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Damage to intact fruit affects quality of slices from ripened tomatoes

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ABSTRACT

Breaker stage fruit (cvs 901 and Bobcat) were subjected to different types of physical damage: 3 impacts of a steel ball (67 g) from a height of 33, 66 or 99 cm, 8 impacts of the ball from 99 cm, or dropping the fruit once 1 m onto a hard surface. Fruit were then held at 20 °C until full red, sanitized, sliced and stored at 5 °C. Damaged fruit were less firm than undamaged fruit when ripe. Slice quality (appearance, translucency, lycopene content, juice loss) and shelf-life were affected by damage to the fruit. Lycopene concentrations were higher in undamaged (4.0 mg/kg) than damaged fruit (3.5 and 2.7 mg/kg with 3 impacts from 99 cm and drop damage) and decreased during storage at 5 °C. Translucency increased with time and onset was more rapid in moderate to high damage fruit. Juice loss was higher in slices from undamaged (6–8 g/100 g FW) than damaged fruit (1–4 g/100 g). Severe damage resulted in collapse of locular tissue and moderate damage may have induced mealiness. PG activities differed little between slices from severely damaged and undamaged fruit and no differences in PME activities were found.

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1. Introduction

Tomato fruit are often subjected to postharvest physical injuries, with bruising being a common type of mechanical damage. Bruise susceptibility is a measure of the response to external loading and depends on a number of elements such a variety, texture, maturity, water status, firmness, temperature, size, and shape (Mohsenin, 1970).

Many studies have focused on various aspects of mechanical damage in tomato. Sargent, Brecht, and Zoellner (1992) studied the development of internal bruising of tomato fruit damaged in early ripening stages. Other authors studied the effect of mechanical impact on bruise susceptibility (Van linden, De Ketelaere, Desmet, & De Baerdemaeker, 2006a, 2006b). Devaux et al. (2005) investigated how mechanical breakdown can influence the development of mealy tissue in tomato, while Moretti, Sargent, Huber, Calbo, and Puschmann (1998) analyzed the chemical composition of tomatoes with internal bruising. Internal bruising can alter the aroma of tomato fruit (Kader, Morris, Stevens, & Albright-Holton, 1978; Moretti, Baldwin, Sargent, & Huber, 2002) and affect enzyme activity in whole tomatoes (Van linden, Sila, Duvetter, De Baerdemaeker, & Hendrickx, 2008). In many fruit an altered balance of PG and PME could lead to incomplete cell wall pectin degradation (Crisosto & Labavitch, 2002) and the development of mealy tissue. In tomatoes, mealy texture could also be related to chilling injury (Jackman & Stanley, 1995; Rugkong et al., 2010).

The preparation and storage conditions to maintain the quality of fresh-cut tomato have been well studied (Aguayo, Escalona, & Artés, 2004; Artés, Conesa, Hernández, & Gil, 1999; Gil, Conesa, & Artés, 2002; Hong & Gross, 2001; Odriozola-Serrano, Soliva-Fortuny, & Martín-Belloso, 2008a, 2008b). However, limited information exists about how the initial quality of the intact fruit affects the quality and shelf-life of the fresh-cut product. Raw material quality is considered to be very important for quality of the fresh-cut product, and mechanical injuries before, during and after cutting are major contributors to more rapid deterioration in minimally processed fruit (Kader, 2002).

The aim of this work was to evaluate the effect of damage to tomatoes at early ripening stages on the subsequent quality, enzyme activity and shelf-life of slices from ripened fruit.

2. Materials and methods

Tomato fruit from two common fresh market field-grown cultivars were subjected to different damage treatments at the breaker

Abbreviations: PG, polygalacturonase; PME, pectin methylesterase; PT, parenchymatous tissue; LT, locular (placenta) tissue; GalA, galacturonic acid.

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(external red color no more than 10%) to turning (red color 30%) stages (USDA color classification; C.F.R., 1991). After ripening at 20 °C, fruit were sliced and the quality of the fresh-cut product was evaluated during storage at 5 °C. Three different experiments were carried out.

2.1. Experiment one: low to moderate damage

Tomatoes (cv 901) were harvested in August 2010 at the mature-green stage at a commercial grower in northern California. Fruit (large size = 6.4 cm average diameter = 190 g average weight) were carefully handpicked to avoid injuries, transported to the laboratory and held overnight at 20 °C, and then treated with ethylene (50 ppm) at 20 °C for 48 h to promote ripening (Cantwell, 2010). After ethylene treatment, only breaker color stage fruit were selected based on color, size and absence of defects. Tests consisted in dropping a 2 cm stainless steel ball (67 g) 3 times on three equidistant points at the equator of the fruit. The ball was dropped through a cylinder from a height of 33 cm (treatment 1F) or 66 cm (treatment 2F). These treatments were compared with undamaged tomatoes (=NO damage, treatment NO). After inflicting the impact damage, the bruised areas were marked, and damaged and undamaged fruit were stored at 20 °C [80–85% relative humidity (RH)] until red ripe stage (stage 6 USDA) or hue 43. Nine fruit per treatment were evaluated at 0 day (=3 h after slicing) and at 3, 7 10, 13 days from slicing and storage at 5 °C.

