HortScience 18(2):235-237. 1983.

Effects of Chilling on Respiration and Ethylene Production of 'Hass' Avocado Fruit at 20°C[1]

Irving L. Eaks
Department of Biochemistry, University of California, Riverside, CA 92521

Additional index words. Persea americana, ripening

Abstract. **The effects of chilling 'Hass' avocado fruit at 0° or 5°C on the respiratory rates, rates of ethylene production, ripening, and chilling injury symptoms at 20° were compared with the same responses of fruit exposed to a nonchilling temperature (10°) and fruit placed directly at 20°. Fruit held at 10° for 2 weeks were beginning the climacteric and ripened after about 4 days at 20°. Longer exposures at 10° resulted in ripe or overripe fruit. Fruit held for 2 weeks at 0° or 5° displayed normal climacteric patterns and ethylene production at 20°, and developed no significant chilling injury symptoms. Exposures of 4 and 6 weeks at 0° or 5° resulted in the development of chilling injury symptoms, abnormal ripening, atypical respiratory rate patterns, and reduced ethylene production rates which peaked after 2 days at 20° and showed a declining rate thereafter, with no increase in the rate of ethylene production associated with fruit softening.**

Chilling injury of tropical and subtropical fruits results from physiological disturbances when exposed to low, but nonfreezing temperatures below about 10° to 12°C (7). The respiratory rates of nonchilling temperatures following chilling exposures have been observed to evaluate the metabolic dysfunction caused by chilling for various fruits (1, 3, 4, 5, 6, 13). Exposure to chilling temperatures stimulates ethylene production during that time and after transfer to nonchilling temperatures in several fruits (2, 5, 8, 9, 10, 12). However, the ethylene production of cucumbers at 25° after chilling at 2.5° for more than 4 days was reduced below that of fruit held at 2.5° for 4 days (11). Data on the ethylene production of avocado fruit at a non-chilling temperature after a series of chilling exposures are not available.

Reported here are the respiratory rates, ethylene production, and ripening of 'Hass' avocado fruit at 20°C after various chilling and nonchilling exposures compared with fruit placed directly at 20°.

Mature 'Hass' avocado fruit were harvested from Experiment Station trees, randomized, and placed at experimental conditions by noon. Experiments were conducted with mid- and late-season fruit during one season and mid-season fruit the next season. Each

[1] Received for publication Sept. 24, 1982. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

treatment consisted of 8 individual fruits. The 8 uniform-sized fruit for each treatment were numbered, weighed, and placed in labeled paper bags for storage. Treatments consisted of a) fruit placed directly in respiratory chambers at 20°C and b) storage for 2, 4, and 6 weeks at 0°, 5°, and 10°. At the end of each storage treatment the fruit were weighed and placed in respiratory chambers at 20°.

The respiratory chambers were aerated with humidified air with the ethylene removed by passing through a glass tube of Purafil (Purafil, Inc.; Chamblee, Ga.) and the CO_2 removed by bubbling through a fritted gas-dispersion tube into 2 N NaOH. The air flow for each chamber was metered through calibrated capillaries at a rate ranging from 8.0 to 8.5 liters/hr. CO_2 production of each fruit was determined by a calibrated Beckman infrared CO_2 analyzer. A switching system sequenced the outlet gas flow from each fruit chamber and an air sample (CO_2-free) through the analyzer. Data were taken from the chart every 12 hr for calculation of respiratory rates. Ethylene production was determined twice daily (0800 and 1600 HR) on 1 ml samples of the outlet gas of each respiratory chamber by a Varian aerograph flame ionization gas Chromatograph equipped with a 2 m x 3.2 mm column packed with 60-80 mesh activated alumina. The gas Chromatograph was calibrated at each sampling with 1 ml samples of a standard ethylene-nitrogen mixture. Fruit ripening was determined subjectively by applying a slight pressure to each fruit by hand. When ripe the external and internal characteristics were evaluated for chilling injury (4).

The data presented are averages for the mid-season fruit for the 2 years. The 2 daily determinations for CO_2 and ethylene were averaged for an average noon reading. The late-season fruit for the first season displayed similar results relative to the patterns of respiratory rates and ethylene production, but ripened at 20°C after about 6 days instead of 10 days for the mid-season fruit.

Fruit placed directly at 20°C displayed the usual climacteric pattern with a 6-day preclimacteric period and the climacteric peak occurred 9 days after harvest (Fig. 1). Fruit stored for 2 weeks at 10° had just finished the preclimacteric phase and went directly into the climacteric, peaking after 3 days at 20°. After 4 and 6 weeks at 10°, the fruit displayed declining postclimacteric respiratory patterns at 20°. The fruit placed directly at 20° and those held 2 weeks at 10° before transfer to 20° ripened about one day after the respective climacteric peaks. The fruit were ripe after 4 weeks at 10° and overripe after the 6-week storage period. Chilling injury was not observed on the fruit during storage at 10° or after transfer to 20°.

