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Influence of photo-selective netting on fruit quality parameters and bioactive compounds in selected tomato cultivars

Peter Phushdi Tinyane, Dharini Sivakumar*, Puffy Soundy

Department of Crop Sciences, Tshwane University of Technology, Pretoria 0001, South Africa

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ABSTRACT

Tomato fruit quality for fresh consumption is determined by size, colour, firmness, flavour, aroma and nutritional properties. Choice of tomato cultivar is important in terms of fruit quality and bioactive compounds. The aim of this study is to verify the influence of photo-selective nettings on fruit quality and nutritional properties of tomato cultivars. Three types of photo-selective nets (red, yellow and pearl with 40% shading) were compared with commercial black net (25% shading) for fruit quality parameters [firmness, soluble solids concentration, titratable acidity, fruit mass, CIE-Lab colour parameters (L^*, a^*, b^*] bioactive compounds (ascorbic acid, lycopene, β-carotene, total phenols) and total antioxidant activity in three tomato cultivars (AlfaV, Irit and SCX 248) at harvest. Principle component analysis illustrated cv. AlfaV fruits under black nets were lower in mass, less firm, higher in bioactive compounds and soluble soild concentration (SSC) but lower in titratable acidity (TA) and intense in red colour. However, under pearl nets cv. AlfaV showed higher fruit mass, firmness and moderately higher bioactive compounds. Cultivar SCX 248 fruits under red nets were moderate in size, firmness, and bioactive compounds in comparison to the other nets. Cv. Irit fruit under all net types were small, less firm, low SSC, higher in TA while the black nets increased their bioactive compounds. Significant correlations were observed between bioactive compounds and the air temperature and photosynthetic active radiation. Cultivar AlfaV grown under the red net showed higher number of odour active aroma compounds in fruit while yellow nets significantly affected the synthesis of odour active aroma compounds. Pearl and red photo-selective nets improved the overall fruit quality; fruit mass, fruit firmness and bioactive components in cv. AlfaV and cv. SCX 248 respectively and can be further implemented within protected cultivation practices.

1. Introduction

Tomatoes (*Solanum lycopersicum*) are a rich source of carotenoids (especially lycopene, β-carotene – a precursor of vitamin A), phenolics (flavonoids), vitamin C and trace amounts of vitamin E (Betancourt et al., 1977; Khachik et al., 2002; Vinson et al., 1998). Lycopene is responsible for the red colour in tomatoes. A 100 g tomato was reported to provide 20–40% of the U.S. recommended daily recommended intake (DRI) for vitamin A and C (Betancourt et al., 1977). In ripened tomatoes, rutin [quercetin 3-*O*-rutinoside; quercetin3-(6-rhamnosylglucoside)] has been reported to be the major flavonoid compound (Davies and Hobson, 1981; Slimestad and Verheul, 2009). Lycopene, carotenoids and flavonoids have been known to show protective effects against cancers and cardiovascular diseases (Rao and Agarwal, 2000; Levy and Sharoni, 2004; Andersen and Markham, 2006). Lycopene, carotenoids and flavonoids act as a strong antioxidant that protects cells from reactive oxygen species (Spencer et al., 2005).

Tomato fruit quality for fresh consumption is determined by size, colour, firmness, flavour, aroma and nutritional properties. The reducing sugars (glucose and fructose) and organic acids (citric and malic acids) are responsible for the sweet-sour taste of tomatoes. Tomato flavour is also linked to the ratio of reducing sugars to organic acids (Bucheli et al., 1999) and aroma volatiles. The odour active volatiles (3-methylbutanal, (Z)-3-hexenal, hexanal, 1-octen-3-one, methional, 1-penten-3-one, 3-methylbutanal, trans-2-heptenal, 6-methyl-5-hepten-2-one, 2-isobutylthiazole, phenyl acetaldehyde, methylsalicylate, 2-phenylethanol, geranyacetone, and β-ionone, furaneol, linaool, methional, citral, 2,4 decadienal) contribute to fresh tomato aroma (Tandon et al., 2001).

Antioxidants and minerals were shown to vary according to the cultivar and crop management practices (Dorais, 2007). The health promoting compounds in tomatoes are also influenced by the maturity stage at harvest (Helyes and Lugasi, 2006). Moreover, interaction effects were reported with respect to the bioactive

* Corresponding author. Tel.: +27 12 382 5303; fax: +27 12 382 5869.
E-mail addresses: dharinisivakumar@yahoo.co.uk, SivakumarD@tut.ac.za (D. Sivakumar).

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compounds and cultivars, environmental factors (light and temperature) and crop management practices (Dorais, 2007). The use of shading nets for cultivation of agricultural crops is becoming a popular non-chemical approach and aims to provide physical protection from weather conditions (excessive solar radiation and temperature), or environmental hazards (wind and hail) or birds and insects transmitting viral diseases, together with promoting desired physiological responses linked to light quality. The photo-selective nettings contain spectral filters with differential light scattering properties and altered proportions of red/far-red waveband (R/FR) ratio (Fletcher et al., 2005). The actual functions of colour shade net depend on chromatic additives to the plastic and the knitting design (Shahak, 2012). The physiological responses linked to light quality include fruit-set, size, weight, colour, and harvest time (Shahak et al., 2004, 2008; Rajapakse and Shahak, 2007). Furthermore, it is also reported that the truss appearance and flowering rate are affected by temperature (Zoltán and Helyes, 2004).

