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Stimulation of Ethylene and CO_2 Production of Mature-green Tomatoes by Impact Bruising[1]

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Abstract. **The severity of internal damage to mature-green tomatoes increased with the number of drops. Impact-bruised, mature-green tomatoes, (*Lycopersicon esculentum* Mill. cvs. Cal Ace and Tropic), exhibited an increase in ethylene production within 1 hour after injury. When mature-green fruits of 'Manapal', 'Tropic', 'Cal Ace' and 'VFN Bush' were impact-bruised all cultivars except 'VFN Bush' exhibited sustained increases in rate of ethylene and CO_2 production. The magnitude of ethylene production increased with number of impacts. Ripening of bruised fruit tended to be accelerated, and titratable acidity was decreased.**

To obtain acceptable consumer quality of tomatoes harvested at the mature-green stage, proper temperature management and careful handling are necessary throughout the marketing system. Bruise damage, resulting from impacts with other objects, including other fruits, is frequently encountered. McColloch (9) and Halsey (4) described symptoms which developed after mature-green tomatoes had been bruised and then ripened. Localized tissue softening and water soaking of fruit wall tissue may be externally visible. Longitudinal splits may be present in severely bruised fruits. Internal damage may exist even though no external symptoms are observed. Locular gel

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may fail to develop normal color, appearing greenish or whitish; and with more severe injury it may be completely disorganized, shrunken or stringy. Cracking and water soaking of radial walls and placenta tissue also occur.

Physical damage to plant tissue is often followed by physiological responses. Increased ethylene production and respiration have been observed in tissue sections of cantaloupe (10) and tomato (5). Sustained increases in respiration rates of intact fruit after damage due to impacts has been observed in oranges (3), freshly harvested apples (7), and tomatoes (1). Increased ethylene production after impact damage has recently been reported for freshly harvested apples (7). Normal handling of mature-green tomatoes during harvest is sufficient to cause a short-term increase in ethylene production (8).

This study evaluated physiological responses of impact-damaged, mature-green tomatoes. Damage levels inflicted experimentally were similar to those observed in commercial handling systems. Ethylene production, respiration rates, ripening rates, compositional changes, and internal damage were evaluated. Each type of experiment was conducted a minimum of 3 times but not necessarily with the same cultivar. Only representative data are presented.

Frequently, impact damage is not detectable externally, making accurate evaluation difficult. A scoring system for internal damage was developed based on a similar system described by Halsey (4) (Table 1). A transverse equatorial cut is made to observe the condition of the locule gel and other tissues. This scoring system allows accurate detection of bruising injury, but does not necessarily indicate the commercial marketability of the fruit.

The time required to observe increased ethylene production after bruising was measured. In each experiment, 6 mature-green 'Tropic' or 'Cal Ace' tomatoes were carefully selected and harvested for uniform weight and size. After temperature equilibration at 20°C, 3 fruit were dropped 4 times from 40 cm onto a hard table top; the remaining 3 were controls. Individual fruits were immediately sealed in 500-ml containers with 30 ml of 0.1N KOH at 20°C. Ethylene accumulation in the head space was monitored using a flame ionization gas chromatograph. After 3 hr, CO_2 and O_2 concn were checked using a dual thermistor gas chromatograph. Oxygen levels never dropped below 17% and CO_2 levels remained below 0.5% in all containers. Within 1 hr after treatment, ethylene production by impact-bruised tomatoes was higher than control fruits (Fig. 1). It remained higher during the 3-hr test period.

Table 1. Scoring system for internal tissue damage in table-ripe tomatoes.

Score	Description
1	None – No visible internal damage.
2	Slight – One or more locules showing discolored gel.
3	Moderate – Less than 5% of tissue water soaked; less than 30% of locule gel disorganized, shrunken, or stringy.
4	Severe – 5 to 20% of exposed tissue shows water soaking; 30 to 60% of locule gel disorganized, shrunken, or stringy.
5	Extreme – More than 20% of exposed tissue shows water soaking; more than 60% of locule gel disorganized, shrunken, or stringy.

