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Quality and physiological parameters of tomato (*Lycopersicon esculentum* Mill.) fruits of Lithuanian selection

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Six Lithuanian selection lines (137, 998/1000, 194/463, 21/1154, 1428, 1429) of edible tomato (*Lycopersicon esculentum* Mill.) were investigated in 2006–2007.

Fruit quality and physiological parameters were evaluated: the content of lycopene and β-carotene and colour indexes (L*, a*, b* and hue angle h^0) at four different stages of fruit ripening (stage I – green, stage II – beginning of ripening, III – not fully ripened, IV – fully ripened), the average fruit number on plant and the average fruit weight.

The colour index a* showed the most obvious change, there was a sharp increase between stage I and other ripening levels with a* changing from negative (green color) to positive (red color) values. This could be related with the start of lycopene and β-carotene synthesis. When these carotenoids started to be synthesized, the L* value went down, indicating the darkening of tomato red colour, but in the selection line 1428 fruit colour from stage III to stage IV became lighter. The colour index b* values reached their peak at stage II when tomatoes started to get the red colour. In all the fruit ripening process, the hue angle had a tendency to decline, particularly the h^0 value decreased between ripening stages I and II.

Key words: colour index, lycopene, *Lycopersicon esculentum*, ripening stage

INTRODUCTION

There are large genotypic variations in tomato quality attributes, and it is possible to develop new cultivars with good quality features.

Tomato (*Lycopersicon esculentum* Mill.) fruit colour is one of the most important and complex attributes of fruit quality [1]. The complexity of tomato colour is due to the presence of a diverse carotenoid pigment system, their appearance being conditioned by pigment types and concentrations, and subject to both genetic and environmental regulation [1, 2]. 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 [3]. Lycopene is the pigment principally responsible for the characteristic deep-red color of ripe tomato fruits and tomato products. It has attracted attention due to its biological physiochemical properties, especially related to its effects as a natural antioxidant. Although it has no provitamin A activity, lycopene does exhibit a physical quenching rate constant with single oxygen almost twice as high as that of β-carotene. This makes its presence in the diet of considerable interest. Increasing clinical evidence supports the role of lycopene as a micronutrient with important health benefits, because it appears to provide protection against a broad range of epithelial cancers. Tomatoes and related tomato products are the major source of lycopene compounds and also are considered an important source of carotenoids in the human diet [4, 5].

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MATERIALS AND METHODS

Six Lithuanian selection lines (137, 998/1000, 194/463, 21/1154, 1428, 1429) of edible tomato (*Lycopersicon esculentum* Mill.) were investigated in 2006–2007. Tomatoes were grown at the Lithuanian Institute of Horticulture, in not heated greenhouse covered with polymeric film, in turfic gleyic albic soil, the granulometric composition of which was loam on loam.

Fruit quality and physiological parameters were evaluated: there was established the amount of lycopene and β-carotene and color indexes (L*, a*, b* and hue angle – h^0) at four different stages of fruit ripening (stage I – green, stage II – beginning of ripening, III – not fully ripened, IV – fully ripened), the average fruit number on plant and the average fruit weight.

To establish the content of lycopene and β-carotene, tomatoes of different stages of ripeness were homogenized with a Bosch Easy Mixx crusher (type CNHR6, Robert Bosch GmbH, Stuttgart, Germany). The content of lycopene and β-carotene was established spectrophotometrically [6, 7].

Colour indexes in the space of even contrast colours [8] were measured with a MiniScan XE Plus spectrophotometer (Hunter Associates Laboratory, Inc., Reston, Virginia, USA). In the regime of light reflection there were measured parameters L*, a* and b* (lightness, colour indexes of redness and yellowness according to scale CIE L*a*b*) and the hue angle was calculated (h° = arctan(b*/a*)) [9]. The volumes L*, a* and b* are measured in NBS units, hue angle h° – in degrees from 0 to 360°. The 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.

Before each series of measurements the spectrophotometer was calibrated with a light catcher and standard of white colour, the color indexes XYZ of which in colour space are X = 81.3, Y = 86.2, Z = 92.7.

The value L* indicates the ratio of white and black colour, value a* – the ratio of red and green colours, value b* – the ratio of yellow and blue colours.

The data are presented as the averages of three measurements. Colour indexes were processed by Universal Software V.4–10. To evaluate data significance, the statistic programs SAS and ANOVA were used [10].

