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Changes in major antioxidant components of tomatoes during post-harvest storage

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Abstract

The objective of this study was to study overall nutritional implication of storage on tomatoes (cv. Tradiro), harvested from a commercial greenhouse in Canterbury, New Zealand. The harvested tomatoes were stored at 7, 15 and 25 °C, for a period of 10 days. The soluble phenolics and ascorbic acid contents of tomatoes showed slight increases during storage, regardless of temperature. The mean lycopene content of tomatoes stored at 15 and 25 °C on the 10th day of storage was, approximately, 2-fold (7.5 mg/100 g) than of the tomatoes stored at 7 °C (3.2 mg/100 g). The soluble antioxidant activity increased from 17–27% during the storage period of tomatoes.

Keywords: Tomatoes; Post-harvest; Storage; Temperature; Soluble phenolics; Flavonoids; Ascorbic acid; Lycopene; Antioxidant activity

1. Introduction

Consumption of fruits and vegetables has been associated with maintenance of health and prevention of diseases (Lister, 2003; Steinmetz & Potter, 1996). Tomatoes are an important vegetable crop and are a major contributor of carotenoids (especially lycopene), phenolics, vitamin C and small amounts of vitamin E in daily diets (Khachik et al., 2002; Vinson et al., 1998). Results from the epidemiological studies have shown that tomatoes and tomato products may have a protective effect against various forms of cancer, especially prostate cancer, and cardiovascular diseases (Arab, Steck, & Harper, 2000; Barber & Barber, 2002; Rao & Agarwal, 1999).

Several important changes occur in the ultra structure of tomatoes during ripening, such as, synthesis of pigments (e.g. lycopene), production of flavour and aroma compounds, and increase in the ratio of citric to malic acid (Grierson & Kader, 1986). Abushita, Hebshi, Daood, and Biacs (1997) and Giovanelli, Lavelli, Peri, and Nobili (1999) reported an increase in ascorbic acid content of tomatoes during their ripening. Total phenolics and flavonoids have also been reported to increase during the ripening of tomatoes (Cano, Acosta, & Arnao, 2003; Hunt & Baker, 1980), whereas the hydroxycinnamic acid content and chlorogenic acid concentrations have been reported to decline during ripening (Buta & Spaulding, 1997; Senter, Horvat, & Forbus, 1988).

The metabolism of tomatoes continues, even after their detachment from the plant, when fruits have reached their red stage. They continue to ripen and finally deteriorate to a point where they become valueless (Yanuriati, Savage, & Rowe, 1999). To extend the shelf life of fruits and vegetables, their respiratory metabolism is slowed by low-temperature storage or storage in a high carbon dioxide atmosphere (Kalt, Forney, Martin, & Prior, 1999). Storage of tomatoes, and other products of tropical or subtropical origin, at below critical temperatures, predisposes them to chilling injury (Grierson & Kader, 1986; Yanuriati et al., 1999). Storage of tomatoes

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at temperatures below 13 °C has been reported to have a significant effect on tomato flavour, even before any visual symptoms are seen. Maul et al. (2000) observed that, when the light-red tomatoes were stored below 13 °C, they were significantly ($p < 0.05$) lower in ripe aroma and tomato flavour, and higher in off-flavours compared to tomatoes stored at 20 °C.

For home consumption, tomatoes are usually purchased when they are ripe; however, there is limited information about the overall nutritional implications of storage on the modern tomato cultivars grown in New Zealand greenhouses. The objective of this study was to determine changes in the major antioxidant components of tomatoes stored at three different temperatures, for a period of 10 days. This experiment forms a part of an ongoing research project to investigate the factors affecting the antioxidant composition of New Zealand grown greenhouse tomatoes.

2. Materials and methods

2.1. Fruit sampling and storage treatments

The tomatoes (*Lycopersicon esculentum* cv. Tradiro) used for this study had been grown using a hydroponic fertigation system, under commercial growing conditions, in a greenhouse located in Christchurch, New Zealand (43°40′S, 172°29′E). Tradiro is a commonly used, salad cultivar of New Zealand having multilocular fruits with an average fruit weight of 102 g. About 60 kg tomatoes were harvested at the light-red stage of ripeness (maturity stage 5; California Tomato Commission (2002)) in the third week of January, 2004. The tomatoes were washed with water, dried with a soft cloth, and randomly placed in a single layer in open cardboard boxes. The tomatoes were stored at different temperatures, in triplicate (6 kg in each replicate) in the dark at 7 ± 0.5 °C in a refrigerator, and at 15 ± 0.5 °C and 25 ± 0.5 °C in temperature controlled incubators for variable time periods (0, 2, 4, 6, 8, and 10 days), to simulate common retail outlets and home storage temperatures.

