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Tomato fruits quality as affected by light intensity using color shade nets

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Abstract

The quality of tomatoes were affected by environmental factors (light and temperature) and agronomic techniques used (open field or plastic-house production). Fruits produced in a plastic-houses were more acidic (greater TA, 0.38) than field-produced fruits (0.34). Fruit grown in the field had greater TSS content (5.42°Brix) than tomato from protected environment (5.10). Fruits produced in the field had greater TSS:TA ratios than those produced in a protected environment. Significantly higher lycopene content was observed in plastic-houses tomato integrated with red shade netting technologies (64.9 μg g^{-1}) than in field-grown tomatoes (48.1 μg g^{-1}). By contrast, shaded fruits have lower content of β-carotene.

Key words: dry matter, soluble solid, pH-values, total acid, lycopene, *β*- carotene.

Introduction

Tomato quality components are influenced by genetic and environmental factors such as climatic conditions; temperature and light (Dumas et al. 2003; Caliman et al. 2010) and cultural practices; soil type (Papadopoulos, 1991), nutrient and water supply, harvesting method, maturity stage at harvest (Kader, 1986) and postharvest handling (Dorais et al., 2001). In traditional vegetable-producing regions, tomato cultivation in a protected environment has expanded to prevent seasonality in the availability of fruit (Andriolo et al., 1998). In Serbia shading are usually applied on plastic-houses and open field in summer to reduce the solar radiation and air temperature for minimizing fruit physiological defects (Ilić et al., 2011). Increasing solar radiation has been shown to increase fruit dry matter and soluble sugars content and pigments (lycopene), Davies and Hobson (1981). The soluble sugar concentration of tomato fruit follows the pattern of solar radiation (Winsor and Adams, 1976). Low light irradiance reduces pigment synthesis, resulting in uneven fruit coloring and low fruit soluble sugar content which results in a 'watery' taste. On the other hand, too high light irradiance, especially direct light on fruit, may reduce fruit quality. Higher sugar and organic acid content improves the quality of tomato fruits (Davies and Hobson 1981). In tomatoes, carotenoids contents, especially of lycopene, significantly increase during maturation and ripening on or off the plant (Carrillo-Lopez and Yahia, 2010), and the magnitude of carotenoid accumulation depends on various factors such as temperature and light intensity (Von Elbe and Hschwartz, 1996). Temperatures ranging between 22 and 25 °C give the most favorable rate of lycopene production, which is further enhanced by sunlight (Lumpkin, 2005). According to some authors (Farkas, 1994), lycopene production is inhibited when environmental temperature is above 32 °C. Although the formation of carotenoids in mature fruits does not require induction by light, shaded fruits have lower content of carotenoids (Dorais et al., 2001). The aim of this work was to study the quality of tomato fruits from screen-house (only color shade nets) and plastic-house (integrated with color shade nets) during summer season in south Serbia.

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Materials and methods

Tomato (*Lycopersicon esculentum*, cv. 'Vedeta') was tested in plastic-house production (simple plastic tunnels 2.0 m high, covered by termolux 150 μ) and open field conditions during 2008-2009. The experiments were performed at the experimental field located in the village of Moravac near Aleksinac, (Longitude: 21°42' E, Latitude: 43°30' N, altitude 159 m) in the central area of south Serbia. The shade nets were applied at the start of warm weather in early June. The shading nets were mounted on a structure about 2.0 m height over the plants (screen-house) or combined with plastic-house technologies. A completely randomized block design was used, with four blocks assigned to each of four treatments (black, pearl, blue and red net) plus control. Each treatment and block consisted of four rows with 20 plants (plant density was 2.6 plants m^{-2}). The plants were grown following the technique that is usually implemented by the local producers. Seedlings were transplanted on beginning of May 5 and 10 and the shading nets were subsequently installed above the crop on June 10 and 15 (35 days after transplanting), while the measurements were carried out until September 5 to 10. All plants were irrigated using drip irrigation. The tomatoes used in the study were harvested at the mature-pink stage. In order to test the effect of shading nets (color and shading intensity), four different shading nets were used: the photoselective nets including "colored-ColorNets" (red, blue and black) as well as "neutral-ColorNets" (pearl) with shading intensity of 40% photosynthetically active radiation (PAR) were compared to the open field microclimate and production. The color shade nets were obtained from Polysack Plastics Industries (Nir-Yitzhak, Israel) under the trade mark ChromatiNet. Tomato samples (20 fruits) were collected each year from June till August and were taken from the third to sixth floral branches. All analyzes were carried out in the Technological Faculty of Novi Sad, Serbia. Determination of total soluble solids (TSS) was performed by a digital refractmeter (Atago, Japan). The results were reported as °Brix at 20 °C. In extracted fruit juice pH-values were measured by a pH meter. The titrable acidity (TA) was measured with 5 ml aliquots of juice that were titrated at pH 8,1 with 0,1N NaOH (required to neutralize the acids of tomatoes in phenolphthalein presence) and the results were expressed as citric acid percentages. After pigments extraction from tomato fruits (method by Cvetkovic and Markovic, 2008) performance preparation of extracts for analysis. HPLC analysis of β-carotene and lycopene contents was carried out with the Agilent 1100 Series system, Waldborn Gemany (pump, detector, software). The LC column Zorbax-Eclipse XDB-C18; 4.6×250 mm, 5 μm was used, with a mobile phase consisting of a mixture of acetonitrile: methanol: ethyl acetate, at a flow rate of 1 cm^3/min. The injection volume was 20 μl using the detector DAD Agilent 1200 Series at 470 nm wavelength. The extracts (1 cm^3) of different concentrations were evaporated to dryness with rotary vacuum evaporators at room temperature and the residues were dissolved in mobile phase (acetonitrile: methanol: ethyl acetate, 3:2:2 v / v) to a concentration of 1 mg/cm3. Extracts were filtered through 0.45 μm Millipore filter before the HPLC analysis.