RESULTS

Analysis of the data presented in Fig. 1 shows that tomatoes of selection line 1429 produced the biggest fruits: the average weight of one fruit reached 90 g, and this was a statistically significant difference in comparison with the average fruit weight of selection lines 998/1000, 194/1463, 21/1154. However, the selection line that produced the biggest fruits formed the least number of fruits (17 units) per plant, and fruits of the selection line 998/1000 which produced the biggest amount of tomatoes per plant (24 units) were the smallest (53 g).

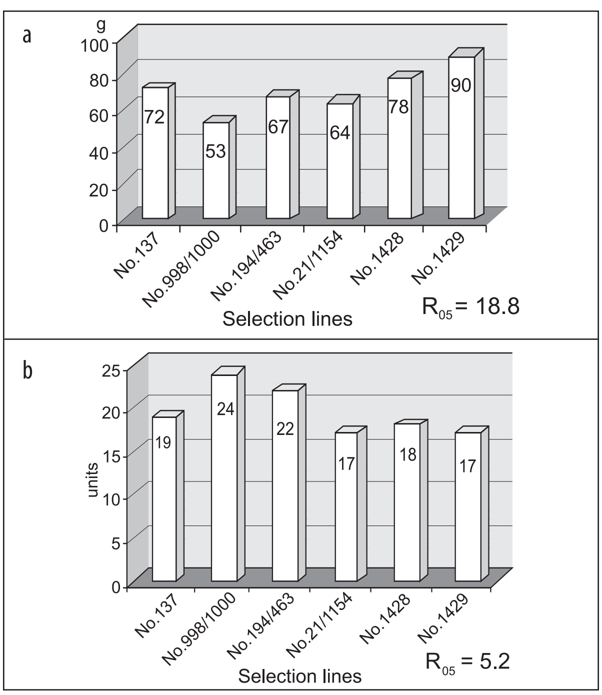

Fig. 1. Tomato fruit features. a – average weight of one fruit, b – average number of fruits on plant

The investigations of lycopene and β-carotene in tomato fruits of different ripeness (Fig. 2) showed that during ripening the content and ratio of these carotenoids increased. A decrease of β-carotene after the fourth measurement was observed only in fruits of selection line 998/1000, but this difference was not significant. Tomatoes of selection line 137 had the largest content of lycopene (12.4 mg g^{-1}) and β-carotene (2.02 mg g^{-1}) in ripen fruits, and the higest ratio of these carotenoids (7 points) was found in fruits of the selection line 194/463.

