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FLAVOR ALTERATION IN TOMATO FRUIT DUE TO INTERNAL BRUISING[1]

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Abstract. **Tomato (*Lycopersicon esculentum* Mill.) fruit, cv. Solar Set and Agriset 743, were harvested at the mature-green stage of development and treated with 50 μL·L^{-1} ethylene at 20°C. At the breaker stage, fruit were dropped from 40 cm to induce internal bruising and stored along with undropped fruit at 20°C and 85-95%RH. At the table-ripe stage, whole fruits were homogenized and a sensory analysis test was immediately performed. Panelists were able to distinguish between bruised and unbruised fruits indicating that internal bruising caused by impact forces significantly altered tomato flavor. Changes in organic acids, vitamin C and carotenoid contents, locule tissue consistency and volatile profiles for bruised fruit may be involved in the flavor differences.**

Flavor and texture are sensory characteristics which significantly affect the overall quality of fresh tomato (Baldwin et al., 1991). Many chemical compounds are involved in the characteristic flavor of a tomato fruit: organic acids (mainly citric), reducing sugars, free amino acids and volatile compounds (Petró-Turza, 1987). Mechanical injuries due to impact, compression, cuts, and abrasion have been shown to be correlated with physiological, metabolic, and quality alterations in different commodities (apples, cucumbers, potatoes and tomatoes). Miller et al. (1987) observed an increase in the activity of pectin methylesterase, xylanase and polygalacturonase in cucumbers following physical impacts. The relationship between mechanical injuries (impact and abrasion) and water loss in potatoes was studied by Hudson and Orr (1977), who noted that 0.5 cm^2 lesions caused a two-fold increase in water loss during storage. Physical impacts can also increase the levels of glycoalkaloids, substances that are potentially toxic and are common in the members of the *Solanaceae* family (tomato, eggplant, pepper, potato) (Carman et al., 1986).

In tomatoes, physical impact can cause internal bruising, a physiological disorder that can impair normal ripening (Halsey, 1955). Tomato fruit with internal bruising have a cloudy, greenish, disorganized gel, and in more severe cases, locule tissue becomes dry after losing water (Hatton and Reeder, 1963). The incidence and severity of internal bruising is dependent on impact energy, number of impacts, cultivar and ripeness stage, and it is cumulative during handling practices (McColloch, 1962; Sargent et al., 1989; Sargent et al., 1992).

In addition to visual symptoms, mechanical injuries can cause metabolic alterations in tomato fruit. MacLeod et al. (1976) concluded that increased numbers of impacts from 40 cm resulted in increased CO_2 and ethylene evolution. Egan (1982) observed that physical impacts decreased tomato firmness from 1.6 to 1.5 kgf.cm^{-2}. On the other hand, Silva and Calbo (1992) determined that fruits under compression stress had depressed respiration rates and delayed ripening.

Moretti et al. (1997a) observed that physical impact altered chemical composition and physical properties of tomato fruit, resulting in fruit with poorer quality. Locule tissue was more affected than pericarp and placental tissues. Total carotenoids, vitamin C content, titratable acidity, and consistency of locule tissue were altered after impact bruising at breaker stage and ripening. Changes in the profiles of volatile compounds of tomato following physical impact was also reported by Moretti et al. (1997b). They observed that volatile profiles of the 16 major volatile compounds were significantly affected in pericarp, locule and placental tissues after a physical impact, suggesting a potential alteration in tomato flavor. Isomerases, peroxidases and lipoxygenases are enzymes which have been determined to be involved in the metabolism of tomato volatile compounds (Petró-Turza, 1987). Geerts et al. (1994) noted that the activity of lipoxygenases was altered in potatoes after physical impacts.

Although a considerable amount of work has focused on the effects of internal bruising on the physiology (appearance and quality of tomato fruit), there is still a lack of information regarding its effects on consumer acceptance. The objective of the present experiment was to determine if there is a difference in flavor between tomatoes with and without internal bruising.

Material and Methods

Plant material. Mature-green tomatoes (*Lycopersicon esculentum* Mill.) were harvested at a commercial field in Bradenton, Fla., in January, 1997 ('Solar Set'), and at the Horticultural Research Unit at the University of Florida, Gainesville, in May, 1997 ('Agriset 743'). At harvest, fruit were placed into polystyrene cell-pack trays to avoid mechanical injury and transported to the Postharvest Horticulture Laboratory in Gainesville the same day.