Standards of β-carotene and lycopene were dissolved in mobile phase (eluent: acetonitrile: methanol: ethyl acetate, 3:2:2 v / v) just before HPLC analysis. From these standards, a series of solutions of appropriate concentration for the calibration curve were made. The external standard method was used for the qualitative and quantitative determination of β-carotene and lycopene. A calibration curve representing the dependence of the peak area (of standard compound) in chromatograms on standard concentrations were made. Based on the obtained linear regression equation, the concentrations of the tested components in the extracts were determined. The data were analyzed by analysis of variance (ANOVA) followed by Tukey's HSD test, using the Statistica 6.1 software (Statsoft, Tulsa, OK, USA). All analyses were performed at a 95 % level of confidence ($p<0.05$).

Results and discussion

The total soluble solid (TSS) content observed in fruits analyzed in this work varied between 4.55 – 5.43 °Brix Loures (2001) found a TSS content of 4.77 and 4.95 for tomato grown in the field and in a protected environment, respectively. It was well known that shading decreased sugar content of tomato fruit. Similar results were observed in °Brix during this experiment. Fruits produced in the field had higher TSS:TA ratio acidity, had more reducing sugar, and TSS than those produced in the protected conditions. Fruit pH generally has an inverse relationship with TA. Tomatoes are still classified as an acidic fruit (pH <4.6) thus, in presented experiment pH- value was 3.9 to 4.2. Low pH is associated with high fruit quality (Davies and Hobson 1981).

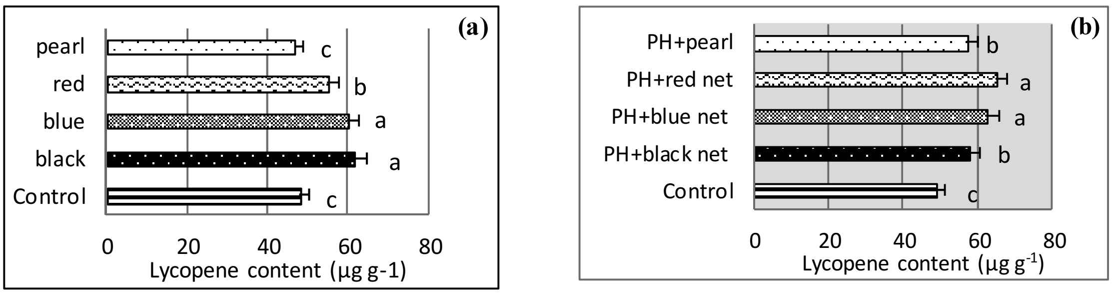
Table 1. Tomato fruits quality from screen-house (only color shade nets) and plastic-house integrated with color shade nets