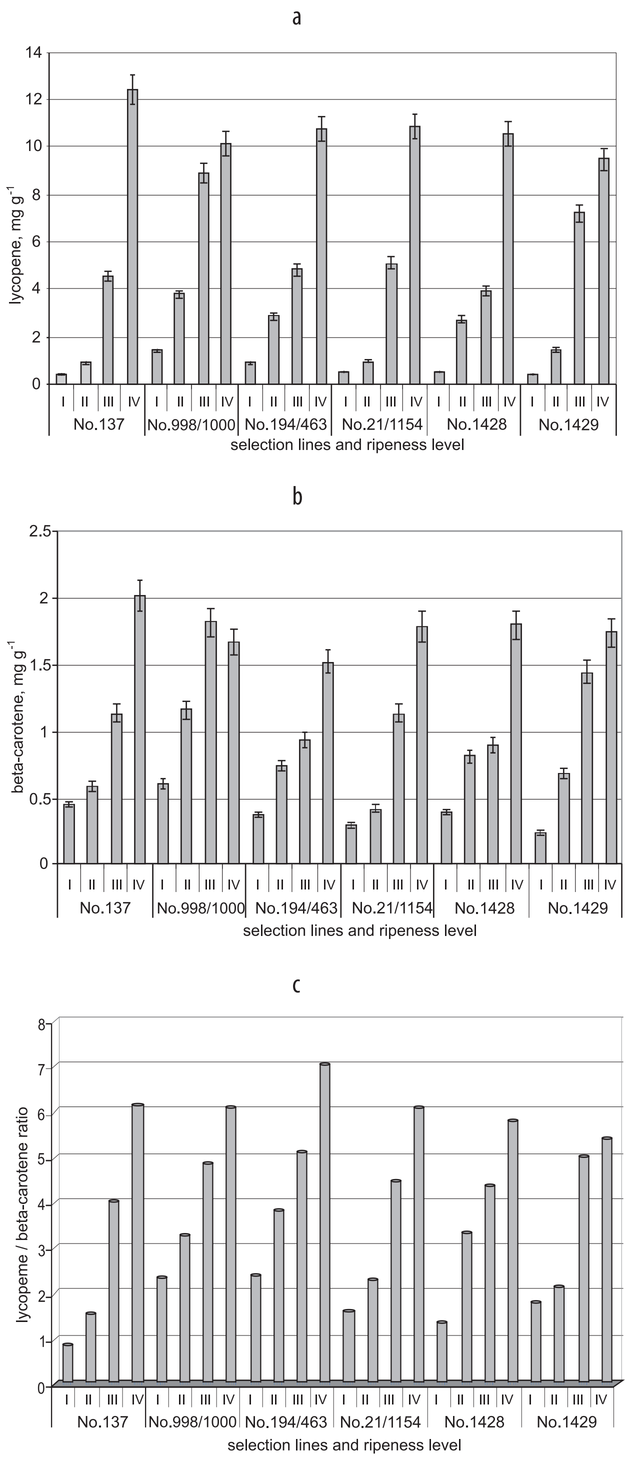

Fig. 2. Carotenoid content in tomato fruit: a – lycopene, b – β-carotene, c – lycopene and β-carotene ratio

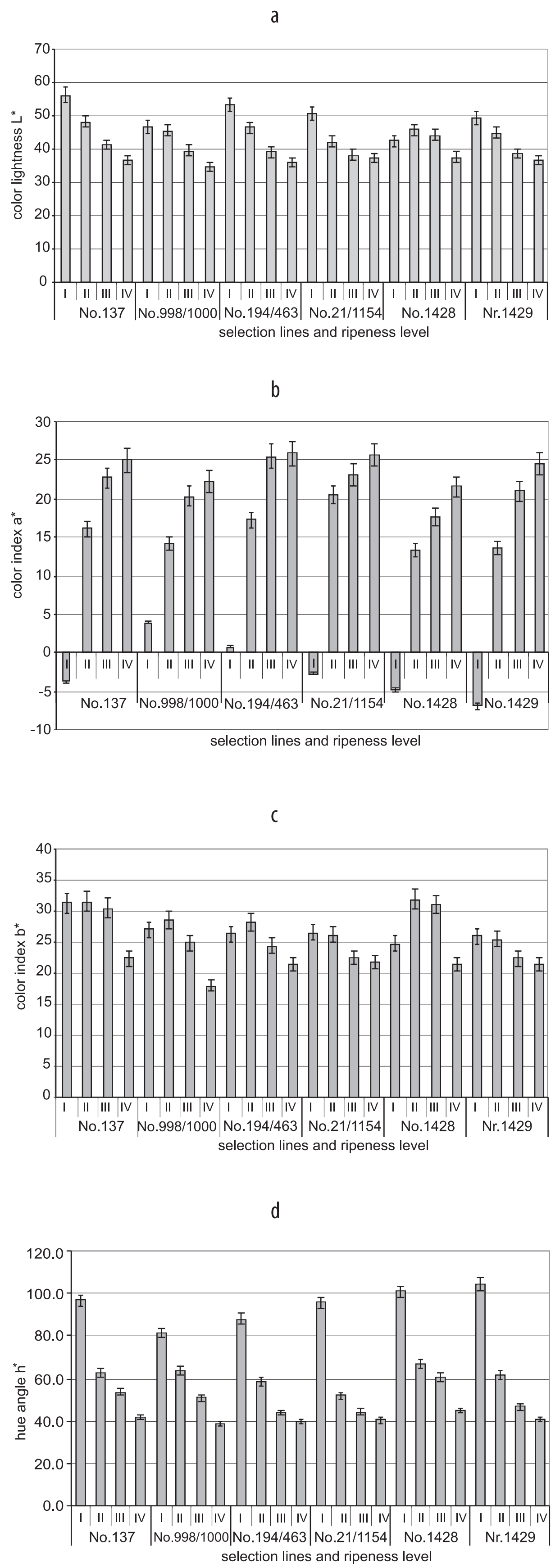

Fig. 3. Colour indexes at different ripening stages of tomato fruits: a – colour lightness L*, b – colour index a*, c – colour index b*, d – hue angle h*

During tomato ripening their colour lightness L* and the ratio of white and black colours decreased (Fig. 3). The lightness of ripen fruits was rather even and fluctuated from 34.5 to 37.6 NBS units.

The colour index a* during fruit ripening increased (Fig. 3). The ratio of red and green colours of selection lines 137, 21/1154, 1428, 1429 at the beginning of fruit ripening was negative, but when fruits ripened the red colour increased, and in the ripened fruits the value of the colour index a* fluctuated from 21.6 (Selection line 1428) to 26.0 (selection line 194/463) NBS units.