Ethylene gassing and impact treatment. After sorting for blemishes and grading for size (medium fruits = 63 to 72 mm in di-

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ameter) and weight (140 ± 10 g), fruit were gassed with 50 $\mu L \cdot L^{-1}$ ethylene in an enclosed chamber using a flow-through system (flow rate = 50 $mL \cdot s^{-1}$) at 20°C and 85-95% relative humidity. At breaker stage (<10% red coloration) (USDA, 1976), half of the fruits were individually held by vacuum (to avoid fruit rotation) and dropped from 40 cm onto a solid, smooth surface. Each fruit was dropped twice, one at each of two equidistant points on the fruit equator avoiding radial pericarp walls. Following impact these fruit were stored along with undropped fruit at breaker stage at 20°C and 85-90% RH until they reached the table-ripe stage. The table-ripe stage was defined as the point at which fully red fruit had a deformation of 3-4 mm as determined when a static force of 9.8 N was applied to the equator with a metallic, convex probe (11 mm in diameter) for 5 seconds. Firmness was measured using the Cornell device (Hamson, 1952) as modified by Gull et al. (1980).

Sensory analysis. At table-ripe stage, whole fruits were chopped in a food processor and a Difference From Control Test (Aust et al., 1985) was performed. Each variety was prepared separately. The chopped samples were placed in small cups: one cup contained the unbruised sample and was labeled "control", and the three remaining cups were labeled with three-digit, random numbers, consisting of a hidden control and two bruised samples. The samples were presented to 20 untrained panelists who were asked to first taste the cup labeled "control" and then taste the three unknown samples. Overall flavor of the three unknown samples were compared to the control and rated using a hedonic scale ranging from 1 (no difference) to 12 (extremely different).

Statistical analysis. Analyses were performed for each tomato variety using a randomized complete block design with panelists as blocks, and three treatments (unbruised fruit and bruised samples 1 and 2). There were four replications (n = 10 fruits). Data were subjected to analysis of variance using the general linear model (GLM) procedure of the Statistical Analysis System package (SAS Institute, 1985). All comparisons were made at P = 0.05.

Results and Discussion

The hidden control tomatoes (unbruised) were rated as having little flavor difference from the labeled control, whereas those which were bruised were rated significantly different from the control for both cultivars. The hidden control was rated 2.20 and 2.11 for 'Solar Set' (Fig. 1) and 'Agriset 743' (Fig. 2), respectively, while bruised samples (IB 1 and IB 2) were rated significantly higher at 6.40 and 6.10, respectively, for 'Solar Set' (Fig. 1) and 5.88 and 5.83, respectively, for 'Agriset 743' (Fig. 2). Some panelists commented that the bruised samples tasted "watery" or "bland" when compared to the control.

Tomatoes with internal bruising have been reported to have significant changes in titratable acidity, vitamin C content, total carotenoids, consistency or viscosity, and in the volatile profiles of key aroma compounds (Moretti et al., 1997a; b). These changes may account for the flavor differences noted by the panelists in this experiment. Moretti et al. (1997a) determined that tissue exhibiting internal bruising had significantly lower organic acids and vitamin C contents, and that bruised locule tissue was more viscous than tissue that ripened normally. Since locule tissue was most dramatically affected by physical impact (Moretti et al., 1997a; b) and its components are more readily perceived by taste receptors (Stevens et al., 1977), it is suggested that increases in the consistency of locule tissue can be a determinant in tomato flavor.

