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Ripening, Respiration, and Ethylene Production of 'Hass' Avocado Fruits at 20° to 40°C[1]

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ABSTRACT. The respiratory rate, ethylene production and ripening of mature 'Hass' avocado fruits (Persea americana Mill.) were determined at 20° to 40°C. Typical climacteric patterns occurred at 20°, 25°, 30° and 35° with the climacteric maximum increasing with temperature, but only a decreasing respiratory rate with time was observed at 40°. Maximum ethylene production decreased as the temperature increased, with a significant decrease between 25° and 30°, only trace amounts were produced at 35° and essentially no ethylene production was detected at 40°. The ripened fruit quality was excellent at 20°, 25° and 30°, fair at 35° and abnormal and unacceptable at 40°. Fruit held at 40° for up to 2 days resumed ripening when transferred to 20°. The exposure to exogenous ethylene or propylene hastened the ripening response up to 35°, however at 40° the respiratory rate was increased, but ethylene production and normal ripening did not occur.

Avocado fruit, which do not ripen while attached to the tree, even when exposed to ethylene (9), may be exposed to high temperature on the tree (fruit temperature in the sun to 50°C) without apparent damage. However, post-harvest, abnormal ripening at temperature above 30° has been reported (7, 16). Similar results have been reported for other fruits (5, 10, 11, 15). The failure of fruit to ripen normally at temperature above 30° to 35° has been attributed to the reduction of ethylene production at these temperatures. Ethylene production for several fruits when held at or above 30° has been reduced (1, 4, 10, 11, 15). However, data were not found for avocados. The ripening, respiratory rate and ethylene production of 'Hass' avocado fruits at 20°, 25°, 30°, 35° and 40° are reported.

Materials and Methods

Mature 'Hass' fruits were harvested from local groves, randomized, weighed and placed individually in respiration chambers at specified temperature within 1 hr. A chamber thermo-regulated at specific temperatures placed in a 20°C constant temperature room, was used to control the temperature of 5° intervals between 25° and 40°. Preliminary

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tests indicated that the airflow through the respiratory chambers influenced fruit temperature. When the chamber was set at 30°, the exhaust air from the respiratory chamber was 27° and the fruit temperature 28° and even greater differences were observed at higher temperatures. Therefore, many previously reported studies at elevated temperatures, where the fruit was assumed to be at the chamber temperature, may be in error because of the cool air flow through the respiratory chambers. To correct this error, the air was passed through a 7 m x 6.35 mm copper tube wrapped with a heating tape connected to a variable autotransformer and the voltage adjusted so that the outlet air was the same as the chamber temperature.

The air flow through the individual fruit respiratory chambers was freed of background ethylene by passing through a 50 cm x 50 mm glass tube containing Purafil, the CO_2 was removed by bubbling through 2N NaOH, and metered at about 16 liters/hr by calibrated capillaries. $C0_2$ production of each fruit was automatically recorded each hr by an infra-red CO_2 analyzer equipped with an automatic switching system and a strip chart recorder. Ethylene production was determined 3 times daily (twice on weekends) on 1 ml samples taken from the outlet of each respiratory chamber by a Varian Aerograph hydrogen flame ionization gas chromatograph equipped with a 2 m x 3.2 mm column packed with 60-80 mesh activated alumina. The system was calibrated at each sampling with 1 ml samples from a cylinder of an ethylene-nitrogen standardized mixture. The $C0_2$ and ethylene data were summarized for an average daily reading except where peak values occurred between the 24 hr intervals.

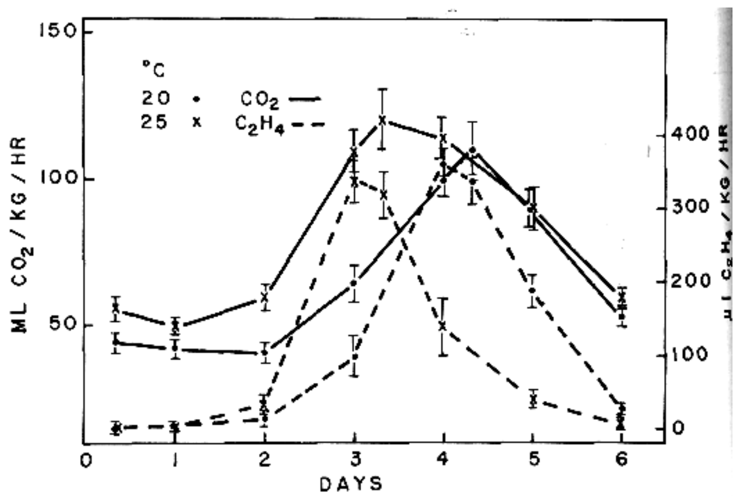

Fig. 1. Respiratory rate and ethylene production at 20° and 25°C.