The ratio of yellow and blue colours in ripen fruits was the least one, and the value of the colour index b* of selection line 998/1000 was the lowest (17.8 NBS units).

After every measurement, the hue angle of all the investigated tomato fruits significantly decreased. The highest hue angle (105 degrees) was found in still green fruits of the selection line 1429. The tomato hue angle of the selection line 998/1000 was the least one and from 82 degrees in green fruits decreased to 39 degrees in fully ripen fruits.

DISCUSSION

Fruit size and number per plant are the two major factors determining yield and quality for many crops including tomatoes [11]. Like most traits important to agriculture, they are quantitatively inherited. Tomato represents a model fruit-bearing domesticated species characterized by a wide morphological diversity of fruits [1]. Although improvement in tomato fruit size has been relatively easy to achieve due to high heritability, inheritance studies show that this trait is quite complex and determined by multiple loci. Classical genetics have suggested that at least 5–6 genes and possibly as many as 10–20 genes govern the trait. It is likely that these genes are involved in a variety of fruit developmental pathways, each contributing to final fruit size [5].

Human identification of colours is quite complex where sensations like brightness, intensity, lightness and others modify the perception of the primary colours (red, blue, yellow) and their combinations (orange, green, purple, etc.), meaning that in many cases colour definition is a matter of subjective interpretation. In 1931, Commission International de l'Eclairage (CIE) made possible to express colour in exact quantitave and numerical terms. This system was improved in 1976 by CIELAB, which defines colour better related to human perception and where all conceivable colours can be located within the colour sphere defined by three perpendicular axes, L* (from white to black), a* (green to red) and b* (blue to yellow) [10]. A given colour is fully defined when the achromatic component L* (relative darkness or lightness) is measured in addition to the chromatic descriptors (a* and b* values) [3, 4]. However, most of the tomato literature mainly express colour changes in terms of different mathematical combinations of b* and a*. Some researches used only a* values, while many others used the a*/b* relationship [1, 5, 10]. In our investigation, we used four values (L*, a*, b* and h^0) to identify tomato fruit colour.

The colour index a* showed the most obvious change – a sharp increase between stage I and other ripening levels with a* changing from negative (green colour) to positive (red colour) values. This could be related with start of lycopene and β-carotene synthesis. When these carotenoids started to be synthesized, the L* value went down indicating a darkening of tomato red colour, but selection line 1428 fruit colour from stage 3 to stage 4 became lighter. The colour index b* values reached their peak at stage II when tomatoes started to get the red colour. In the whole fruit ripening process the hue angle had a tendency to decline, particularly the h^0 value decreased among ripening stages I and II.

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LIETUVIŠKOS SELEKCIJOS POMIDORŲ (*LYCOPERSICON ESCULENTUM* MILL.) VAISIŲ KOKYBINIAI IR FIZIOLOGINIAI PARAMETRAI

Santrauka

2006–2007 m. Lietuvos sodininkystės ir daržininkystės institute ištirti šeši lietuviški valgomojo pomidoro (*Lycopersicon esculentum* Mill.) selekciniai numeriai: 137, 998/1000, 194/463, 21/1154, 1428, 1429.

Tyrimo metu įvertinti vaisių kokybiniai ir fiziologiniai parametrai: nustatytas likopeno ir β-karotino kiekis bei spalvos laipsnio rodikliai (L*, a*, b* ir spalvos tonas – h^0) keturiais skirtingais vaisių nokimo tarpsniais (I tarpsnis – dar žali; II tarpsnis – pradėję nokti; III tarpsnis – dar ne visiškai sunokę; IV – visiškai sunokę), apskaičiuotas vidutinis vaisių kiekis ant augalo ir vidutinė vieno vaisiaus masė.

Tyrimais nustatyta, kad daugiausia kito spalvos laipsnio rodiklis a* – nuo neigiamo (žalia vaisiaus spalva) iki teigiamo (raudona vaisiaus spalva), ir tai galėjo būti susiję su likopeno ir β-karotino sintezės pradžia. Sintetinant šiuos karotinoidus, L* reikšmė mažėjo, ir tai reiškė, kad pomidoro raudona spalva tamsėjo. Spalvos laipsnio rodiklio b* reikšmė didžiausia buvo tik pradėjus raudonuoti pomidorų vaisiams, o vaisių nokimo metu spalvos tonas h^0 mažėjo.