Abstract

Postharvest storage, handling and distribution of fruit at low temperatures is the most common and manageable approach to control ripening and subsequent deterioration and to maximize product shelf-life. However, tomatoes, as many other subtropical fruits, are susceptible to develop symptoms of chilling injury, a physiological disorder caused by the exposure to low temperature above the freezing point. Development of chilling injury depends on temperature, time, ripening stage and tomato type/cultivar. We studied the effect of home-refrigerator storage temperature on the quality of two types of tomato: cocktail tomato (cultivars ‘Amoroso’ and ‘Brioso’) and truss tomato (cultivars ‘Capricia’ and ‘Roterno’). Fully ripe tomatoes were stored for 10 days at two temperatures: 4°C as simulation of home-refrigerator storage and 15°C as an optimal storage temperature. We evaluated several quality parameters: weight loss, firmness, soluble solid content, titratable acidity, carbohydrates, titratable acidity and citrate content. Although we did not observe any apparent symptom of chilling injury, we found that 4°C temperature stimulates firmness decay in both cocktail tomato cultivars, increasing fruit susceptibility to mechanical injury. Moreover, already after 5 days of 4°C storage, tomatoes generally showed decreased sugar and increased acid content (especially in cocktail tomatoes) compared to 15°C stored fruit, indicating a loss of sensoric quality at 4°C.

INTRODUCTION

Postharvest storage, handling and distribution of fruit at low temperatures is the most common and manageable approach to control ripening and subsequent deterioration and to maximize product shelf-life. However, tomatoes and many other subtropical fruits are susceptible to chilling injury, a physiological disorder caused by the exposure to low temperature above the freezing point (Soto-Zamora et al., 2005). Therefore, crops which are susceptible to chilling injury often have a short storage life as low temperatures cannot be used to slow deterioration and pathogen growth.

Typical symptoms of chilling injury in tomato fruits include failure to ripen, development of skin lesions, surface pitting, water-soaked areas, and susceptibility to decay (Lurie et al., 1997). In addition to these visible symptoms, cell ultrastructure is altered following prolonged chilling. Damage to cells and tissues of tomato fruits occurs primarily during exposure to the chilling temperature, while development of injury symptoms mainly occurs upon removal from chilling to warmer, non-chilling temperatures (Cheng and Shewfelt, 1988). Chilling injury can lead to increased postharvest losses due to premature senescence, the development of mealiness and enhanced softening and an increase in susceptibility to mechanical injury and pathogen invasion (Morris, 1982).
Chilling injury may occur in the field, in transit or distribution, in retail or in supermarket displays and home refrigerators. Development of chilling injury depends on temperature, time, ripening stage and tomato type/cultivar. In this study we investigated the effect of home-refrigerator storage temperature on the quality of different types of tomatoes: cocktail and truss tomatoes.

MATERIALS AND METHODS

Fully ripe tomatoes (trusses) were obtained from a commercial grower in the south east of the Netherlands in the middle of the growing season. We used two different cultivars for each tomato type: ‘Amoroso’ and ‘Briosò’ as cocktail tomato; ‘Capricia’ and ‘Roterno’ as truss tomato. To minimize the variability of fruit ripening, we selected the fruits from the middle part of the truss comparing the skin color of the tomatoes using a color scale from The Greenery. Tomatoes were stored at two temperatures: 4°C as simulation of home-refrigerator storage and 15°C as an optimal storage temperature. We randomly selected 20 fruits for each storage duration: harvest time, five and ten days of storage (t0, t1, t2, respectively).

Fruit weight and firmness of each fruit were determined. Firmness of whole fruit was measured with a Zwick Z2.5/TS1S materials testing machine (Ulm, Germany) using a cylindrical probe (Ø 15 mm). Tomatoes were placed on a plastic ring to keep the tomatoes upright during measurement. Firmness was determined as the maximum force needed to compress the tomato 1 mm at 40 mm/min (Schouten et al., 2007).

Thereafter, half of each fruit was freeze dried for determination of carbohydrates and acids, while the other part was squeezed for the analysis of total soluble solids and titratable acidity. Total soluble solids content of fruits (expressed as °Brix) was determined using a hand refractometer, and titratable acidity (expressed as citric acid concentration) was measured according to the method adopted by the Association of Official Analytical Chemists.

Total carbohydrates and anions content were determined according to the method of Hajjaj et al. (1998). Fifteen mg of freeze dried material were extracted in 5 ml of a 75% (v/v) boiling ethanol containing 10 mM HEPES, pH 7.1, for 20 minutes at 75°C. After cooling down the mixture and centrifuging for 5 min at 7000 g, the supernatant was reduced by evaporation at 45°C using a rotavapor apparatus. The residue was resuspended in a final volume of 1 ml distilled water, centrifuged 15 min at 25000 g to remove the insoluble particles, diluted and finally analyzed by HPAEC (High Performance Anion Exchange Chromatography). The anions and carbohydrates separation was made using two different columns of Dionex: CarboPac PA1 and IonPac AS11-HS.