In a second experiment, locally grown 'Cal Ace' tomatoes were carefully harvested at the mature-green stage, washed and sorted. Tomatoes of comparable weight, size and shape were evenly distributed among experimental lots. Three replicates of 10 tomatoes were used for each treatment. Tomatoes were placed in 10-liter containers under a humidified air stream of 10 liter/hr at 20°C for a 24 hr equilibrium period. After initial CO_2 and ethylene readings were taken, the tomatoes were removed and impact treatments (8 drops from 40 cm) applied. Care was taken to rotate the fruit 45° following each drop. After treatment, they were placed back in respiration chambers. Ethylene and CO_2 were measured daily; ripeness stage and visual quality were scored every 2 days. Respiration rate (CO_2 production) was determined using the Claypool-Keefer method (2). After 12 days, 5 fruits were selected from each lot for compositional analysis. Only table-ripe fruits that had previously attained the breaker stage on the same day were used. For each replicate small longitudinal segments from selected fruits were placed immediately in 1% oxalic acid and blended for ascorbic acid analysis using the Loeffler and Ponting method (6). The remaining fruit portions were blended together for pH, soluble solids and titratable acidity determinations. Fruits not used for compositional analysis were scored for internal damage.

Impact damage resulted in a sustained increase in ethylene production (Fig. 2). Respiration rates increased 1 day after treatment. Peak respiration rates of damaged fruit were observed 1 to 2 days after injury. These results are in line with previous reports (1, 3, 7).

Impact treatment decreased the average no. of days required for tomatoes to reach the dark-pink ripeness stage (Table 2). Although the difference was not significant, this trend was observed wherever an ethylene response to bruise injury was detected. No external symptoms of bruising were observed. However, internal damage scores were significantly different. After ripening, fruits bruised at the mature-green stage had significantly lower levels of titratable acidity and slightly lower (nonsignificant) ascrobic acid content than controls. Compositional changes of this magnitude may be sufficient to alter taste and nutritive quality (11). No consistent differences were observed in pH or total soluble solids content.

The effect of no. of impacts was

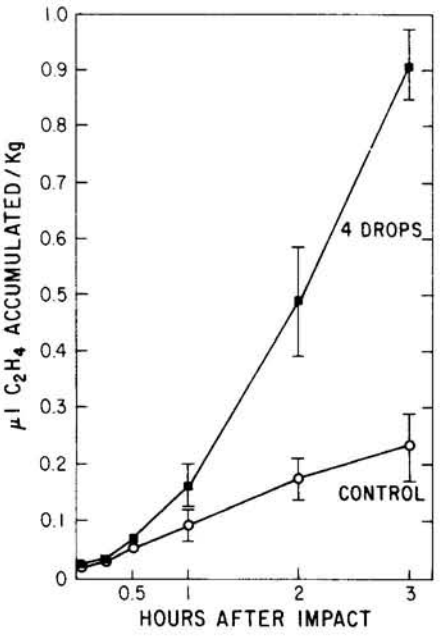

Fig. 1. Ethylene accumulated during 3 hr following 4 impacts of mature-green 'Tropic' tomatoes held at 20°C (mean of 3 replicates per treatment).

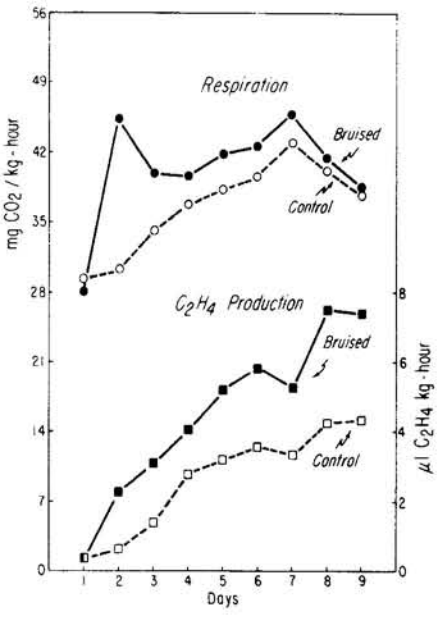

Fig. 2. Effect of 8 impacts on CO_2 and ethylene production of 'Cal Ace' tomatoes damaged at the mature-green stage and held at 20°C (mean of 3 replicates per treatment).

Table 2. Influence of impact bruising on ripening rate, visual quality, internal damage, and composition of 'Cal Ace' tomatoes harvested at the mature-green stage and held at 20°C.[z]

Treatment	Avg no. days to reach dark-pink stage	Internal damage score at table-ripe stage[y]	Composition at the table-ripe stage			
			pH	Titratable acidity (%)	Total soluble solids (%)	Ascorbic acid (mg/100 g)
Control	10.8a[x]	1.4a	4.4a	0.35a	4.6a	15.0a
8 impacts	9.7a	3.6b	4.4a	0.31b	4.8a	14.3a

[z]Values shown are means of 6 replicates.

[y]See Table 1.

[x]Mean separation in columns at 5% level.