The respiratory rates for fruits held 2 weeks at 5°C displayed a typical preclimacteric (4 days) and climacteric pattern peaking after 6 days at 20° (Fig. 2). These fruit ripened normally about 2 days after the climacteric peak. Fruit held 4 weeks at 5° had a high initial respiratory rate, showed a respiratory rate increase from the first to the second day at 20° followed by a gradually declining rate, and ripened after about 9 days. After 6 weeks at 5°, the respiratory rate of the fruit was initially high and decreased with time. Although the fruit softened after about 11 days at 20°, ripening was abnormal in that the texture was rubbery. Symptoms of chilling injury were not found on the fruit during storage at 5° nor at 20° on fruit held 2 weeks at 5°. Storage for 4 and 6 weeks at 5° resulted in the development of chilling injury symptoms rated at slight and moderate, respectively, at 20°.

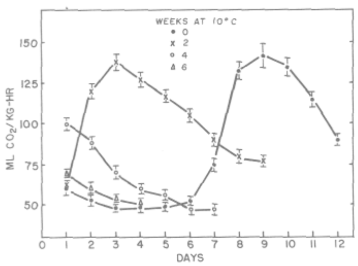

Fig. 1. Respiratory rates at 20°C following 0, 2, 4, and 6 weeks storage at 10°.

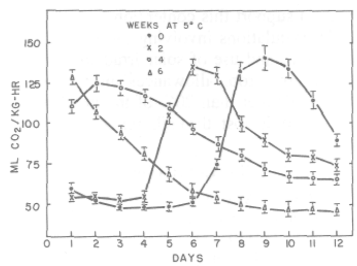

Fig. 2. Respiratory rates at 20°C following 0, 2, 4, and 6 weeks storage at 5°.

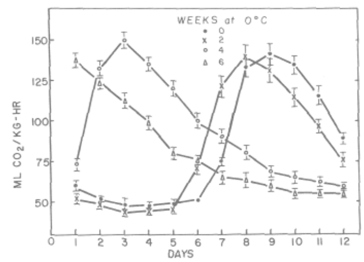

Fig. 3. Respiratory rates at 20°C following 0, 2, 4, and 6 weeks storage at 0°.

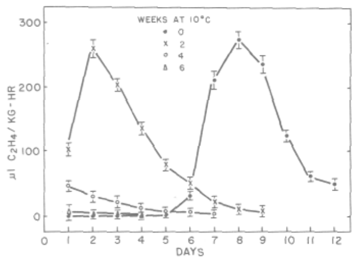

Fig. 4. Ethylene production rates at 20° following 0, 2, 4, and 6 weeks storage at 10°.

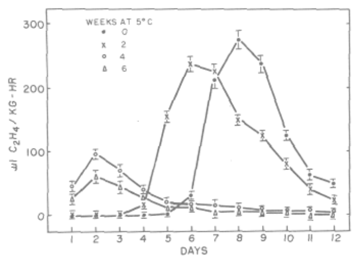

Fig. 5. Ethylene production rates at 20° following 0, 2, 4, and 6 weeks storage at 5°.

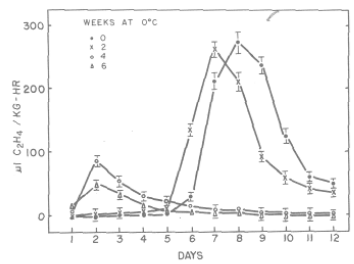

Fig. 6. Ethylene production rates at 20° following 0, 2, 4, and 6 weeks storage at 0°.

Fruit held at 0°C (Fig. 3) displayed respiratory patterns at 20° similar to those of fruit held at 5° (Fig. 2). The climacteric peaks of fruit at 20° following 2 and 4 weeks storage at 0° occurred after 8 and 3 days, respectively. These peaks were delayed by one and 2 days compared with fruit held at 5°. However, the days to ripen at 20° were not significantly different. The respiratory rates at 20° for fruit held 6 weeks at 0° were initially high and declined continuously; the fruit softened slightly after about 12 days at 20°, but remained rubbery. This is a symptom of chilling injury. Chilling-injury symptoms were not observed at the time of transfer from 0° to 20°. Symptoms displayed by fruit held 2 weeks at 0° were not of commercial significance. However, after 4 and 6 weeks at 0°, symptoms at 20° were moderate and severe, respectively.

Ethylene production by fruit placed directly at 20°C (Fig. 4) followed the typical pattern and the peak production rate preceded the climacteric peak by one day. Fruit held 2 weeks at 10° were starting into the climacteric when transferred to 20° and reached the peak rate of ethylene production on the second day at 20°. After 4 and 6 weeks at 10°, the fruit were ripe; therefore, the rate of ethylene production was low at 20°.