Exogenous ethylene or propylene was applied by mixing the respective gas with air (12). The concentration was checked periodically by gas chromatography. Ethylene concentration was 10 ± 1 µl/ liter and the propylene concentration was 1000 ± 50 µl/liter,

Results and Discussion

The respiratory rate and ethylene production at 5°C increments between 20°and 40° are given in Fig. 1 and 2. Typical climacteric respiratory responses, similar to those previously reported for avocados (3, 6, 14), were observed for fruit held at 20° to 35°: At 40° the respiratory rate 8 hr after harvest was higher than for other temperatures, but subsequently the rate declined with time, showing no climacteric (Fig. 2). Ethylene production at 20° and 25° (Fig. 1) showed the characteristic rise associated with the climacteric reported earlier (1, 3, 4, 14). Avocados held at 30° and 35° produced some ethylene during the climacteric, but the peak rates were much lower than for fruit held at 20° and 25°, especially for fruit at 35°. Fruit held at 40° did not produce significant quantities of ethylene (less than 0.1 µl/kg-hr).

The peak respiratory rate and ethylene production for each temperature is summarized in Fig. 3. The climacteric maximum increased as the temperature increased from 20° to 35°C. A climacteric was not observed for fruit held at 40° (Fig. 2). The respiratory rate shown in Fig. 3 for 40° is the 1-day value.

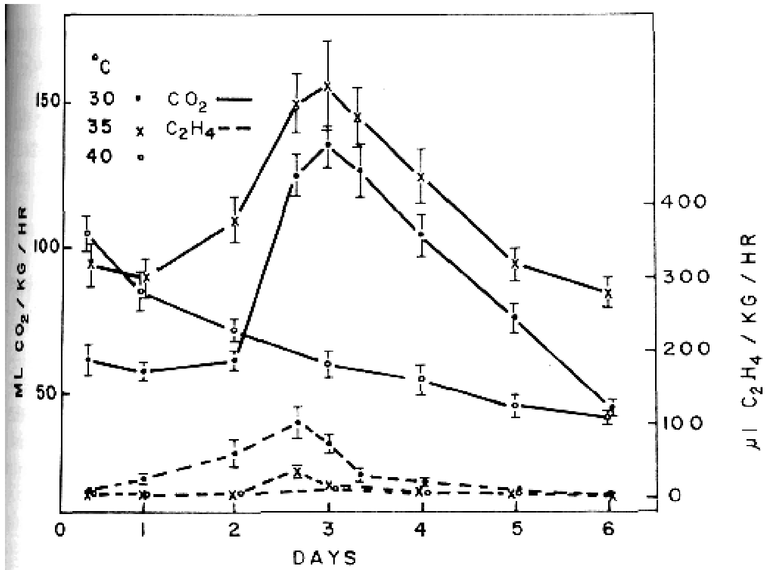

Fig. 2. Respiratory rate and ethylene production at 30°, 35° and 40°C.

High temperatures have inhibited the climacteric in other fruit. The climacteric was shown for Wickson plums at 25° C, but not at 30° or 35° (5). Pears displayed a climacteric at 20°, but not at 30°, 40° or 50° (11). In both these examples the climacteric was inhibited at 30°, while the avocado, a subtropical fruit, showed a climacteric at 30° and 35°.

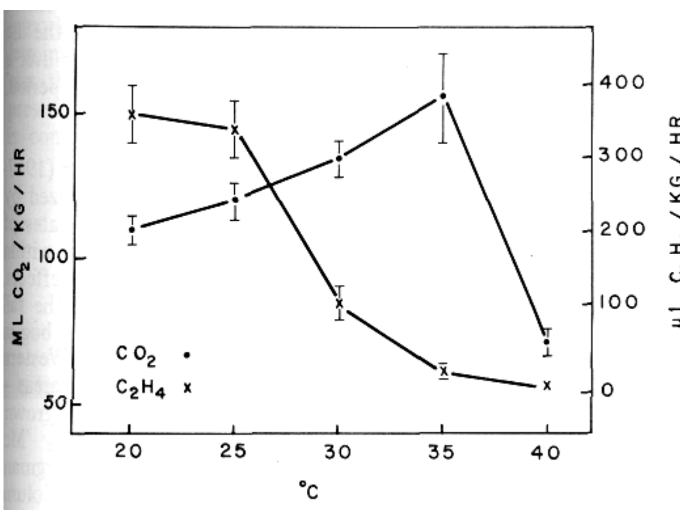

Fig. 3. Peak respiratory rate and ethylene production at 20°, 25°, 30°, 35° and 40°C. The respiratory rate at 40° is the 1 day value.

Peak ethylene production decreased as the temperature increased, although the decrease between 20° and 25°C was not significant (Fig. 3). At 30° the maximum ethylene production was decreased to about one-third the rate produced at 20° or 25°. Only trace amounts were produced at 35°, and at 40° ethylene production was essentially undetectable. The maximum ethylene production of pears was about 40 lb/kg-hr at 20°, but dropped to 0.01 to 0.07 µl/kg-hr at 30° and was essentially non-existent at 40° and 50° (11). The mechanism controlling the climacteric and ethylene production in avocados appears to be less sensitive to high temperature than in pears.