	Total invert %	D. M. %	TSS ^{0}B	pH-values	TA	Saharose %
Screen-house - Red nets	2.59	6.32b	5.00b	3.94b	0.43a	2.46
Screen-house -Black nets	2.65	6.55a	5.06b	4.03b	0.40a	2.52
Screen-house -White nets	2.47	6.43a	4.60c	4.21a	0.36b	2.35
Screen-house -Blue nets	2.65	6.35b	4.55c	4.13a	0.36b	2.52
Control/Open field	2.53	6.24b	5.43a	4.16a	0.33b	2.40
Significance	ns	*	*	*	*	ns
Plastic-house + Red nets	2.53	5.92c	4.81b	4.12a	0.34	2.40
Plastic-house + Black nets	2.59	6.33b	5.18a	3.97b	0.40	2.41
Plastic-house + White nets	2.53	6.40b	5.20a	3.96b	0.38	2.41
Plastic-house + Blue nets	2.59	6.38b	5.23a	4.07a	0.35	2.46
Control / Plastic house	2.53	7.17a	5.10a	4.05a	0.37	2.40
Significance	ns	*	*	*	ns	ns

D.M.- Dry matter; TSS - Total soluble solids; TA - Total acid; Different letters indicate significant differences at P < 0.05 (Tukey's test)

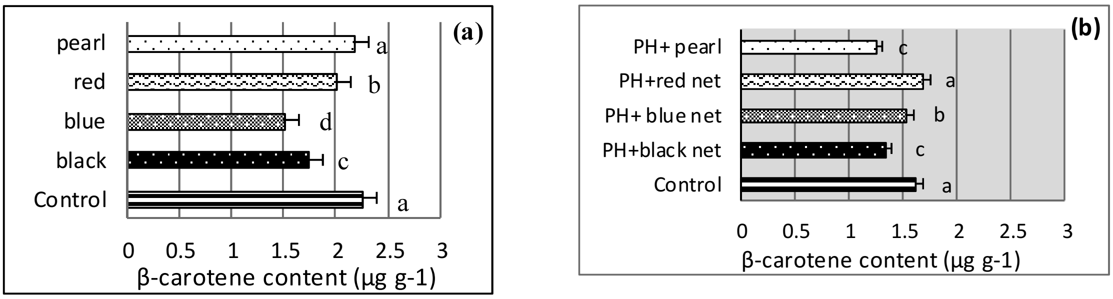
The quality of fruits harvested during the hot summer was characterized by high titratable acidity. However, the effect of shading on the acidity was not clear in this experiment. Sakiyama (1968) reported that titratable acidity was increased by high air temperature but unaffected by shading, just as we found. In fresh tomatoes the rate of lycopene synthesis is completely inhibited at 32-35 °C but not that of *β*- carotene. It was postulated that high temperatures (35 °C) specifically inhibit the accumulation of lycopene because they stimulate the conversion of lycopene into *β*-carotene (Dumas et al., 2003). No significant differences in lycopene contents were observed in tomatoes grown in plastic houses (48.9 μg g^{-1}fw) compared to control, open field conditions (48.1 μg g^{-1}fw). The highest concentration of lycopene was detected in tomatoes grown in plastic houses integrated with red color nets (64.9 μg g^{-1}), while fruits grown in fields covered with pearl nets had the lowest levels of lycopene (46.7 μg g^{-1}).

Similar results were found by López et al., (2007), who showed that the lycopene content of tomatoes grown under red and pearl frame nets were 51 and 37 μg g^{-1}, respectively. These values are similar to those reported by Martínez-Valverde et al., (2002) in Spanish commercial tomato varieties. Only tomatoes grown under pearl net had lower lycopene content than those reported by Gomez et al. (2001) in field-grown tomatoes. This fact could be attributed to two abiotic factors, temperature and light quality.



Control (open field) **Control (plastic house); PH-plastic house**

Figure 1. The average content of lycopene in tomato fruits from screen-house (only color shade nets - a) and plastic-house integrated with color shade nets (b); Different letters indicate significant differences at P < 0.05 (Tukey's test)



Control (open field) Control (plastic house); PH-plastic house

Figure 2. The average content of β-carotene in tomato fruits from screen-house (only color shade nets - a) and plastic-house integrated with color shade nets (b); Different letters indicate significant differences at $P < 0.05$ (Tukey's test)

Tomato fruits grown in open field (control) and under pearl net had significantly more β-carotene 2.25 µg g^{-1} and 2.17 µg g^{-1} respectively, than fruits grown under blue nets (1.50 µg g^{-1}). Tomato fruits grown in a plastic house-control (1.61 µg g^{-1}) and under integrated plastic house with red net (2.01 µg g^{-1}) had significantly more β-carotene level than fruits grown under plastic house covered by black (1.33µg g^{-1}) or pearl net (1.25µg g^{-1}) Figure 2. Achieved results should provide useful preliminary data for detecting differences among environment variation in lycopene and β-carotene content and color shade nets.

