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Ripening, Chilling Injury, and Respiratory Response of ‘Hass’ and ‘Fuerte’ Avocado Fruits at 20° C following Chilling[1]

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ABSTRACT. The ripening, chilling injury and respiratory responses of 'Hass' and 'Fuerte' avocado fruit *(Persea americana* L.) were determined at 20°C subsequent to 0 to 5 weeks storage at 10°, 5° and 0°. Fruit held at 10° showed no chilling injury symptoms and were ripe by the third week. No softening or chilling injury symptoms occurred during the 5 weeks at 5° or 0°. However, after transfer to 20° fruit held at 5° and 0° longer than 1 week developed chilling injury and the severity increased as the exposure period increased. Short exposures to 5° and 0° tended to hasten ripening at 20° compared with fruit placed directly at 20°, but fruit held 5 weeks at 5° and 0° took longer to ripen at 20° than control fruit. Fruit placed directly at 20° showed a typical climacteric respiratory pattern which was associated with ripening. Chilling at 5° and 0° for more than 1 week resulted in high initial respiratory rates at 20°, followed by decreasing respiratory rates with no climacteric pattern associated with ripening.

Avocados and many other tropical fruits sustain physiological disturbance and chilling injury when exposed to low storage or transit temp (11). Lutz and Hardenburg (10) indicate that cold-tolerant cultivars of avocados may be stored at 4.4°C (40°F) while cold-intolerant cultivars store best at 12.8°C (55°F) and that the 'Fuerte' stores best at 7.2°C (45°F). The effect of various chilling exposures on subsequent chilling injury and ripening of avocados has been reported (2, 3, 5, 13, 14, 16, 18). Although detailed studies on the respiratory response for other crops following chilling have been reported (1, 7, 8, 12, 17) only meager data are available on the respiratory response of avocados following chilling (2, 3, 4). Presented here are data on the ripening, chilling injury and respiratory responses of 'Hass' and 'Fuerte' avocado fruits at 20° following exposure of from 1 to 5 weeks at 0°, 5°, and 10°C.

Materials and Methods

Mature 'Hass' and 'Fuerte' fruits were harvested from local groves, randomized, and placed in storage by noon. Twenty-four fruits from each temp were transferred to 20°C at weekly intervals after 0 through 5 weeks. At 20°, 12 fruits from each temp were individually placed in respiration chambers and 12 fruits were placed in open

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containers. Each day the ripening (softening) of all fruit was determined subjectively by applying a slight pressure to the fruit placed in the palm of the hand. Categories of softening were: hard, firm, softening, and ripe. When the fruits were ripe chilling injury was evaluated relative to internal and external discoloration and quality of ripening as: none = 0; slight = 1; moderate = 2; and severe = 3. The chilling injury index was calculated by multiplying the number of fruit in each category by the respective score, summing the products and dividing by the total no. of fruits. The respiratory rate of individual fruits were taken twice daily (8 AM and 4 PM) by the method of Claypool and Keefer (6) starting the day after transfer. The 2 daily determinations for each fruit were averaged and these values summarized for each treatment.

Results and Discussion

The effect of 0 to 5 weeks storage at 0°, 5° and 10°C on ripening and chilling injury of 'Hass' avocados at 20° is given in Table 1. Significant differences in ripening rates of fruits in respiratory chambers and in open containers at 20° were not observed. Therefore, data represents averages of 24 fruits. Fruits placed directly to 20° (0 weeks storage) began to soften after 6.2 days and were eating ripe after 8.7 days. At 10° the fruit began to ripen and were eating ripe after the 3-week storage period. Fruit held at 5° and 0° did not show evidence of ripening while at these temp. After transfer to 20° the fruit held at 5° for 1, 2, 3, and 4 weeks and fruit held at 0° for 1, 2, and *3* weeks ripened in a shorter time than control fruit. However, longer chilling exposures (5 weeks at 5° and 0°) significantly increased the time required for ripening at 20° compared with control fruit.

Table 1. Effect of storage at 10°, 5°, and 0°C on ripening and chilling injury of 'Hass' avocados at 20°.

