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Ripening Processes in Avocados Stored in Ethylene Atmosphere in Cold Storage[1,2]

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ABSTRACT. Continuous ethylene treatment (100 ppm) of avocado fruit stored at 6°C, for 13 days, caused acceleration in respiration rate for the duration of the treatment. At the end of the low temperature treatment and, also, after transfer of the fruit to 20°C, polygalacturonase activity and softening of the fruit were enhanced by ethylene treatment in comparisons with non-treated fruit. Endogenous ethylene production of ethylene-treated fruit was suppressed markedly after transfer to 20°C. Fruit treated 24 hours with ethylene at 6°C at the beginning of the storage period, ripened similarly to untreated control fruits. For avocado we suggest that in cold storage (6°C) the presence of ethylene should be avoided so that the shelf-life period of the fruit will not be reduced.

The question whether ethylene has an effect on avocado fruit in cold storage (6°) or not is not merely theoretical. This temperature is recommended for commercial storage and transportation of avocado in Israel; thus, the question and answers would have practical implications. It was reported (2) that the respiration of avocado fruit was not affected by ethylene treatment for 35 days at 5°C. On the other hand, it was recently reported that ethylene had an effect on the quality of 'Lula' avocado, stored in controlled atmosphere at 10°C (4). There are conflicting reports (2, 3) about the effect of ethylene on cold-storage apples. Data presented herein show that ethylene has an effect on ripening processes of 'Haas' avocado stored for 12 days in 100 ppm ethylene in air at 6°C. Respiration rate and softening of the fruits were accelerated, while inhibition of ethylene production during the respiratory climacteric was evident.

Materials and Methods

Mature avocado fruits of 'Haas' (ca. 170 g each) were harvested and transferred to 6°C. Twenty fruits were placed in a 16-liter glass jars washed with continuous air now of 200 ml/min for 24 hr at about 95% R.H. At the end of this period the fruit was brought to room temp and the respiration rate and ethylene production were determined. At this point, 3 different treatments were applied: 1) continuous air flow - as control; 2) continuous flow of 100 ppm ethylene in air for 24 hr and then a flow of air only, for the remainder of the experiment; and 3) continuous flow of 100 ppm ethylene in air for 12 days. On the 12th day, the flow of ethylene was replaced by pure air in the third treatment. One day later, all fruit was transferred to 20°C in continuous air-flow for the

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remainder of the experiment. Three fruits from each treatment were used for studies of respiration rate and ethylene production throughout the experiment. The fruits were transferred to a 2-liter glass jar and sealed for 1 hr, afterwards the atmosphere in the jars was assayed for CO_2 and ethylene content by gas chromatography. The lowest quantity which could be detected was 0.04 ppm ethylene in a 1-ml sample. After 1 hr these fruits were returned to the large jars for further treatment. In order to study the effect of ethylene treatment on ethylene production and respiration rate during the treatment itself, 3 additional fruits from the continuous ethylene flow treatment were transferred to similar jars and identical determinations were made. These fruits were then kept for 24 hr in the open air and respiration rate and ethylene production were determined as described above. These fruits were discarded after the second determination. This procedure was followed during the first 13 days of the experiment.

