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Effect of Postharvest Heat Treatments for Insect Control on the Quality and Market Life of Avocados

Eduardo L. Kerbel, F. Gordon Mitchell, and Gene Mayer
Department of Pomology, University of California, Davis, CA 95616

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Abstract. **The tolerance of avocado *(Persea americana* Mill. cv. Fuerte) to different heat treatments, using hot air at 43°C, was evaluated. The heat-treated avocados did not soften or ripen normally and exhibited severe surface browning after a 14-day simulated transit period at 7° followed by a 4-day simulated marketing period at 20°. Heat treatments also increased rate of weight loss, susceptibility to vibration injury, and loss of fresh avocado flavor.**

The avocado is an important fruit grown in California and is listed as one of the Mediterranean fruit fly *[Ceratitis capitata* (Wied.)] host commodities (4). Only fumigation, cold treatments, and heat treatments have been accepted as disinfestation procedures by quarantine authorities in importing countries (6). However, fumigants are difficult to use because of their extreme toxicity to humans, and cold treatments (10 days at $\leq$0°C to 16 days at $\leq$2° for the Mediterranean fruit fly) are of limited use for chilling-sensitive commodities like avocado.

The vapor heat treatment approved by the quarantine authorities for certain commodities consists of gradually raising the fruit temperature by exposure to saturated water vapor at 43°C until the center of the fruit reaches that temperature, then keeping the fruit at 43° for at least 8 hr (6).

Nothing has been reported on heat treatment of avocado since 1955, when Sinclair and Lindgren (5), working with 'Fuerte' and 'Dickenson' cultivars, found that this fruit would not tolerate a 16-hr treatment in a saturated atmosphere at 43°C.

The purpose of this study was to investigate the tolerance of 'Fuerte' avocado fruits to different heat treatments using hot air at 43°C, and a procedure to cool the fruit rapidly.

'Fuerte' avocados were obtained from the Ventura coastal area of California on 1 Mar. 1982. Fruit were selected for uniformity of size, maturity, and freedom from defects. One initial sample of 15 fruit was evaluated for flesh color and firmness, skin color, and oil content. Flesh and skin color were recorded using the Rd, a, and b modes of a Gardner

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Color Difference Meter (COM Model XL-23) calibrated to a white reference plate (X = 81.7, Y = 84.1 and Z = 97.9). For this test, one cheek, with a 2 to 3-cm-diameter portion of skin removed, was placed in a watch-glass over the large aperture of the colorimeter. Firmness measurements were taken on opposite cheeks of each fruit after skin removal using a UC Fruit Firmness Tester (1) fitted with an 8-mm plunger. Oil content was determined using the relation of dry weight to oil content reported by Lee et al. (2). In this relationship, dry weight is always 10% higher than percentage of oil content. For dry weight and oil analyses, the avocados were quartered longitudinally, peeled, and pitted. A potato peeler was used to take thin slices of tissue from one cut surface of each quarter. Ten grams of tissue were put into a tared petri dish. These dishes were weighed and set uncovered in a microwave oven (Amana model RR-10). The avocado slices were dried to constant weight (about 15 min at high power), after which dry weight was calculated as percentage of fresh weight. Oil content was calculated from dry weight values.