Storage treatment		Days at 20°C		Chilling injury index[z]
Temp (°C)	Duration (weeks)	To softening	To ripe	
–	0	6.2d[y]	8.7f	0.0a
10	1	2.5b	4.4c	0.0a
	2	0a	1.5b	0.0a
	3	0a	0a	0.0a
	4	0a	0a	0.0a
	5	0a	0a	0.0a
5	1	5.7d	7.4e	0.0a
	2	4.6c	6.5d	0.0a
	3	4.4c	6.4d	0.2a
	4	5.8d	7.5e	1.3b
	5	7.3e	9.8g	2.2c
0	1	6.0d	7.5e	0.0a
	2	4.5c	6.3d	0.3a
	3	6.1d	7.7e	1.1b
	4	7.2e	8.8f	2.3c
	5	8.4f	9.9g	2.7d

[z]Chilling injury index: 0 = none; 1 = slight; 2 = moderate; 3 = severe.
[y]Means separation in columns by Duncan's multiple range test, 5% level.

Table 2. Effect of storage at 10°, 5°, and 0°C on ripening and chilling injury of 'Fuerte' avocados at 20°.

Storage treatment		Days at 20°C		Chilling injury index[z]
Temp (°C)	Duration (weeks)	To softening	To ripe	
–	0	5.5d[y]	8.1e	0.0a
10	1	1.8b	3.1b	0.0a
	2	0a	1.4b	0.0a
	3	0a	0a	0.0a
	4	0a	0a	0.0a
	5	0a	0a	0.0a
5	1	5.0d	7.3d	0.0a
	2	4.5c	6.3c	0.0a
	3	4.6c	6.5c	0.3a
	4	5.2d	7.3d	1.1b
	5	6.6e	8.7f	2.4c
0	1	5.1d	7.6d	0.0a
	2	4.6c	6.7c	0.4a
	3	5.2d	7.8de	1.5b
	4	6.6e	8.1e	2.1c
	5	7.5f	9.0f	2.8d

[z]Chilling injury index: 0 = none; 1 = slight; 2 = moderate; 3 = severe.
[y]Means separation in columns by Duncan's multiple range test, 5% level.

Chilling injury symptoms were not evident during storage or after transfer to 20°C for fruit held at 10° or after 1 and 2 weeks at 5° or after 1 week at 0° (Table 1). The

incidence and severity of chilling injury increased with increased duration of exposure at 5° and 0° and for the same exposure period was more severe after exposure to 0° than 5°.

The ripening and chilling response of 'Fuerte' avocados (Table 2) was essentially the same as that of 'Hass'.

The effect of various chilling exposures on subsequent ripening at a non-chilling temperature of avocados has not been previously documented. Zauberman et al. (18) indicate that the longer the storage at 6°C the shorter the time to soften at 14°, but no data are given. Hatton et al. (9) present days to soften (ripen) at 21.1°C (70°F), but in many cases only a range of storage periods at a given temp was presented instead of a specific storage period. The significant increase in the time required for 'Fuerte' and 'Hass' avocados to ripen at 20° following 5 weeks storage at 5° and 0° compared to fruit placed directly at 20° has not previously been reported for avocados. However, it has been reported that increasing the exposure of tomatoes to 2° delayed ripening at 18° (15). The average respiratory rates of 'Hass' and 'Fuerte' fruits at 20°C subsequent to exposure to 10°, 5°, and 0° are presented in Fig. 1. The 'Hass' fruit placed directly at 20° (0 weeks exposure) produced a typical climacteric, reaching the peak at 6 days. Variation among the 12 fruits tended to flatten the peak. After 1 week at 10° the fruit were well into the climacteric and peaked on the 2nd day after transfer. Those held 2 weeks were essentially at the climacteric peak when transferred. Fruit held longer at 10° were ripe and post-climacteric (Table 1).

'Hass' fruit held for 1, 2, and 3 weeks at 5°C showed climacteric-like patterns at 20°, but the peak respiratory rates did not coincide with softening and ripening (Table 1). Fruit held for 4 and 5 weeks at 5° had high initial respiratory rates 1 day after transfer to 20° followed by a continual declining rate with no climacteric associated with ripening.

Similarly, the respiratory rates of 'Hass' fruit held 1, 2, 3, and 4 weeks at 0°C rose to a peak 2 to 3 days after transfer to 20° and then declined during softening and ripening. The fruit held 5 weeks at 0° had high initial respiratory rates at 20° and decreased as the fruit ripened.

Although there are minor variations, the respiratory responses of fruit of 'Fuerte' was qualitatively similar to that just described for 'Hass'. The notable exceptions are that 'Fuerte' fruit held for 1 week at 5° and 0°C displayed a normal climacteric at 20° whereas comparable 'Hass' fruit did not. However, in these cases the climacteric peaks preceded the full ripe stage of the fruit by 2 or 3 days, which is different from the relationship between the climacteric peak and full ripe fruit for fruit placed directly at 20°.