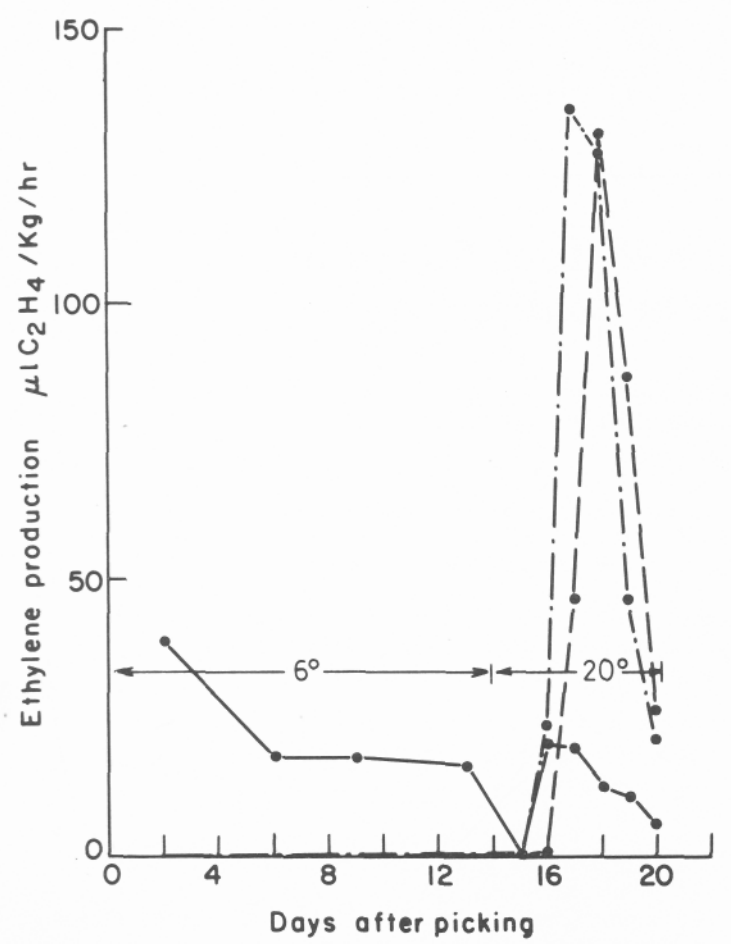

Fig. 1. Ethylene production of cold-stored (6°C), ethylene-treated avocado fruit. Each mean represents 3 determinations. Analysis of variance showed that continuous ethylene treatment (———) was very significantly (at 1%) lower than 24 hr ethylene (– – –) or continuous air treatments (– . – .).

As described previously (6) polygalacturonase activity was determined on the basis of substrate viscosity loss caused by action of the enzyme. Firmness was determined without removing the epidermis by a 'Chatillon' pressure tester Determination of firmness and polygalacturonase activity was started on the 13th day after harvest.

Results

ETHYLENE PRODUCTION. No detectable Level of Ethylene production was observed from fruit treated with ethylene for only 24 hr, or from the control fruit at 6°C (Fig. 1). Fruit from the continuous ethylene treatment released ethylene immediately after transfer from the flowing ethylene environment; however, no ethylene production from this fruit could be detected after 24 hr in standard room atmosphere at6oC. The earliest actual ethylene production recorded in this experiment was observed 1 day after the fruit was transferred to 20°C. It is clear that fruit from the continuous ethylene treatment produced much less ethylene than the rest of the fruit after transfer to 20°C (Fig. 1).

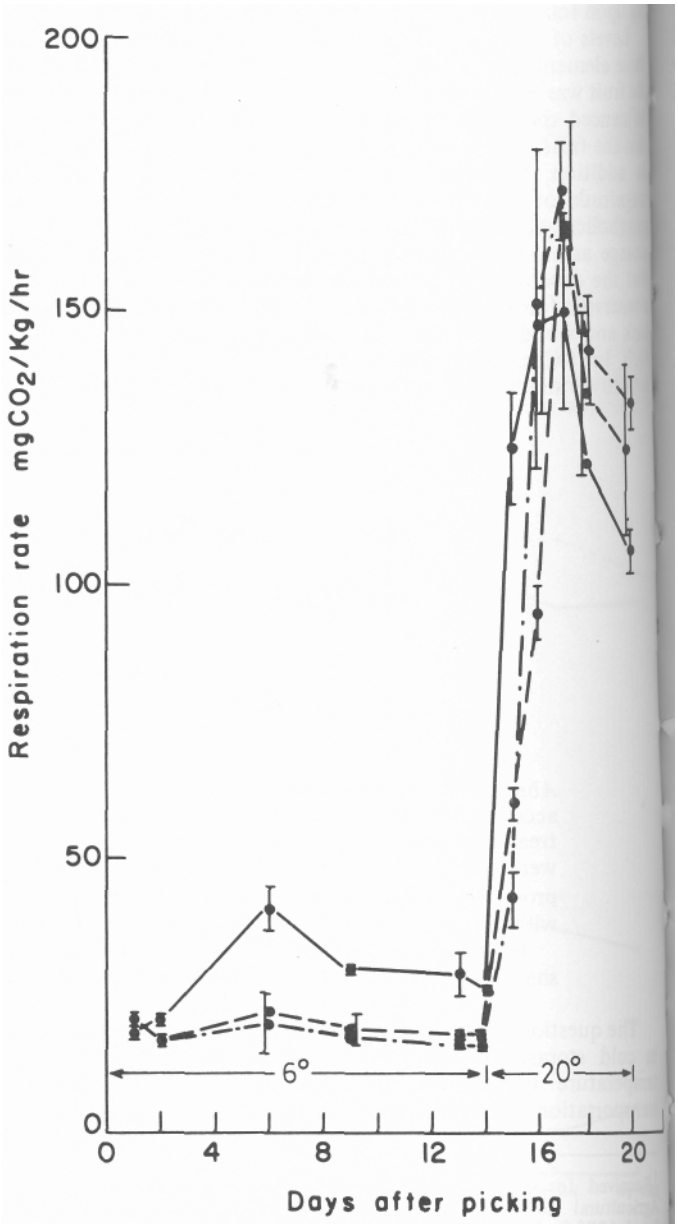

Fig. 2. Respiration rate of cold-stored (6°C), ethylene-treated avocado fruit. Each mean represents 3 determinations with the standard deviations indicated by vertical bars. Continuous ethylene flow (———), ethylene for 24 hr (– – –), and continuous air flow (–.–.).