Conclusions

Changing the light intensity (with 40% shade) and radiation spectrum (color net) has a large impact on the tomato fruit quality. There are differences in fruit quality were observed in tomatoes grown in plastic houses compared to open field conditions or between fruits from screen-house (color shade nets) and plastic-house integrated with color shade nets. The lycopene content of plastic-house grown tomatoes integrated with color shade nets was higher than content at tomatoes grown in the plastic-house and open field.

References

Andriolo, J.L., Streck, N.A., Buriol, G.A., Ludke, L., Duarte, T.S. (1998). Growth, development and dry matter distribution of a tomato crop as affected by environment. Journal of Horticultural Science and Biotechnology. 73: 125-130.

Carrillo-Lopez, A., Yahia, E.M. (2010). Qualitative and quantitative changes in carotenoids and phenolic compounds in tomato fruit during ripening. Acta Horticulture. 877: 1303-1308.

Caliman. F. R. B., da Silva, D. J. H., Stringheta, P.C., Fontes, P. C. R., Moreira. G. R., E. C. Mantovani (2010). Quality of tomatoes grown under a protected environment and field conditions. Idesia (Chile). 28: 75-82

Cvetkovic, D., Markovic, D., (2008). UV-induced changes in antioxidant capacities of selected carotenoids toward lecithin in aqueous solution. Radiation Physics and Chemistry. 77: 34–41.

Davies, J.N.; Hobson, G.E. (1981). The constituents of tomato fruit - the influence of environment, nutrition, and genotype. Critical Reviews in Food Science and Nutrition. 15: 205-280.

Dorais, M., Papadopoulos, A.P., Gosselin, A. (2001). Greenhouse tomato fruit quality. Horticultural Reviews. 26: 239-319.

Dumas, Y., Dadomo, M., Di Lucca, G., Grolier, P. (2003). Effects of environmental factors and agricultural techniques on antioxidant content of tomatoes. Journal of the Science of Food and Agriculture. 83: 369-382.

Farkas, J. (1994). *Paradicsom* (Tomato), Mezögazda Kiadó, Budapest, pp. 195-225.

Gomez, R., Costa, J., Amo, M., Alvarruiz, A., Picazo, M., Pardo, J.E. (2001). Physicochemical and colorimetric evaluation of local varieties of tomato grown in SE Spain. Journal of the Science of Food and Agriculture. 81: 1101-1105.

Ilić, Z., Milenković, L., Đurovka M., Kapoulas. N. (2011). The effect of color shade nets on the greenhouse climate and pepper yield. 46th Croation and 6th InteR. Symp. on Agriculture. Opatija, Croatia. Symposium Proceedings pp. 529-533.

Kader A.A. (1986). Effects of postharvest handling procedures on tomato quality. Acta Horticulturae. 190: 209-221.

López, D., Carazo, N., Rodrigo, M.C., Garcia, J. (2007). Coloured shade nets effects on tomato crops quality. Acta Horticulture. 747: 121-124.

Loures, J.L. (2001). Estabelecimento e avaliação do sistema de produção denominado Fito, em estufa e campo. Ph.D.Thesis. Universidade Federal de Viçosa, Viçosa, Brazil. 109 pp.

Lumpkin, H.A. (2005). Comparison of lycopene and other phytochemicals in tomatoes grown under conventional and organic management systems. Technical Bulletin No. 34. AVRDC 05-623.Taiwan, pp. 48.

Martínez-Valverde, I., Periago, M.J., Provan, G., Chesson, A.(2002). Phenolic compounds, lycopene and antioxidant activity in commercial varieties of tomato (*Lycopersicum esculentum*). Journal of the Science of Food and Agriculture. 82: 323-330.

Papadopoulos, A. P. (1991). Growing greenhouses tomatoes in soil and in soilless media. Agic. Agri-Food Can. Publ. 1865/E, 79 pp.

Sakiyama, R. (1968). Effects of irrigation, temperature and shading on the acidity of tomato fruits. J. Japan. Soc. Hort. Sci. 37: 67–72.

Von Elbe, J., Hschwartz, S.J.(1996). In Colorants in Food Chemistry (R. Owen and E. Fennema, Eds.), Marcel Dekker, Inc., New York, Basel, Hong Kong. pp. 685–691.

Winsor, G.W. Adams, P. (1976). Changes in the composition and quality of tomato fruit throughout the season. Ann Rep Glasshouse Crops Res Inst. 1975: 134–142.

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