After sorting and randomizing, the fruit (240 ± 5 fruit per treatment) were distributed to the 8 treatments (Table 1). The fruit were placed into 45 x 45 x 90 cm (1½ x 1½ x 3 ft) open wooden bins with 5% vented bottoms. The bins were placed on top of fan boxes in rooms adjusted to the treatment temperature. In order to achieve 43°C quickly when transferred, and therefore to reduce possible injury at 43° by long exposure to this temperature, fruit from Treatments 2, 3, 4, 5, 6, and 7 (Table 1) were conditioned (preheated) for 6¾ hr in air at 35° and then kept in air at 43° for the designated times. About 2¼ hr were required for the center of the fruit to achieve 35°, and thereafter about 1 hr more to achieve 43°. Treatment 8 fruit (no conditioning) were kept in air at 43° for 12 hr, in this instance it took about 3½ hr for the center of the fruit to achieve 43°. In all instances, forced-air heating [0.06 $m^3 min^{-1} \cdot kg^{-1}$ (1 $ft^3 min^{-1} \cdot lb^{-1}$)] was used until the specified temperatures were achieved in the center of the fruit (as checked with thermocouple probes). After heating, the fruit were moved to 0° where they were forced air cooled for 2 to 3 hr and then stored in vented corrugated boxes and covered with plastic film (to reduce water loss) for 14 days at 7° (simulated transit conditions). After storage, the fruit were ripened at 20° for 4 days (simulated marketing conditions). Relative humidities at 0°, 7°, 20°, 35°, and 43° were 94% ±1%, 90% ±1%, 83% ±1%, 62% ± 2%, and 68% ± 2%, respectively.

Flesh firmness and color, skin color, and internal and external appearance were evaluated on 15 individual fruit per treatment, at time of transfer to 20°C and at the end of the 4-day ripening period. External and internal appearance were evaluated subjectively by scoring for browning of skin and flesh on the following scale: 0 = none, 1 = very slight, 2 = slight, 3 = moderate, 4 = severe, and 5 = extreme. Weight loss was determined on a composite sample by difference in weight before treatment and after storage and ripening. Carbon dioxide and C_2H_4 production were monitored on six individual fruit per treatment kept in individual 500-ml glass jars that were ventilated with a continuous air flow at 100 $ml \cdot min^{-1}$. Gas samples (10 ml) were withdrawn with disposable syringes and used for CO_2 and C_2H_4 analyses using Carle Model 111 thermal conductivity and Model 211 flame-ionization gas chromatographs, respectively. Measurements were made every 3 days during storage at 7° and every day during ripening at 20°.

Vibration injury and impact bruising tests were conducted on sets of 15 fruit per treatment 48 hr after treatment and following storage. For vibration injury, fruit were placed in smooth-surface open boxes and vibrated at 1.1 x *g* acceleration for 10 min. For impact bruising, each fruit was impacted once on each cheek from a standard 91.4-cm (3-ft) height with a 2.5-cm (1-inch) steel ball dropped through a vertical column. The results of both tests were recorded 48 hr after the test.

A panel of 10 judges participated in the sensory evaluation of avocado flavor. Panelists were selected for their taste perception and were trained for 4 days on the use of the scoring system and the definitions of the flavor characteristics of avocados. Judges scored the samples for "cooked flavor", "sourness", and "fresh avocado flavor." Evaluations were replicated 3 times and the flavor characteristics were evaluated by the least significant difference multiple comparison test (3), using analyses of variance to test for significance.

Skin color and impact bruising did not differ significantly among treatments (data not included). Only fruit from Treatments 4, 5, and 7 lost more weight than control fruit. Relative to control fruit, only fruit from Treatments 7 and 8 developed more severe flesh browning, had lower flesh color "a" values, and softened less after 4 days ripening at 20°C (Tables 1 and 2). When fruit from Treatments 5, 6, 7, and 8 were peeled, there were many black spots (0.5 to 4.0 mm in diameter) in the flesh.

Table 1. Effect of heat treatments on weight loss, flesh firmness, internal appearance, and external appearance of 'Fuerte' avocado fruit[z] (n = 15) after 14 days of storage at 7°C + 4 days ripening at 20°.

Treatment	Hr of exposure to 43°C air	Wt loss (%)	Flesh firmness (N)	Internal appearance[y] (score)	External appearance[y] (score)
1 Control (7°)	0	5.5 ab[w]	5.8 a	0.1 a	0.6 a
2 Preheated only[v]	0	5.1 a	7.6 a	0.2 a	1.1 a
3 Preheated + air at 43°	3.5	6.3 bc	23.1 a	0.4 ab	4.1 b
4 Preheated + air at 43°	4	6.7 c	23.1 a	0.6 ab	4.3 b
5 Preheated + air at 43°	5	6.8 c	24.0 a	0.8 abc	4.4 b
6 Preheated + air at 43°	7	6.4 bc	41.4 a	1.0 abc	4.7 b
7 Preheated + air at 43°	11	7.0 c	161.5 b	1.4 bc	4.7 b
8 Air at 43° only	12	6.5 bc	170.0 b	1.7 c	4.3 b