2.2. Physicochemical characteristics

The dry matter content of tomatoes was measured by placing the homogenised seedless samples in an oven at 105 °C for 24 h (AOAC, 2000). The titratable acidity was measured on fresh, homogenised samples using a Metrohm 670 titroprocessor (Metrohm Herisau, Switzerland). The results for titratable acidity were expressed as % citric acid.

2.3. Sample preparation

The whole fruits were homogenised in a blender (Braun Multiquick, MR-400, Spain). A 4 g sub-sample of homogenised tomatoes was mixed with 10 ml of 80% acetone and placed on a rotary mixer in the dark for 4 h at 5–7 °C. Samples were then centrifuged at 3400*g* for 10 min and the supernatant was used to measure the soluble phenolics, flavonoids and soluble antioxidant activity.

2.4. Measurement of antioxidants

The soluble phenolics, total soluble flavonoids, lycopene, ascorbic acid and soluble antioxidant activity in samples were measured as described in detail by Toor and Savage (2005).

2.5. Statistical analysis

Analysis of variance (ANOVA) was used and the least significant difference (LSD) at $p < 0.05$ was calculated using the Genstat 6th edition (Genstat, 2000) to determine significant differences in the physicochemical characteristics and antioxidant components of tomatoes stored at different temperatures for different storage periods.

3. Results and discussion

Tomatoes have usually reached the light-red or red stage of ripeness, when they are available for sale in supermarkets. Therefore, this study was conducted on tomatoes, which had attained a light-red colour. The dry matter content of tomatoes during the study period ranged from 4.8% to 5.4% and was not affected by storage. The mean titratable acidity of tomatoes stored at 15 and 25 °C (0.97% and 1.06% citric acid, respectively) was significantly ($p < 0.05$) higher than that of refrigerated tomatoes (0.77% citric acid). These results suggest that the production of organic acids is inhibited at refrigeration temperatures, whereas it continues to increase during storage at ambient temperatures and this may affect the sensory characteristics of tomatoes stored at different temperatures.

The tomatoes stored at 15 and 25 °C developed a brighter red colour than tomatoes stored at 7 °C. The increase in redness of tomatoes during ripening is due to lycopene accumulation, in association with the internal membrane system (Grierson & Kader, 1986). The mean lycopene content of tomatoes stored at 15 and 25 °C was 1.8-fold higher than that of refrigerated tomatoes (Fig. 1). This effect has also been observed earlier by Ajlouni, Kremer, and Masih (2001). They reported that the lycopene values increased from an initial level of 3.6–9.0 mg/100 g in greenhouse-grown tomatoes during storage at 22 °C for a period of 14 days. However, during storage at 4 °C, no significant changes in the lycopene content were observed.

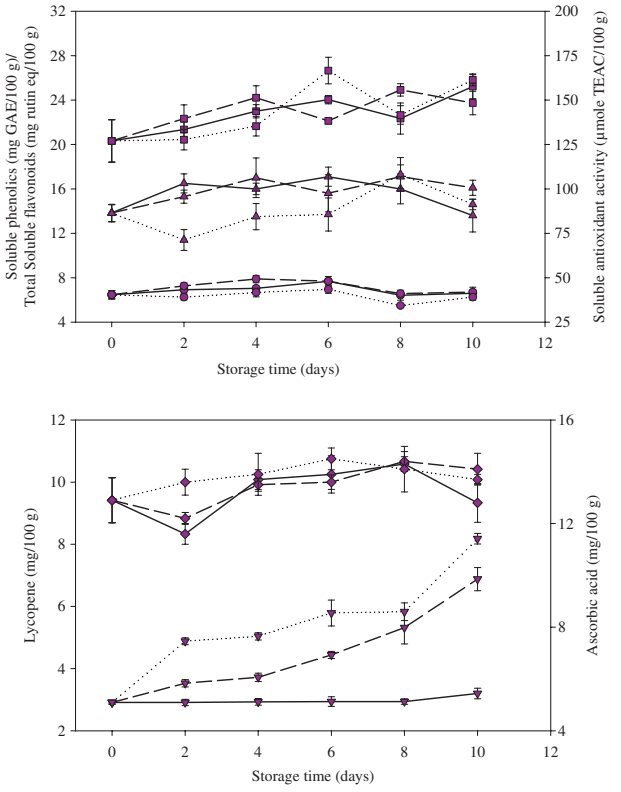

Fig. 1. Changes in the soluble phenolics (▲), total soluble flavonoids (●), soluble antioxidant activity (■), lycopene (▼), and ascorbic acid content (◇) of tomatoes (cv. Tradiro) during storage at 7 °C (—), 15 °C (– –), and 25 °C (. . .) for a period of 10 days (values are means ± standard errors).

