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The influence of hot air treatment and UV irradiation on the quality of two tomato varieties after storage

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ABSTRACT

The influence of hot air and ultraviolet (UV) radiation on the sensory quality of tomatoes after storage was compared. Two tomato varieties ("Zouk" and "Camry") were harvested in turning ripening stage and treated with hot air (60 °C) or UV radiation. Fruits were stored for 14 days in semi-controlled conditions (temperature range 14.4–19.9 °C, relative humidity range 35–55%), while non-treated tomatoes stored under the same conditions were used as a control. Sensory evaluation of samples was performed by trained panel, and instrumental measurements of color and texture were also carried out. Both postharvest treatments were effective in preventing tomato fruit spoilage. Hot air treatment resulted in better quality of tomato fruits in terms of sensory properties after two weeks of storage, but the UV irradiation resulted in favorable effects in terms of extension of tomato shelf life because it led to delayed ripening of tomato.

1. Introduction

Fresh tomato (*Solanum lycopersicum* L.) is one of the most widely grown vegetable crops in the world, with global tomato production exceeding 161 million tonnes per year (FAO, 2012). However, tomato is climacteric and very perishable fruit, susceptible to microbial infection as a result of rapid ripening at ambient conditions which facilitate pathogen development (Maharaj, Arul, & Nadeau, 1999; Pinheiro, Alegria, Abreu, Gonçalves, & Silva, 2013Maharaj, Arul, & Nadeau, 1999; Pinheiro, Alegria, Abreu, Gonçalves, & Silva, 2013). Low temperatures are effective in delay of these physiological changes, but it is not possible to apply them since tomatoes are susceptible to chilling injury (Maharaj et al., 1999; Luengwilai, Beckles, & Saltveit, 2012). Different technologies have been used to extend the postharvest life of tomato (Tzortzakis, 2010; Pinheiro et al., 2013). The chemicals such as chlorinated water have been used as disinfectants for horticultural crops (Tzortzakis, 2010). However, the use of chlorine has been associated with the formation of carcinogenic compounds; in addition, it has been shown that some pathogens gained resistance to these compounds (Bermúdez-Aguirre & Barbosa-Cánovas, 2013).

The interest for postharvest heat treatments has been increased in the last two decades, partly because of the growing demand to decrease the postharvest use of chemicals for decay and insect control (Lurie, 1998; Ferguson, Ben-Yehoshua, Mitcham, McDonald, & Lurie, 2000). Heat treatments can also be used for prevention of chilling injury development and ripening process control (Lurie, 1998; Paull & Chen, 2000; Luengwilai et al., 2012). There are three methods used for postharvest heating of fruits: hot water, vapor heat and hot air. Hot air has been used for both fungal and insect control, and can be applied as static or with high flow rate; moreover, it can have humidity regulation (Lurie, 1998). Heat treatment has been shown to induce many physiological changes in tomato fruits. The high temperature treatment (38 °C) of tomatoes in duration of 3 days was shown to reversibly inhibit ethylene production, color development and fruit softening by decreasing expression of mRNAs related to ripening (Lurie, Handros, Fallik, & Shapira, 1996). The research of Soto-Zamora, Yahia, Brecht, and Gardea (2005) showed that heating of tomatoes in air at 34 °C and 50% RH for 24 h before storage at 10 °C for up to 30 days resulted in non significant heat injury and losses in antioxidant content, while fruit color developed normally. Uniformity of heating is also an important factor for chilling injury and color development in tomatoes, leading to uniform ripening of fruits as demonstrated by Lu, Charles, Vigneault, Goyette, and Raghavan (2010).

Ultraviolet (UV) radiation used for its germicidal activity has spectral peak emission at 254 nm and is called UV-C radiation (Maharaj et al., 1999; Liu, Jahangir, & Ying, 2012). UV-C is generally harmful but can produce several beneficial effects on horticultural crops at low doses, a phenomenon known as hormesis (the stimulation of beneficial responses by low levels of stressors which

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are otherwise detrimental) (Maharaj et al., 1999; Barka, Kalantari, Makhlouf, & Arul, 2000). Exposure of horticultural crops to UV-C light has been considered as an alternative to chemical fungicides for the control of postharvest diseases, since it is both harmful to spoilage organisms (bacteria and moulds) and can activate disease resistance in plants (Maharaj et al., 1999; Jagadeesh et al., 2011; Bravo et al., 2012). UV irradiation of tomatoes was found to induce reduction of cell wall-degrading enzymes activity and higher resistant of fruits to penetration, indicating that irradiation retards tomato fruits softening (Barka et al., 2000). Bu, Yu, Aisikaera, & Ying (2013) suggested that the inhibition of ethylene production, which down-regulated the expression of genes encoding cell wall degrading enzymes could be the mechanism of tomato fruit softening delay caused by UV-C radiation. UV-B radiation (spectral peak at 311 nm) was also exploited in several researches as possible postharvest treatment of tomato. The results of Liu et al. (2012) suggested that treatment of mature green tomatoes with UV-C or UV-B irradiation in appropriate doses prior to storage at 2 °C alleviated chilling injury. UV-C and UV-B treatment of ripe tomatoes during postharvest handling was successfully combined with modified atmosphere (MA) storage, resulting in a product that was minimally changed during storage and had higher antioxidant capacity (Vunnam et al., 2014). Moreover, UV-C radiation was shown to increase ascorbic acid, lycopene, and total phenolic content in tomato fruit (Jagadeesh et al., 2011; Liu, Zabaras, Bennett, Aguas, & Woonton, 2009; Bravo et al., 2012).