2.2. Experiment two: moderate to high damage

Tomatoes (cv Bobcat, large size = 6.4 cm diameter = 180 g average weight) were harvested in September 2010 at the mature-green stage at a commercial grower in northern California. Fruit were handled as in the previous experiment. Breaker stage fruit were subjected to the following controlled damage tests: dropping a 2 cm stainless steel ball 3 times on the fruit from a height of 66 cm (treatment 2F) or 99 cm (treatment 3F) or dropping the whole fruit on the blossom end from a height of 100 cm onto a hard surface (treatment D). The control treatment was undamaged fruits (treatment NO). Fruit were stored at 20 °C (80–85% RH) until red ripe and at 5 °C after slicing. Twelve fruit per treatment were evaluated at −10 (=1day after damage), −5, −1, 0 (=3 h after slicing), 6, 10 days from slicing.

2.3. Experiment three: severe damage

Fruit (cv 901) at the breaker stage were obtained from the northern California grower's repack facility in July 2012. Fruit (small-medium size = 5.4 cm average diameter = 100 g average weight) were manipulated as in the previous experiments except that the fruit were handled commercially and the ethylene treatment was given at the repack facility. With the purpose of understanding the effect of the damage on enzyme activity, fruit at early ripening stage (between breaker and turning, average score of 2.7) were subjected to severe damage (SD), dropping a 2 cm stainless steel ball on the fruit from a height of 99 cm eight times per fruit at four different locations (two times per location). A control undamaged treatment was used for comparison (treatment NO). Fruit were stored at 20 °C (80–85% RH) until red ripe and at 5 °C after slicing. Twelve fruit per treatment were evaluated at −8 (=3 h after damage), −7, −4, −1, 0 (=3 h after slicing), 6, 11, and 14 days from slicing.

2.4. Slice preparation

When fruit reached red color with average peel hue 43 for cv 901 and hue 40 for cv Bobcat, they were held at 10 °C in a clean area for 16 h to ensure a pulp temperature of 10 °C, sanitized in 50 ppm sodium hypochlorite (pH 7) for 1 min, rinsed in potable tap water for 1 min and blotted dry with paper towels. A manual tomato slicer (Nemco model II, Phoenix AZ, USA) with razor sharp blades was used to slice the fruit perpendicularly to the stem axis, obtaining slices 4.5 mm thick. To minimize dehydration during storage and to simulate commercial preparation, all slices, included the ends, were regrouped to reconstruct the initial whole tomato. Each sliced tomato was placed in a small polypropylene tray and trays were covered by food-grade plastic film (not sealed) and placed on a large tray inside a polyethylene bag at 5 °C. Nine (expt. 1) or twelve (expt. 2 and 3) fruit were analyzed for each treatment and evaluation date.

2.5. Quality evaluation

Firmness of the whole fruit was analyzed on a texture analyzer (TA.XT PLUS Stable Micro Systems, Goldaming, UK) as the force to compress the fruit 5 mm at the equator using a flat cylinder (25 mm diameter) moving at 1 mm/s. External color of the whole fruit was measured with a Minolta CR200 colorimeter (Konica Minolta Sensing, Inc., Osaka, Japan). The L^* (Lightness), a^* (red-green) and b^* (yellow-blue) parameters (CIELAB Color Space, 1976) were recorded (3 equally spaced measurements at the equator) and hue was calculated as arctangent b^*/a^*. Slice color was determined on the parenchymatous tissue in three equidistant points on the top slice of 3 stacked slices.

Juice loss is one of the major problems with sliced tomato quality. For this reason, after slicing and during storage at 5 °C, total juice loss was evaluated. Immediately after slicing (day = 0) the measure of juice loss was based on the weight difference (nearest 0.01 g) between the whole fruit and the reconstructed sliced fruit. During storage at 5 °C, the amount of juice released from the sliced fruit was weighed when slices were evaluated. For this, the reconstructed fruit were kept at room temperature until their internal temperature (measured by a needle probe thermometer) reached 16 °C (1–2 h). The total juice loss was calculated as: [(Juice loss after slicing (g) + Juice loss during storage (g))*100 (g)]/initial fruit weight (g). We considered a juice loss of <3 g/100 g fresh weight (FW) as low, 4–6 g/100 g FW as moderate, and >6 g/100 g as high.

Visual quality of the slices was scored by the same experienced operator under the same light conditions. A 9–1 scale was used, where 9 = excellent, fresh appearance, 7 = good, 5 = fair, limit of marketability, 3 = poor, limit of usability, 1 = unusable. Typical aroma, translucency and dehydration of the slices were scored on 1–5 scales, where 1 = none, 2 = slight, 3 = moderate, 4 = almost typical aroma or moderately severe, and 5 = maximum or severe.

Tomato fruit can differ in the number of locules and in the quantity of locular tissue (composed of gel and tissue that can liquefy) in the locular cavity. To assess fruit uniformity, the surface filled by locular tissue (LT) was evaluated visually once, just after slicing, on the central slice of each tomato using a 1–4 scale where: 1 = low (LT was less than *1/10* of the slice surface), 2 = medium-low (*1/10* < LT < *3/10* of the slice surface), 3 = medium (*3/10* < LT < *5/10* of the slice surface), 4 = high (LT > *5/10* of the slice surface).

Two central slices per tomato were homogenized and centrifuged for determination of soluble solids content (SSC) by a digital refractometer (model PR 100 Atago U.S.A. Inc, Bellevue, USA), pH and titratable acidity (TA) using NaOH (0.1 mol equiv/L) to titrate to 8.1 pH endpoint and calculating TA as mg citric acid/100 g FW.

2.6. Lycopene

Lycopene extraction and determination were based on the spectrophotometric method of Davis, Fish, and Perkins-Veazie (2003). A pooled sample from two central slices of each of three

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