Ripening as determined by the firmness of the fruit was hastened by high temperature. Time to ripen at the various temperatures were: 6 days at 20°C; 5 days at 25°; 4 days at 30°; and 4 days at 35°. Fruit held at 40° did not ripen normally; the tissue was discolored and rubbery. The eating quality of the fruit ripened at 20°, 25°, and 30° was excellent, those ripened at 35° were fair and those ripened at 40° were completely unacceptable.

The climacteric and ethylene production are associated in most ripening fruit under normal ripening conditions (1). However, avocados held at 30°C and especially at 35° exhibited a characteristic climacteric pattern and ripened, but produced very little or only trace amounts of ethylene compared with fruit held at 20° or 25°. Therefore, it appears that the climacteric and ethylene production in avocados are independent at high temperature (35°), but at 40° both mechanisms are inhibited. The mechanism of high temperature inhibition is not known, however, protein synthesis may be involved since it has been shown that the inhibition of protein synthesis does not inhibit the climacteric, but does inhibit ethylene synthesis and softening (8).

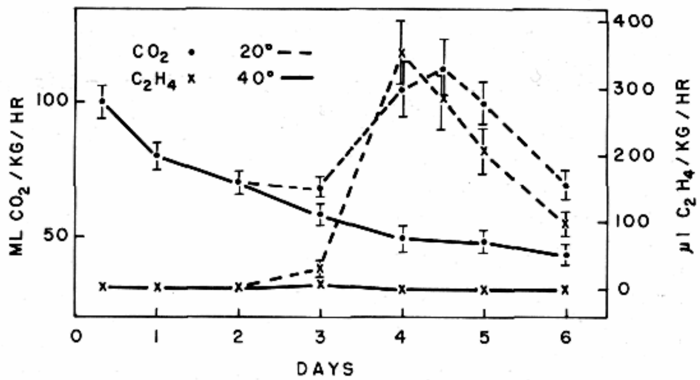

Fig. 4. Respiratory rate and ethylene production at 40°C and at 20° after 2 days at 40°.

The response of avocado fruits held continuously at 40°C compared with fruit held 2 days at 40° and then transferred to 20° is shown in Fig. 4. When transferred to 20° the fruit resumed normal ripening functions as evidenced by a climacteric rise in respiration, ethylene production and softening. Fruit held for 1 day at 40° and transferred to 20° had similar response patterns. This indicates that, at least after 2 days at 40°, the inhibition is reversible, i.e., enzyme denaturation did not occur or other mechanisms involved in the inactivation of the climacteric and ethylene production were not permanently damaged.

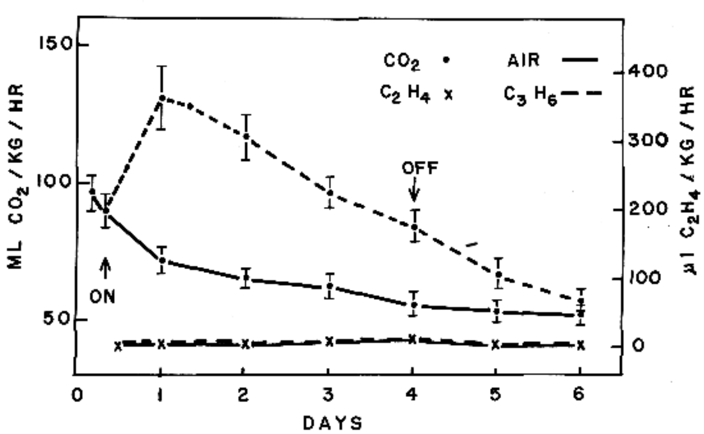

Fig. 5. Respiratory rate and ethylene production at 40°C in air and in 1000 ppm propylene (propylene on from 8 to 96 hr after initiation of experiment).

Several experiments were conducted applying exogenous ethylene (10 µl/liter) and propylene (1000 µl/liter) for 1 to 4 days at the various temperatures. At the concentrations used the physiological responses to the 2 gases were similar. The use of propylene facilitated the determination of ethylene production during the treatment period. Fruit held at 20°, 25°, 30° or 35°C gave the typical response to ethylene, i.e., an increased respiratory rate, ethylene production and softening (1, 6). Treated fruit produced less ethylene at the respective temperatures than untreated fruit and the maximum rate of ethylene production occurred after the maximum respiratory rate. Fruit treated with ethylene (data not shown) or propylene at 40° starting 8 hr after harvest increased in respiratory rate similar to fruit held at lower temperatures, but did not induce ethylene production (Fig. 5). Also, the exposure of ethylene or propylene did not enhance the rate of softening or the quality of the fruit held at 40°. Similar results were obtained with pears (11). Although exposure to ethylene stimulated the respiratory rate, it did not overcome the inhibition of ethylene production and normal ripening processes. The suggested disassociation of the ethylene stimulation of respiration from other ripening processes previously reported (13) could explain the observed effects of high temperature on avocados.

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