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Postharvest responses of red and yellow sweet peppers grown under photo-selective nets

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ABSTRACT

Postharvest responses of red ('HTSP-3') and yellow ('Celaya') sweet pepper fruit yield, quality parameters and bioactive compounds (to three types of photo-selective nets and a standard black net) were investigated in this study. Red and yellow peppers produced under the black net retained higher β-carotene, lower total phenolic contents and showed deep red and orange colour after storage. Both peppers produced under the pearl net retained a higher ascorbic content, antioxidant scavenging activity, fruit firmness and also reduced weight loss after storage. Red and yellow peppers grown under pearl and yellow nets resulted in a higher percentage of marketable fruit, after storage. Red pepper grown under the yellow net showed a higher number of odour active aroma compounds in the fruit, while black nets significantly affected the synthesis of odour active aroma compounds during storage. Sensory analysis indicated a preference for red pepper fruits after storage from plants grown under pearl nets.

1. Introduction

Sweet or bell peppers (*Capsicum annum* L., family Solanaceae) are a rich source of ascorbic acid, flavonoids, phenolic acids and carotenoids, known as antioxidants (Castro, Saraiva, Lopes-da-Silva, Deladillo, Van Loey, Smout, 2008). These antioxidants have been proven to prevent certain types of cancers, cardiovascular diseases, atherosclerosis and a delay in the ageing process (Simonne, Simonne, Eitenmiller, Mills, Green, 1997). Consumers prefer fresh sweet peppers that are free from decay, insect infestation or mechanical injury, have a uniform size, colour, firmness and crispness (Maalekuu, Elkind, Tuvia-Alkalai, Shalom, & Fallik, 2004). The taste of sweet peppers is determined by the sugar and organic acid contents (Kong et al., 2013). Aroma and odour active compounds, such as 2,3-butanedione 1-penten-3-one, hexanal, 3-carene, (Z)-β-ocimene, octanal and 2-isobutyl-3-methoxyyrazine, (E)-2-hexen-1-ol (Luning, de Rijk, Wichers, & Roozen, 1994), (Z)-linalool-oxide (Luning et al., 1994), (Z)-2-penten-1-ol, (E)-geranylacetone (Mosciano, 1998), (*E,Z*)-2,6-nonadienal, and (*E,E*)-decadienal, have been reported to influence the flavour of sweet peppers.

Fruit softening and shrinkage, due to water loss and pathological decay, also affects the quality and acceptability of green sweet peppers during postharvest storage. Photo-selective shade nets provide physical protection against hail and wind, and are also proven to improve plant growth, marketable yield and product quality in different horticultural crops (Shahak, 2008). Photo-selective shade nets have the ability to modify the light quality by increasing the relative proportion of diffuse light (scattered) and also by absorbing different spectral bands (Shahak, Gal, Offir, & Ben-Yakir, 2008). Although few reports are available on photo-selective shade nets on the yield and quality parameters of peppers (Kong et al., 2013), their impacts on the bioactive compounds of red and yellow sweet peppers has not been fully investigated. Therefore, the objective of this study was to investigate the effect of different coloured photo-selective shade nets (pearl, red and yellow) in comparison to the commercially used black net on (1) overall quality parameters (SSC, TA, fruit mass, firmness and sensory parameters), (2) bioactive compounds (ascorbic acid, total phenols, flavonoid, carotenoids, β-carotene and lycopene contents) and antioxidant scavenging activity (of sweet pepper cultivars 'HTSP-3' (red) and Celaya (yellow)) during postharvest storage, and (3) to investigate the odour active aroma compounds and the sensory quality of red sweet pepper 'HTSP-3' during postharvest storage.

2. Materials and methods

2.1. General

This study was conducted during the 2011–2012 growing seasons in tunnels (5 m high, 12 m length and 12 m width) covered

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with photo-selective coloured nets [ChromatiNet(™), (Polysac Plastics Industries (Pty) Ltd.), Israel] at the Tshwane University of Technology (TUT) Experimental Farm (latitude: 25° 37′ S, longitude: 28° 12′ E; elev. 1173 m above sea level).

2.2. Planting materials

Sweet pepper (cultivar 'HTSP-3' or Celaya) seedlings were obtained from Seedcor (Pty, Ltd.) South Africa, and transplanted into 5 L black polyethylene grow bags filled with a coir-sand growing medium. Plants were grown following typical commercial practices for protected culture production used by local growers. Plants were irrigated daily using drip irrigation system, and were fertilised using a soluble complete nutrient solution (Hygrotech®, Pretoria, South Africa).

2.3. Light interception by nets and microclimate measurements

The growth tunnels were covered with three different photo-selective, coloured shade nets namely: 'Coloured-ColourNets' (red, yellow, 40% shading) and 'neutral-ColourNet' (pearl, 40%. shading). The commercial black net (25% shading) was used as a control. Photosynthetically active radiation (PAR) (400 ± 700 nm outside and inside the nets above the plant canopies) was measured weekly using a Ceptometer (AccuPAR model LP-80; Decagon Devices Ltd., USA). Air temperature (T) and relative humidity (RH) were also recorded using Tinytag T/RH data loggers (Gemini data loggers Ltd., UK) (Table 1).