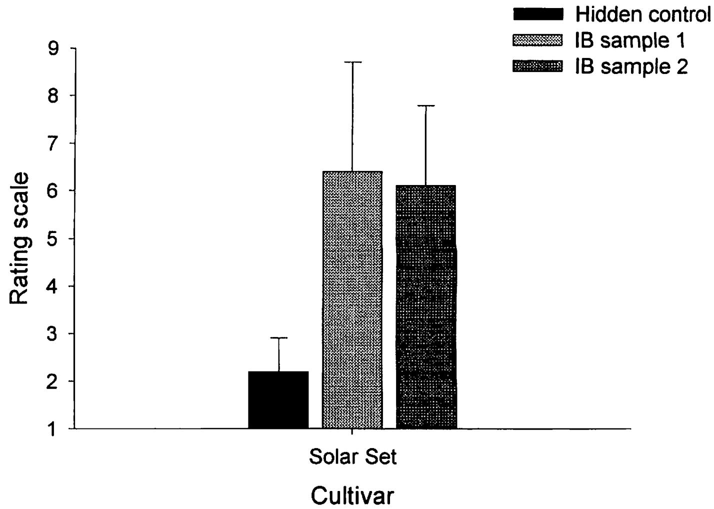

Figure 1. Mean sensory ratings by panelists for bruised samples (IB 1 and IB 2) and unbruised (hidden control) ripe tomatoes (cv. Solar Set) using Difference from Control Test (Rating scale: 1 = no difference; 12 = extremely different). Vertical bars represent ± standard deviation.

The perception of altered flavor, in addition to changes in organic acids, vitamins, and consistency, could have been due to the disruption of metabolic pathways for compounds such as *cis*-3-hexenal (green aroma), *cis*-3-hexenol (green flavor), and 6-methyl-5-hepten-2-one (fruit-like aroma) (Petró-Turza, 1987). Volatile compounds such as 6-methyl-5-hepten-2-one and β-ionone originate from open and cyclic-chain carotenoids (Buttery and Ling, 1993). Moretti et al. (1997a) observed that bruised locule tissue had lower total carotenoids content than normal fruit and Moretti et al. (1997b) determined that 6-methyl-5-hepten-2-one, a compound that is suspected to be a lycopene-breakdown product (Petró-Turza, 1987), was significantly reduced in bruised tissues.

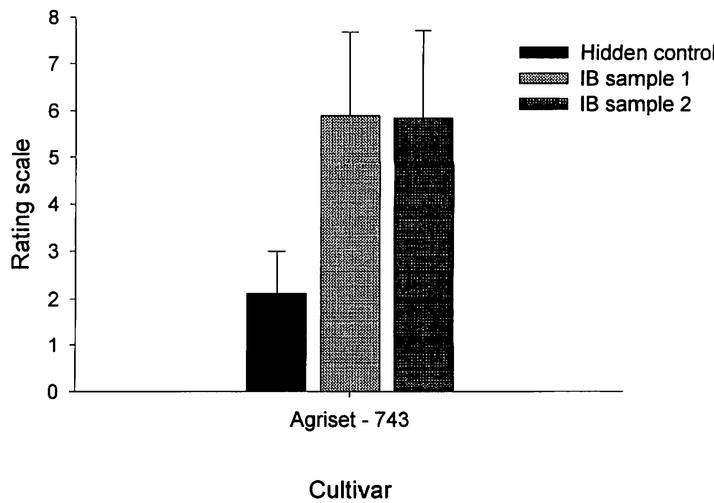

Figure 2. Mean sensory ratings by panelists for bruised samples (IB 1 and IB 2) and unbruised (hidden control) ripe tomatoes (cv. Agriset-743) using Difference from Control Test (Rating scale: 1 = no difference; 12 = extremely different). Vertical bars represent ± standard deviation.

The results reported here, in conjunction with previous reports on changes in physical characteristics and chemical composition, strongly suggest that internal bruising modifies tomato quality and flavor, potentially lowering consumer acceptance. From a postharvest quality point-of-view, it is crucial that all the segments in the tomato industry reduce impacts during harvest and handling operations, particularly for mature-green and breaker-stage fruits, to minimize the development of internal bruising.

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COOLING METHOD AND SHIPPING CONTAINER AFFECT LYCHEE FRUIT QUALITY

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Abstract. **A comparison of forced-air cooling (FA), room cooling (RC), hydrocooling (HC), two shipping containers (polystyrene clamshell and corrugated carton) and panicle attachment were conducted on lychees (*Litchi chinensis Sonn.*), Mauritius cultivar. HC lychee packed in cartons retained pericarp color better than the other treatments after 15 days storage at 3 to 5°C. Transferring stored lychees to 20°C for one day significantly increased pericarp browning for all treatments. The results also suggested that lychees stored without panicle had higher pulp quality in terms of total titratable acidity, pH, and total soluble solids content compared to those stored with panicle attached.**

Two major lychee production areas in the United States are Hawaii and Florida. However, fruit availability has been limited by many factors such as the small production area, short storage life, and rapid loss in postharvest quality. Improper handling and shipping methods have a great effect on

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