RESULTS AND DISCUSSION

The four tomato cultivars used in this study, significantly differ in their basic features (Table 1). The two truss tomato cultivars, ‘Capricia’ and ‘Roterno’, besides bigger size, have also a higher firmness value than the cocktail tomatoes. These cultivars show significant lower values of total soluble solids, titratable acidity, total carbohydrates and anions content compared to the cocktail tomatoes.

Tomatoes of the same type showed generally the same behavior during the postharvest period and also with respect to both storage temperatures. All four cultivars linearly lost weight (data not shown) during the shelf life, independent of storage temperature. However, total weight loss was directly proportional to the size of the tomato: cocktail tomatoes, after 10 days of storage, showed around 2.5% of weight loss compared to 1% for truss tomatoes. However, no differences in water loss were observed between the two different cocktail tomatoes, especially ‘Briosò’, shows pronounced softening at 4°C storage. The low temperature does not seem to enhance softening in ‘Capricia’ and ‘Roterno’ (Fig. 1).

The soluble solids showed no significant changes during the shelf life and there were no relevant differences in the content of soluble solids with respect to temperature (data not shown). Likewise, total carbohydrates content (Fig. 2) showed little changes
during the shelflife at 15°C except for ‘Brioso’ where carbohydrates decreased. Cold storage decreased the carbohydrates content in all cultivars except for ‘Amoroso’. Total acids content (mainly citric acid) is an important factor that influences tomato sensoric quality. The two methods (acid titration and HPAEC) that we used, gave comparable results. Titratable acidity (Fig. 3) is more stable at 4°C storage than at 15°C for all cultivars. In cocktail tomatoes a decrease was observed at 15°C. These results were confirmed by measurements of citrate content (Fig. 4).

**CONCLUSIONS**

We have shown in this study that home refrigerator conditions (4°C) negatively affects tomato quality. Although we did not find any apparent visual symptoms of chilling injury, such as skin lesions, surface pitting or water-soaked areas, we found that this low temperature significantly stimulated firmness decay in both tested cocktail tomato cultivars. Moreover, already after 5 days of storage at 4°C, tomatoes generally showed lower sugar and higher acid content (especially in cocktail tomatoes) than after storage at 15°C, indicating a loss of sensoric quality at 4°C. Results indicate that addition of tomatoes in vegetable mixes that are stored at low temperature may lead to rapid loss of quality.

**ACKNOWLEDGEMENTS**

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**Literature Cited**


**Tables**

Table 1. Tomato fruit characteristics at harvest time.

<table>
<thead>
<tr>
<th>Typology</th>
<th>Weight (g)</th>
<th>Firmn. (N)</th>
<th>SSC (°Brix)</th>
<th>T.A (%)</th>
<th>Carb. (mg/g DW)</th>
<th>Anion (mg/g DW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoroso</td>
<td>Cocktail</td>
<td>38.5</td>
<td>6.4</td>
<td>6.7</td>
<td>1.10</td>
<td>507.4</td>
</tr>
<tr>
<td>Brioso</td>
<td>Cocktail</td>
<td>42.6</td>
<td>6.4</td>
<td>5.6</td>
<td>0.87</td>
<td>508.0</td>
</tr>
<tr>
<td>Capricia</td>
<td>Truss</td>
<td>110.5</td>
<td>9.3</td>
<td>4.6</td>
<td>0.58</td>
<td>405.3</td>
</tr>
<tr>
<td>Roterno</td>
<td>Truss</td>
<td>93.6</td>
<td>8.1</td>
<td>5.2</td>
<td>0.68</td>
<td>394.4</td>
</tr>
</tbody>
</table>
**Figures**

![Graph A](image1.png)

**A**
- Amoroso 15°C
- Amoroso 4°C
- Brioso 15°C
- Brioso 4°C

![Graph B](image2.png)

**B**
- Capricia 15°C
- Capricia 4°C
- Roterno 15°C
- Roterno 4°C

**Fig. 1.** Fruit firmness decay of cocktail tomato (A) and truss tomato (B) during 10 days of shelf life at 15°C (lines) and 4°C (dashed lines). Average values of 20 fruits with standard errors are shown.

![Graph C](image3.png)

**C**
- Amoroso 15°C
- Amoroso 4°C
- Brioso 15°C
- Brioso 4°C

![Graph D](image4.png)

**D**
- Capricia 15°C
- Capricia 4°C
- Roterno 15°C
- Roterno 4°C

**Fig. 2.** Fruit carbohydrates content (mg/g DW) of cocktail tomato (A) and truss tomato (B) during 10 days of shelf life at 15°C (lines) and 4°C (dashed lines). Average values of 20 fruits with standard errors are shown.
Fig. 3. Fruit titratable acidity (expressed as % Citric Acid) of cocktail tomato (A) and truss tomato (B) during 10 days of shelf life at 15°C (lines) and 4°C (dashed lines). Average values of 20 fruits with standard errors are shown.
Fig. 4. Fruit citrate content (mg/g DW) of cocktail tomato (A) and truss tomato (B) during 10 days of shelf life at 15°C (lines) and 4°C (dashed lines). Average values of 20 fruits with standard errors are shown.