Avocado fruit placed directly at 20°C displayed a typical climacteric respiratory pattern and the ripening of the fruit followed the climacteric peak by 1 to 2 days. However, fruit held at chilling temp of 5° and 0° for periods longer than 1 week failed to show a normal climacteric and had high initial rates at 20° which declined with time. No climacteric pattern was associated with softening and ripening. The mechanism responsible for this abnormal phenomenon is not known, but it appears to be associated with the metabolic disturbance caused by chilling.

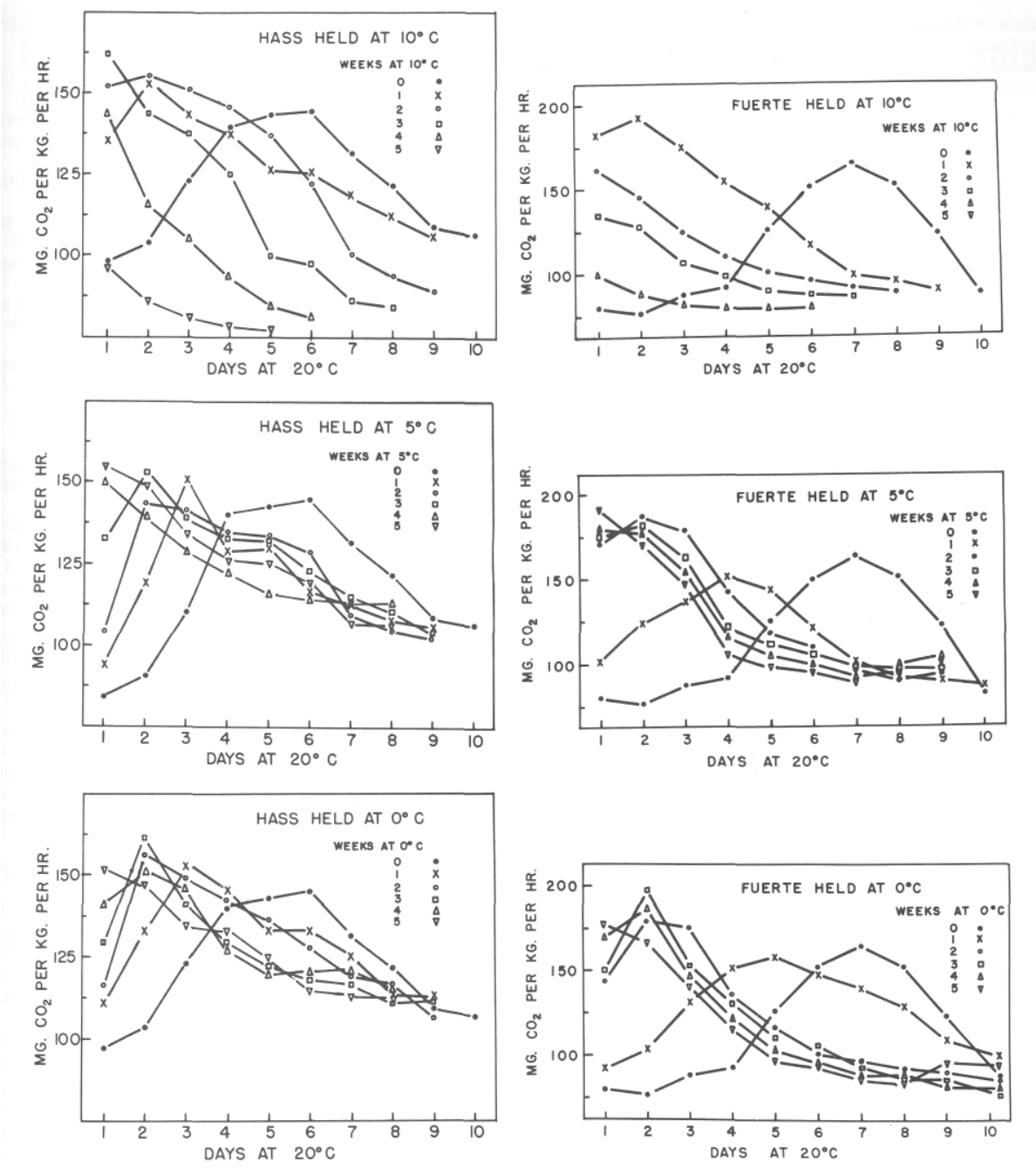

Fig. 1. Respiratory rates of 'Hass' and 'Fuerte' fruits at 20°C following chilling at 0°, 5°, and 10° for 0, 1, 2, 3, 4, and 5 weeks.

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