fruits of cultivars ‘Svara’ and ‘Jurgiai’ was approximately six times larger compared to the concentration of β-carotene.

Our investigations showed that during fruit ripening colour index a* (Fig. 4) increased. The greatest increase was recorded between the first ripeness stage, when the fruits were still completely green, and the second ripeness stage, when the tomatoes started to redden. The least ratio of the red and green colour with a negative value (-3.7 NBS units) was recorded in the green fruits of the cultivar ‘Jurgiai’). The highest value of colour index a* (28.9 NBS units) was recorded in completely ripened tomatoes of the hybrid ‘Vaisa’.

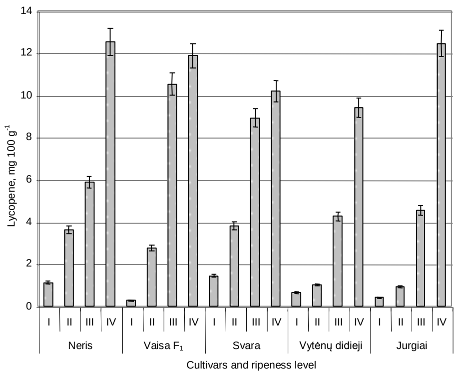

Fig. 1. Lycopene content in tomato fruits.

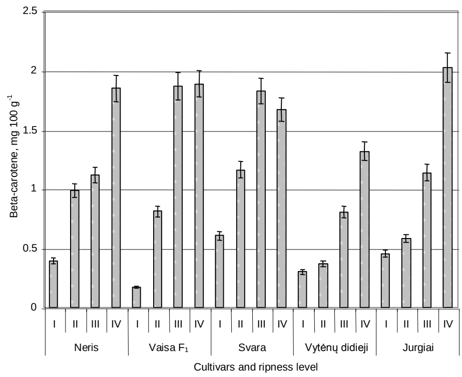

Fig. 2. β-carotene content in tomato fruits.

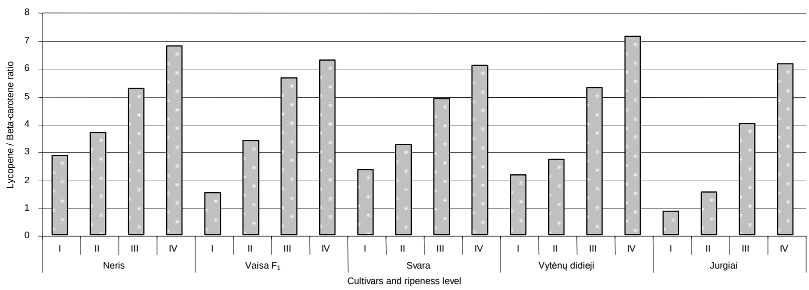

Fig. 3. Lycopene and β-carotene ratio in tomato fruits.

During tomato ripening the ratio of white to black colour decreased (Fig. 5), and this indicates a darkening of the fruits. Only the fruits of the hybrid 'Svara' recorded a (small) increase of this ratio between the third and fourth ripeness stage, but this increase was not statistically significant. The lowest colour lightness L* value (33.4 NBS units) was recorded in the completely ripened fruits of the cultivar 'Neris', and the highest L* value (56.3 NBS units) was found in the completely ripened fruits of the cultivar 'Jurgiai'.

Colour chroma (C) value varied at different fruit ripening stages of the investigated cultivars (Fig. 6). The lowest C value was detected in the green fruits of the hybrid 'Svara'. The highest chroma value (40.0 NBS units) was recorded in the tomatoes of the cultivar 'Neris' at the beginning of ripening.

Hue angle (h^o) of all investigated cultivars significantly decreased after each measurement (Fig. 7). Hue angle of the cultivar 'Jurgiai' was highest, and it decreased from 97 degrees in green fruits to 42 degrees in fully ripened fruits. The cultivar 'Neris' had the least hue angle value; only 79 degrees in fully ripened fruits and thisdecreased to 32 degrees.

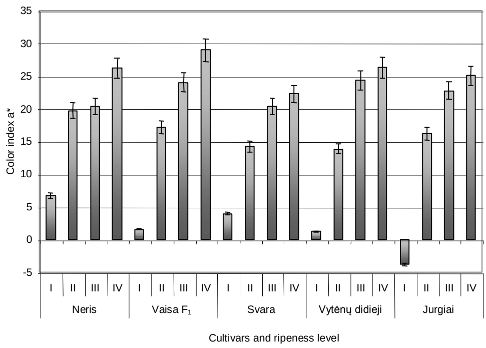

Fig. 4. Colour index a* at different ripening stages.