2.4. Postharvest storage

Sweet pepper fruits, HTSP-3 and Celaya, were harvested four times at ripe red and yellow stages, respectively, from January to March during 2011 and during the summer of 2012. For postharvest quality evaluations, disease- and defect-free uniform fruits (n = 300) were selected from each net treatment. A set of eight fruits were packed in commercial polypropylene packaging (with 2 cm holes) and stored at 7.5 °C and 90% RH for 21 days, and thereafter for 3 days at 20 °C (~70–75% RH) to simulate retail shelf conditions (postharvest storage). At the end of postharvest storage, fruits were evaluated for fruit weight loss and quality parameters (firmness, colour, soluble solid content and titratable acidity), bioactive compounds (ascorbic acid, lycopene, β-carotene, total phenols, flavonoid contents), antioxidant scavenging activities, odour active compounds and sensory parameters. After postharvest storage the percentage of marketable fruits was recorded. Marketability of the fruits was determined based on absence of shrivelling, decay and red colour development due to initiation of ripening. Incidence of decay after postharvest storage was expressed as a percentage of the total initial fruit number. Fruits with fungal mycelia on the skin or calyx were considered as decayed fruits.

Table 1
Air temperature relative humidity and photo synthetically active radiation measurements under different photo-selective nets and the control net throughout the sweet pepper production period.

Type of shade net	Air temperature (°C)	Relative humidity (%)	Photosynthetically active radiation (μmol m^{-2} s^{-1})
Yellow	36.00 ± 1.055*a	30.47 ± 2.309c	432.1 ± 9.46b
Pearl	35.26 ± 0.779ab	33.04 ± 1.433bc	401.2 ± 6.00c
Red	33.75 ± 0.998b	35.00 ± 2.440ab	365.2 ± 4.03d
Black net	31.67 ± 0.486c	37.00 ± 0.721a	641.5 ± 4.59a

Different letters in the same column indicate statistically significant differences (sign. level P < 0.05).

2.5. Fruit quality analysis

Fruit colour was objectively measured at harvest and after postharvest storage with a Minolta CR-400 chromameter (Minolta, Osaka, Japan). Fruit surface colour measurements were taken at two marked points on opposite sides at the equatorial region of the fruit (Kong et al., 2013). The chromameter was calibrated with a standard white tile. In the CIE colour system, positive a^* values describe the intensity of red colour, positive b^* values, lower hue angles ($h°$) or higher *chroma** describe the intensity of yellow colour and the L^* values describe lightness.

Fruit firmness measurements were taken at two points per fruit according to Kong et al. (2013). Soluble solid concentrations (SSC) of each fruit were determined using a refractometer (Atago Co., Tokyo, Japan) and expressed as a percentage. Titratable acidity (TA) was determined according to Kong et al. (2013) by titrating 5 ml of pepper juice with 0.1 N NaOH, using phenolphthalein as an indicator and expressed as a % of malic acid.

2.6. Determination of bioactive compounds

The ascorbic acid content was determined according to Tinyane, Sivakumar, and Soundy (2013) and expressed as mg per 100 g of fruit. β-carotene and lycopene were determined according to the methods described by Nagata and Yamashita (1992) and modified according to Tinyane et al. (2013). The acetone: n-hexane (4: 6 ml v/v) mixture was used as blank and the assays were carried out in triplicate.

Total phenolic contents were determined according to Singleton, Orthofer, and Lamuela-Raventos (1999) and Tinyane et al. (2013). Total phenolic content was quantified using a 9 μl aliquot of pepper extract mixed with 109 μl of Folin–Ciocalteau reagent, and the results were expressed as mg of gallic acid equivalents (GAE) 100 g^{-1} FW. The flavonoid content was determined as described by Zhishen, Mengcheng, and Jianming (1999), using the Microplate Reader (Zenyth 200rt Microplate Reader UK-Biochrom Ltd.) method according to Tinyane et al. (2013). Flavonoid content was calculated using a standard curve of quercetine and expressed as mg of quercetine equivalents 100 g^{-1} FW.

Antioxidant scavenging activities were determined by using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Kong et al., 2013). Pepper pericarp samples were macerated in n-hexane and methanol extracts. A decline in absorbance at 515 nm was measured using a Microplate Reader (Zenyth 200rt Microplate Reader UK-Biochrom Ltd.) after 60 min (Kong et al., 2013). Antioxidant scavenging activities were expressed as EC 50 (sample required to reduce the absorbance of the radical by 50%) in mg of gallic acid equivalent per gram of fruit.

2.7. Aroma volatile analysis

Aroma volatile profiles were determined from a set of 20 fruits for red (HTSP-3) and yellow (Celaya) sweet peppers for each replicate shade net after postharvest storage. Extraction of volatiles was carried out using the head-space micro-extraction (SPME fibre holder containing a 50/30 μm DVB/ CAR/ PDMS/ fibre, Supelco Inc., Bellefonte, PA, USA) method previously described by Tinyane et al. (2013) based on Marković, Vahčić, Kovačević and Banović (2007). The volatile compounds were desorbed by inserting fibre into the glass-lined splitless injector port of the GC (Agilent 7890, CA, USA) (coupled with a 5975 mass selective detector) (Tinyane et al., 2013). The identities of observed volatiles were confirmed by comparing the collected mass spectra with those of authenticated chemical standards (Sigma Aldrich, Fluka Johannesburg, South Africa) and to a reference spectra in a mass spectral library (NIST Version 2.0).