Tomato production under photo selective shade net has shown to increase marketable yield and to protect the fruit from physiological disorders such as sunscald injury (El-Gizawy et al., 1992; El-Aidy and El-Afry, 1983), blossom end rot and cracked skin (Lorenzo et al., 2003). Use of photo selective shade netting decreases the light quantity and also alters light quality to a varying extent, and causing a change in thermal climate (Elad et al., 2007).

The biosynthesis of lycopene is affected by air temperature and sunlight. Exposure of fruits to excessive sunlight was reported to inhibit the synthesis of lycopene (Brandt et al., 2006). Brandt et al. (2003) stated that the growing methods such as water supply, open field or greenhouse conditions affected the lycopene content in tomatoes and the lycopene content varied between cultivar types (Daniela, cherry tomato and Delfine F1).

The optimum temperature for lycopene synthesis is between 22° and 25 °C (Dumas et al., 2003; Lumpkin, 2005). Higher temperatures were reported to reduce the vitamin C content in fruit and vegetable crops (McKeon et al., 2006). Also, growing tomato without shading under slight water stress and strong light intensity predicated increased sugar content and antioxidant compounds. Bertin et al. (2000) reported higher sugar content in tomato fruit grown during summer with increased sweetness in tomatoes. On the other hand, antioxidants in fruit and vegetable crops can also be altered by exposure to high temperatures during the growing season. Recently, the aroma volatiles in tomatoes such as (Z)-3-hexenal, 3-methylbutanol and 6-methyl-5-hepten-2-one were reported to increase in tomato fruits of shaded plants (Krumbein and Schwarz, 2012).

Effect of photo-selective netting on lycopene content was reported by Gomez et al. (2001) and Lopez et al. (2007). Ilić et al. (2012) reported the effect of photo-selective netting on lycopene and β-carotene contents in tomato cv. Vedeta. With the consumer and grower's concern about fresh produce quality, the quality and quantity values of radiation and microclimate parameters under the photo-selective netting technology should be correlated with crop performance and produce quality (Stamps, 2009).

However, little information is available on the influence of photo-selective shade netting on overall fruit quality parameters, bioactive compounds and odour active aroma compounds at harvest in different tomato cultivars. On the other hand, the use of shading in horticulture production is becoming popular due to the increase in temperature during summer.

Therefore, the objective our study was to investigate the effect of different colour photo- selective netting in comparison to the commercially used black net on (1) overall quality parameters (SSC, TA, fruit mass and firmness), (2) bioactive compounds (ascorbic acid, total phenols, flavonoid, lycopene, β-carotene contents) and antioxidant scavenging activity at harvest in three commercial tomato cultivars grown in South Africa and (3) to determine the influence of photo-selective netting on odour active aroma compounds of tomato cv. AlfaV.

Table 1
Nutrient composition of fertilizer applied during tomato production.

Period	Composition (%, w/v)
Transplant to 1st flower truss	0.05 (1.39 kg hydroponics ® and, 1.11 kg $Ca(NO_3)_2$)
1st flower truss to 3rd flower truss	0.08 (2.4 kg hydroponics ® and, 1.6 kg $Ca(NO_3)_2$)
3rd flower truss to end	0.12 (3.125 kg hydroponics ® and, 2.095 kg $Ca(NO_3)_2$, 0.78 kg KNO_3)

2. Materials and methods

Tomato cvs. AlfaV, Irit and SCX 248 were grown during 2011 and 2012 seasons in a tunnel (5 m high), covered with photo-selective shade nets (pearl yellow and red) and a black (control) net. The study was conducted at Tshwane University of Technology, Experimental Farm, Bon-Accord, Pretoria North (latitude: 25°37′S, longitude: 28°12′E, altitude 1173 m). The colour-nets (ChromatiNet$^{(TM)}$) were manufactured by Polysack Plastic Industries in Israel, placed as permanent structures. A completely randomized block design was used, with three replicate nets assigned to each of the four treatments (red, pearl, yellow and black control net). Black net is used commercially in South Africa for production of fruits and vegetable. Each treatment and block consisted of eight rows of 36 plants. The three cultivars were replicated three times in a Latin square layout within each net.

2.1. Planting materials

Three indeterminate tomato cvs. AlfaV, Irit and SCX 248, were used in this study. The seedlings were obtained from Seedcor (Pty, Ltd) South Africa. The plants were grown following the technique usually implemented by the local producers. The seedlings were transplanted into 5 L black polyethylene bags using coir-sand as a growing medium (plant density was 2.88 plants m^{-2}). All plants were irrigated using drip irrigation. The nutrient solutions for irrigation were mixed in a 5000 L tank as presented in Table 1. The hygroponic® fertilizer was supplied by Hygrotech Pty. Ltd., Pretoria South Africa.

2.2. Coloured net characteristics

In order to test the effect of photo-selective nets (ChromatiNet$^{(TM)}$, Israel) four different shading nets were used: the photo-selective nets included 'coloured-ColorNets' (red, yellow) as well as 'neutral-ColourNets' (pearl) and the traditional black net that is used commercially for tomato production (used as a control 25%). The shading intensity of red, yellow and pearl nets were 40%. The nets are unique in that they both modify the non-visible spectrum and enhance light scattering. The photo-selective nets are based on the incorporation of various chromatic additives, light dispersive and reflective elements into the netting materials during manufacturing. The shading nets were mounted on a steel structure (12 m × 12 m) about 5 m in height over the plants and the dimension of the tunnels.

2.3. Light interception by nets and microclimate measurements

Photosynthetically active radiation (PAR) (400 ± 700 nm) outside and under the nets was measured weekly using a Ceptometer