Total soluble flavonoids were only slightly affected during storage at different temperatures. Soluble phenolic content showed a small increase during storage at 7 °C (Fig. 1) and 15 °C, for the first eight days, and showed some decline toward the end of the storage period. At 25 °C, the total phenolics initially showed a significant decline, but their accumulation increased with time, and again decreased towards the end of storage (Fig. 1). The decrease in soluble phenolics observed toward the end of storage may be due to the breakdown of the cellular structure, due to chilling injury at 7 °C, and the over-ripening of fruits at 15 and 25 °C when stored for 10 days. The vacuoles in fruit cells form the main compartment in which soluble phenolic compounds accumulate (Macheix, Fleuriet, & Billot, 1990). At chilling temperatures, there is a change in the permeability of the cell membranes, and activity of membrane-bound enzymes (Yanuriati et al., 1999), which causes an accumulation of toxic intermediates (Macheix et al., 1990) in the cells. This creates physiological stress in plant cells and, therefore, the levels of phenylalanine ammonialyase (PAL) and hydroxycinnamoyl quinate transferase (HQT), enzymes involved in synthesis of flavonoids and chlorogenic acids, respectively, which have been reported to increase considerably only when tomatoes are stored below 10 °C (Macheix et al., 1990). Tomatoes stored at 25 °C had significantly ($p < 0.05$) lower mean soluble phenolic and flavonoid content during the study period (14.1 mg GAE/100 g and 6.32 mg rutin eq/100 g, respectively) than the tomatoes stored at 15 °C (16.2 mg GAE/100 g and 7.22 mg rutin eq/100 g, respectively) and 7 °C (15.9 mg GAE/100 g and 6.93 mg rutin eq/100 g, respectively). It was expected that the refrigerated tomatoes would have an increased production of PAL and HQT enzymes and, subsequently, higher total phenolics and flavonoids. However, the levels of total phenolics and flavonoids in tomatoes stored at 7 °C were not significantly different from the tomatoes stored at 15 °C. This is probably due to the disruption of vacuoles as a result of chilling injury that may have led to loss of some phenolic substances.

A slight accumulation of ascorbic acid was observed during storage of tomatoes at all three temperatures (Fig. 1). Kalt et al. (1999)observed no losses in ascorbic acid content during post-harvest storage of strawberries and blueberries. High titratable acidity is responsible for the stability of ascorbic acid in fruits (Mapson, 1970), and as tomato is a highly acidic fruit, it showed a relatively stable ascorbic acid content during post-harvest storage. In addition, phenolic substances have been reported to have a protective effect on the ascorbic acid (Miller & Rice Evans, 1997). Therefore, the presence of phenolics and flavonoids in tomato cells may have helped to maintain the ascorbic acid content.

The soluble antioxidant activity was more affected by storage time than by storage temperature. After 10 days of storage, the soluble antioxidant activity was 24% higher in tomatoes stored at 7 °C toward the end of their storage, whereas it increased by 17% and 27% at temperatures of 15 and 25 °C, respectively (Fig. 1). Previous study has shown that soluble antioxidant activity contributes >92% toward the total antioxidant activity of tomatoes, while the lipophilic antioxidants, mainly lycopene and lipophilic phenolics, contributed only about 8% to the total antioxidant activity of tomatoes (Toor & Savage, 2005). Ascorbic acid and soluble phenolics are the major contributors to the soluble antioxidant activity. It has been reported that ascorbic acid contributes by 28–38% to the soluble antioxidant activity, while the remaining activity is mainly due to soluble phenolics (Toor & Savage, 2005). During storage, a slight increase in the levels of total phenolics, and ascorbic acid occurred in the tomatoes and their possible synergistic interactions may have been responsible for the observed increase in the soluble antioxidant activity in the tissue.

4. Conclusions

The results of this study demonstrate that the post-harvest storage of light-red tomatoes does not have

any deleterious effect on the total phenolics, flavonoids, ascorbic acid content or antioxidant activity of tomatoes. Storage at lower temperatures (7 °C) inhibits the accumulation of lycopene in tomatoes, whereas the lycopene level of light-red tomatoes can be increased up to 3-fold by storing at 15–25 °C.

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