Ethylene production of avocados at 20°C following storage at 5° (Fig. 5) and 0° (Fig. 6) were similar. Fruit held for 2 weeks showed a typical ethylene pattern when transferred to 20°. However, after 4 and 6 weeks at 0° and 5°, the fruit produced some ethylene after one day at 20° and reached a peak rate of production on the second day, which was very low compared with fruit placed directly at 20° or the other ripening fruit not showing chilling injury. The peak rate of ethylene production at 20° was suppressed more by previous storage at 0° or 5° for 6 weeks than for 4 weeks.

The respiratory rates, time to ripen, and chilling injury of avocados at 20°C following chilling exposures presented here basically corroborate data previously reported (4). The peak rates of ethylene production of ripening avocados at 20° were essentially the same for those not displaying chilling injury (direct to 20° and 2 weeks at 0°, 5°, and 10°). However, those fruits which displayed chilling injury had much lower peak rates of ethylene production, with peaks occurring after 2 days at 20°. Increases in ethylene production were not associated with softening by these fruits.

Pears, a temperate-zone fruit which requires exposure to cold temperatures (0° to 5°C) to initiate ripening, produces more ethylene when removed from cold exposure to a ripening temperature (23°) than fruit placed directly at 23° (8). Therefore, the cold treatment caused metabolic changes which increase ethylene production and thus induce ripening. Ethylene production by citrus fruits, a chilling-sensitive nonclimacteric fruit, is induced by chilling exposures; in general, more ethylene is produced the longer the exposure or the lower the temperature (2, 5, 9). The ethylene production of cucumbers at 23° increased as the chilling exposure at 2.5° increased from one to 4 days and then decreased rapidly as the exposure period increased to 7 days (II). However, 1-aminocyclopropane-1-carboxylic acid (ACC) at 23° increased as the exposure period at 2.5° increased to 7 days (11). Therefore, the ability of the cucumber to convert ACC to ethylene decreased as chilling exposure began causing symptoms of chilling injury. Although ACC was not determined in the present study, the data support the hypothesis that chilling in avocados may also suppress the capacity of the fruit to synthesize ethylene. The reduced level of ethylene production of chilled fruit may be responsible for the failure of these fruit to ripen normally.

Literature Cited

1. Appleman. C.O. and C.L. Smith. 1936. Effect of previous cold storage on the respiration of vegetables at higher temperatures. J. Agr. Res. 53:557-580.
2. Cooper, W.C., G.K. Rasmussen, and E.S. Waldon. 1969. Ethylene evolution stimulated by chilling in citrus and *Persea* Sp. Plant Physiol. 44:1194-1196.
3. Eaks, I.L. 1960. Physiological studies of chilling injury in citrus fruits. Plant Physiol. 35:632-636.
4. Eaks, I.L. 1976. Ripening, chilling injury, and respiratory response of 'Hass' and 'Fuerte' avocado fruits at 20°C following chilling. J. Amer. Soc. Hort. Sci. 101:538-540.
5. Eaks, I.L. 1980. Effect of chilling on respiration and volatiles of California lemon fruit. J. Amer. Soc. Hort. Sci. 105:865-869.
6. Eaks, I.L. and L.L. Morris. 1956. Respiration of cucumber fruits associated with physiological injury at chilling temperatures. Plant Physiol. 33:308-314.
7. Lyons, J.M. 1973. Chilling injury in plants. Annu. Rev. Plant Physiol. 24:445-466.
8. Sfakiotakis. E.M. and D.R. Dilley. 1974. Induction of ethylene production in 'Bosc' pears by postharvest cold stress. HortScience 9:336-338.
9. Vines, H.M., W. Grierson, and G.J. Edwards. 1968. Respiration, internal atmosphere, and ethylene evolution of citrus fruit. Proc. Amer. Soc. Hort. Sci. 92:227-234.
10. Wang, C.Y. and D.O. Adams. 1980. Ethylene production by chilled cucumbers

(Cucumis sativus L.). Plant Physiol. 66:841-843.

11. Wang, C.Y. and D.O. Adams. 1982. Chilling-induced ethylene production in cucumbers *(Cucumis sativus* L.). Plant Physiol. 6:424-427.

12. Wang, C.Y., W.M. Mellenthin, and E. Hansen. 1971. Effect of temperature on development of premature ripening in 'Bartlett' pears. J. Amer. Soc. Hort. Sci. 96:122-126.

13. Watada, A.E. and L.L. Morris. 1966. Effect of chilling and non-chilling temperatures on snap bean fruits. Proc. Amer. Soc. Hort. Sci. 89:368-374.