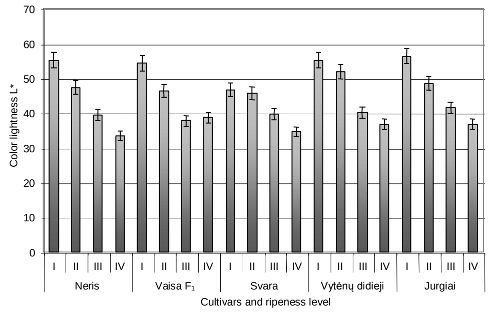

Fig. 5. Colour lightness L* at different ripening stages.

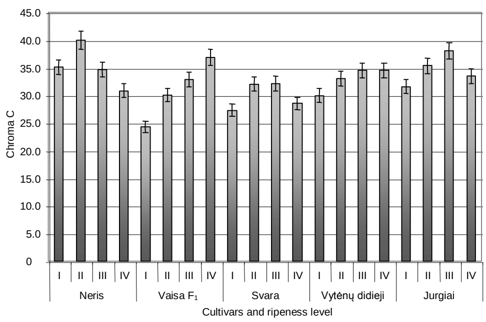

Fig. 6. Chroma (C) at different ripening stages.

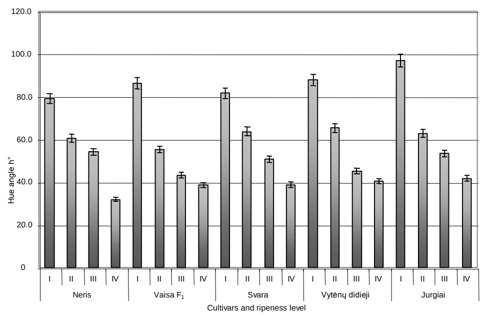

Fig.7. Hue angle (h^o) at different ripening stages.

DISCUSSION

This study is a first report on investigations of fruit quality and physiological parameters of Lithuanian tomato cultivars. The data presented is of value for the future use of these cultivars for tomato breeding.

Ripening of tomatoes is a combination of processes including the breakdown of chlorophyll and build-up of carotenes. Chlorophyll and carotenes have specific, well-known, reflection spectra. Using knowledge of the known spectral properties of the main constitutive compounds, it is possible to calculate their concentrations using spectral measurements (Arias et al., 2000).

Most studies compare lycopene and β-carotene concentration of fruits at the red ripeness stage (the fully ripened stage). Since carotenoid concentration in tomato fruit increases rapidly during fruit ripening, the concentration should be compared throughout the fruit ripening period (from the green stage to the red stage), rather than at the last stage of ripeness, to better understand lycopene synthesis. Furthermore, ripening of tomato fruit is accompanied by chlorophyll degradation and carotenoid synthesis, as chloroplasts are converted into chromoplasts (Brandt et al., 2006).

The index a* had a sharp increase between stage I and the other ripening stages with a* value changing from negative (green colour) to positive (red colour). This process could be related to the start of carotenoids synthesis, because the amount of lycopene and β-carotene increased with each subsequent stage of fruit ripeness. When these carotenoids accumulated, the colour lightness (L*) decreased, indicating darkening of the tomato red colour.

Chroma increased as the tomatoes changed from green to light red and finally declined at the red stage. But chroma of the hybrid 'Vaisa' increased at all ripening stages. Nevertheless, chroma is not a good indicator of tomato ripening because it essentially is an expression of the purity or saturation of a single colour (different colours may have the same chroma values). In the case of tomato ripening, different colours are present simultaneously, since chlorophyll is degraded from green to colourless compounds at the same time that carotenoids are synthesized from a colourless precursor (phytoene) to lycopene (red), β-carotene (orange), xanthophylls and hydroxylated carotenoids (yellow). Because chroma reflects colour purity or saturation, it could be a good indicator of consumer acceptance when tomatoes are completely ripe (Lopez & Gomez, 2004).

External colour was expressed in terms of hue angle, considered the most important measure in the perception of tomato quality, because external fruit colour relates better to perception of colour by the human eye (Shewfelt & Prussia, 1993). All the analysed tomato cultivars developed a similar colour at the mature stage, with average hue angles generally close to 40 degrees, except for the cultivar 'Neris' that had a lower hue value (32 degrees).

CONCLUSIONS

1. The highest concentration of lycopene (12.51 mg 100 g^{-1}) was determined in fully ripened fruits of the cultivar 'Neris' and they had the highest chroma value (40.0 NBS units).
2. The cultivar 'Jurgiai' had the highest concentration of β-carotene (over 2 mg 100 g^{-1}) and the highest colour lightness and hue angle values in fully ripened fruits.
3. The hybrid 'Vaisa' had the highest colour index a* value (28.9 NBS units) in fully ripened fruits.
4. Concentrations of lycopene and β-carotene increased rapidly during tomato fruit ripening.

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