Table 3. Effect of impact treatment of mature-green fruit of 'Tropic' tomato on internal tissue damage and ripening rate.[z]

No. of impacts	Internal damage score[y]	Days to reach dark-pink ripeness
0	1.7a[x]	10.5a
1	2.8b	9.5a
2	3.3bc	9.2a
4	3.6c	8.8a
8	4.3d	8.3a
12	4.4d	8.2a

[z]Means of 20 fruit per treatment.

[y]See Table 1.

[x]Mean separation in columns by Duncan's multiple range test, 5% level.

studied. Commercially packed mature-green fruit of 'Tropic', 'Manapal', 'VFN Bush', and locally grown 'Cal Ace' were tested. Tomatoes were carefully handled and transported to the laboratory. Experimental procedure was similar to that described above. Two replications of 10 fruit per treatment were used. The no. of impact treatments were 1, 2, 4, 8 and 12 impacts. For illustrative purposes, only data from the 'Tropic' experiment are presented.

Stimulation of ethylene and CO_2 production varied with the no. of drops, the amount and type of damage, and the cultivar. In 'Manapal', 'Tropic', and 'Cal Ace' tomatoes, impact damage resulted in an increase in ethylene production within 1 day after treatment (Fig. 3). Increased no. of drops tended to increase the sustained ethylene production rate. In these tests, 12 drops did not increase internal damage, ethylene or CO_2 production rates above 8-drop treatments. 'VFN Bush' fruits did not show any ethylene response regardless of the no. of drops.

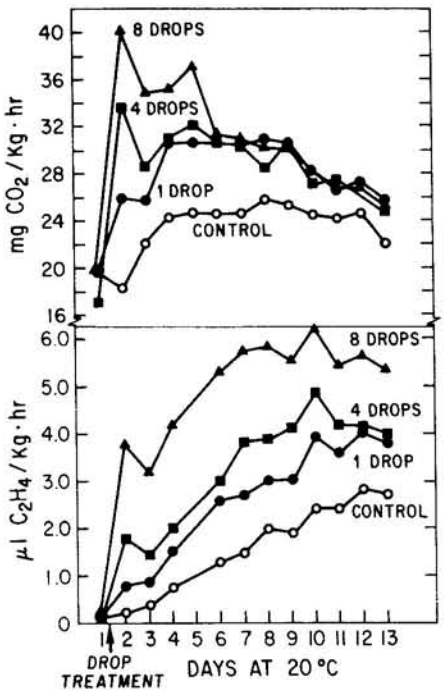

Fig. 3. Effect of 1, 4 and 8 impacts on CO_2 and ethylene production of 'Tropic' tomatoes damaged at the mature-green stage and held at 20°C (mean of 2 replicates per treatment).

Ethylene response of 'Tropic' during the first 2 days following impact varied from that observed in 'Manapal' and 'Cal Ace'. Although 'Manapal' and 'Cal Ace' had sustained levels of ethylene production, neither exhibited an ethylene peak on day 2. Drop treatment caused 'Tropic' tomatoes to develop longitudinal splits. Splits could have allowed a temporary increase in ethylene diffusion or production rate from exposed tissues. Cultivar, initial maturity or other factors, may account for the variations observed.

Respiration rates 1 day after impact increased in all cultivars tested. Increased no. of drops caused larger increases in repiration rates (Fig. 3). The duration of treatment effect varied with cultivar. Respiration rate of impact-bruised 'VFN Bush' returned to control levels 2 days after treatment. Respiration rates of damaged 'Manapal', 'Tropic', and 'Cal Ace' fruit remained higher than controls over the entire test period. However, after 6 days, no difference among drop treatments could be detected.

Although significance could not be shown, fruit receiving impact injury ripened faster (Table 3). Again, this trend was observed only when a sustained ethylene response to injury was detected. The severity and amount of internal tissue damage increased with increasing no. of drops in all cultivars.

Bruising can result in sustained increases in ethylene production rates within 1 hr after injury. Ethylene production is relative to the amount and type of tissue damaged, and the cultivar. Whether increased ethylene production is limited to damaged tissue or is in part a whole fruit response triggered by initial increases in production from damaged tissue is not clear. Impact bruising also directly or indirectly causes sustained increases in respiration rates.

The increased ethylene production and possibly other physiological changes seem to provide a condition conducive to faster ripening of damaged fruits. Damage of internal tissues results in significant decreases in titratible acidity and possibly in ascorbic acid content. Even though bruised mature-green tomatoes may retain acceptable external quality during ripening, physiological and physical changes induced by the damaged tissue can alter the composition and reduce the internal appearance quality.

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