Quality attributes of fresh tomato which are the most important to consumers are skin color and texture (Batu, 2004; Liu et al., 2011). Color is the first characteristic that determines the degree of consumer acceptance, while firmness is the final quality attribute by which the consumer decides to buy fresh tomato (Pinheiro et al., 2013). Flavor is also an important factor for purchasing of fresh tomato (Krumbein, Peters, & Brückner, 2004; León-Sánchez et al., 2009), but in the last decades, commercial tomatoes have been criticized by consumers for lacking desirable flavor (Maul et al., 2000; Krumbein et al., 2004). This flavor problem is partly caused by the research focus on development of tomato cultivars with increased yields, greater disease resistance and longer shelf life (Maul et al., 2000; Hongsoongnern & Chambers, 2008). The other reasons stated in literature are that tomatoes are harvested at the mature-green stage (Kader, Stevens, Albright-Holton, Morris, & Algizi, 1977) and subjected to different storage treatments in order to prolong the shelf life (Maul et al., 2000).

In this context, the aim of this research was to compare the influence of hot air (60 °C during 60s) and UV radiation (16 h) treatments on the sensory quality of tomatoes after storage determined both by instrumental methods (color and texture measurement) and sensory evaluation by panel. Tomato varieties "Camry" and "Zouk", common in contemporary greenhouse production, were chosen for this study.

2. Material and methods

2.1. Material and storage conditions

Two tomato varieties ("Camry" and "Zouk"), grown in the commercial greenhouse (Gložan, Serbia), were used in this study. Tomato fruits were harvested at the turning stage of ripeness according to USDA standard (USDA, 1991) without calyx and transported to laboratory immediately. One batch was treated with hot air in the convective dryer at temperature of 60 °C during 60 s. Another batch was left overnight under germicidal UV lamp (EI Niš, Serbia) with radiation dose of4 kJ/m^2 per each tomato fruit. After treatments, all tomato fruits were placed in plastic trays and stored in semi-controlled conditions for 14 days. Storage temperature and relative humidity were measured twice a day, at 8:00 am and 2:00 pm. Their values ranged from 14.4 to 19.9 °C and from 35 to 55%, respectively. One tray of untreated tomatoes for each variety was stored at room conditions for 14 days and used as a control sample.

2.2. Sensory evaluation

Methodology applied for sensory evaluation was adapted from previous work by Belović et al. (2012). Additional panel discussion was held in order to determine which sensory properties are the most important for consumer's decision to purchase fresh tomato. Sensory evaluation of tomatoes was performed in two replications by six trained sensory panelists after storage period. Technique for intensity scaling, which includes labeling a mark on a line to indicate the intensity of appearance, color, hardness, odor and taste, was applied. The panelists made a mark on a numbered line (1–9) to indicate the intensity of the appropriate properties. Central reference point (5) was used to represent the value of a standard or baseline product on the scale. Values <5 indicated that certain sensory property had lower intensity than for standard product (red, fully ripe tomato), and values >5 that intensity of sensory property is higher than for standard product. Color value 5 was defined as red color of fully ripe tomato; color values <5 indicated less prominent red tone (as in tomato that is not fully ripe), and values >5 darker red color (as in overripe tomatoes). All samples were coded with three random numbers and presented simultaneously to the assessors. Water was used as a palate cleanser after each sample.

2.3. Color measurements

Color measurement of tomatoes before and after storage was performed by a Chroma Meter CR-400 (Konica Minolta Co., Ltd., Osaka, Japan). Five tomatoes per batch were chosen randomly for color measurement at six points (two locations between the equator and the stem; two on the equatorial region; and two between the equator and the blossom end). The results expressed as CIE L^* (lightness), CIE a^* ($+a^*$ = redness, $-a^*$ = greenness), CIE b^* ($+b^*$ = yellowness, $-b^*$ = blueness), and DWL (dominant wavelength, nm) were read using a D_{65} light source and the observer angle of 2°. The tristimulus values of CIE $L^*a^*b^*$ readings were calibrated against a standard white plate (Y = 84.8; x = 0.3199; y = 0.3377).

Chroma (C^*) and hue angle ($h°$), as derived color parameters, were calculated using the following equations (Arias, Lee, Logendra, & Janes, 2000):

$$C^* = (a^*2 + b^*2)^{1/2} \quad (1)$$

$$h^{\circ} = \arctan(b^*/a^*) \quad (2)$$

Total color change (ΔE) between samples stored for a different period was calculated according to the following formula (Ergüneş and Tarhan, 2006):

$$\Delta E = [(L^*{}_2 - L^*{}_1)^2 + (a^*{}_2 - a^*{}_1)^2 + (b^*{}_2 - b^*{}_1)^2]^{1/2} \quad (3)$$

2.4. Texture measurements

Textural analysis was carried out on three randomly chosen tomatoes from each batch using TA.XT Plus Texture Analyser (Stable Micro Systems, England, UK) before and after two week storage period. Penetration test was used to measure the skin strength of tomato fruit. Texture profile analysis (TPA) was