[z]Fruit characteristics (mean ± SD) at harvest: flesh firmness (N) = 214 ± 2.1, flesh color ("a" value) = −14.9 ± 3.2, skin color ("a" value) = −10.1 ± 1.9, oil content = 24% ± 1%.
[y]Browning of flesh based on a scale of 0–5 (0 = none, 5 = extreme).
[x]Browning of surface based on a scale of 0–5 (0 = none, 5 = extreme).
[w]Mean separation within columns by least significant difference at the 1% level. Statistical analysis was made on data transformed using the arcsin transformation.
[v]Preheated at 35° for 6¾ hr.

In contrast with control fruit, surface browning was more severe on fruit from all treatments except Treatment 2 (Table 1). These results suggest that surface browning was caused by the 43°C air treatment.

The heat treatments increased fruit susceptibility to vibration injury on all fruit that were exposed to 43°C air for 4 hr or more (Table 2). The judges scored fruit from Treatments 6, 7, and 8 as lacking fresh avocado flavor compared to control fruit.

Fruit from Treatments 2, 3, and 4 showed slightly lower CO_2 production rates than control fruit but reached their climacteric peak at the same time (i.e., after 2 days at 20°C). Fruit from Treatments 5, 6, 7, and 8 had not reach their climacteric peak after 4 days at 20° (data not shown). Ethylene production by control fruit and fruit from Treatment 2 reached the climacteric peak after 2 days at 20°. In fruit from all other treatments, C_2H_4 production rates continued to increase during the 4 days at 20°, which may have been due to heat stress injury, since it did not parallel changes in fruit softening.

Table 2. Effect of heat treatments on flesh color and vibration injury (n = 15) after 14 days of storage at 7°C, and 'fresh avocado flavor' (n = 10) after 14 days of storage at 7° + 4 days ripening at 20°, of 'Fuerte' avocado fruits.

Treatment	Hr of exposure to 43°C air	Flesh color (CDM "a")	Vibration injury[z] (score)	Fresh avocado flavor (score)
1 Control (7°)	0	−13.5 c[x]	1.2 a	4.6 b
2 Preheated only[w]	0	−13.2 c	1.2 a	4.6 b
3 Preheated + air at 43°	3.5	−13.2 c	1.4 a	4.6 b
4 Preheated + air at 43°	4	−13.6 c	1.7 b	4.5 b
5 preheated + air at 43°	5	−11.6 c	2.0 b	4.4 b
6 Preheated + air at 43°	7	−11.1 bc	2.6 c	3.2 a
7 Preheated + air at 43°	11	− 8.1 a	4.9 e	3.3 a
8 Air at 43° only	12	− 8.3 ab	3.2 d	3.3 a

[z]Based on a scale of 0–5 (0 = none, 5 = extreme).
[y]Based on a scale of 0–5 (0 = lowest, 10 = highest).
[x]Mean separation within columns by least significant difference at the 1% level. Statistical analysis was made on data transformed using the arcsin transformation.
[w]Preheated at 35° for 6¾ hr.

We should mention that we were not able to achieve "saturated water vapor" conditions (100% RH) at 43°C in our laboratory. Therefore, the low relative humidity that was maintained during the experiments could have had an effect in the development of the observed heat injury symptoms.

The remarkable retention of firmness by the long exposures to 43°C (Treatments 7 and 8; Table 1) indicates inhibition of softening (which accompanies normal ripening) by heat stress. Presumably the enzymic degradation of polysaccharides that brings about softening was impaired.

Based on the extent of fruit injury, particularly surface browning and susceptibility to vibration injury, we conclude that these heat treatments were sufficiently injurious to be eliminated as potential quarantine procedures.

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