RESPIRATION RATE. Respiration rate was doubled during continuous ethylene treatment for 12 days at 6°C (Fig. 2). Twenty-four hr of ethylene treatment, however, had no marked effect on the respiration rate. It is obvious that the presence of ethylene is essential in order to maintain the high respiration rates. Determination of respiration rate 24 hr after the fruit was removed from the ethylene treatment showed a reduction in the respiration rate level to that of the controls. Upon transfer to 20°C (on the 15th day), the respiration rate of the fruit under continuous ethylene treatment increased at least 2-fold over the fruit of the 2 other treatments (Fig. 2). All fruit reached the climacteric peak on the same day and climacteric maxima were essentially identical.

POLYGALACTURONASE ACTIVITY AND FIRMNESS. Changes in the polygalacturonase activity (Fig. 3) and fruit firmness (Fig. 4) of avocados were evident on the 16th day in the continuous ethylene treatments, while only 2 days later such changes could be observed in fruit of the other treatments. These results show that fruit with continuous ethylene treatment has a shorter shelf-life than fruit of the other treatments.

Discussion

Storage of avocado fruit in ethylene atmosphere at 6°C had an effect on the respiration rate of the fruit both during and after ethylene treatment. Similarly, there were notable effects on ethylene production, polygalacturonase activity, and softening of the fruit. Similar results were obtained with fruit of 'Fuerte' (unpublished data).

The suppression of the endogenous ethylene production at 20°C by the previous exogenous ethylene treatment at 6°C (Fig. 1) is most striking. It seems that the enzymatic apparatus which is producing ethylene is affected irreversibly, since ethylene production remained low throughout the experiment. It should be noted, however, that the experimental procedures did not enable the measurement of endogenous ethylene

production during the period of the ethylene treatment itself. It is suspected that in the first determination of fruit under continuous ethylene treatment, our measurements were primarily of that ethylene which was applied and absorbed by the fruit and then evolved by diffusion to the atmosphere, rather than of the ethylene produced by the fruit. Similar inhibitory effects of ethylene treatment at 20°C on the endogenous ethylene production of banana were reported recently by Vendrell and McGlasson (5). Respiration rate was accelerated by continuous treatment with ethylene (Fig. 2). This is in contrast to what was reported previously (1), but it does agree with, and substantiate our other findings (Figs. 3 and 4) that polygalacturonase activity and softening rate were accelerated by ethylene treatment.

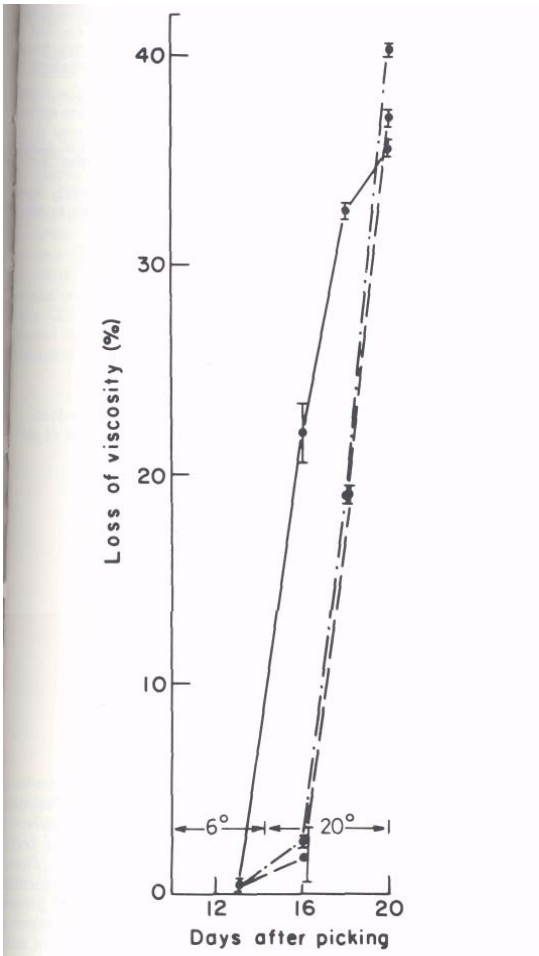

Fig. 3. Polygalacturonase activity of cold-stored (6°C), ethylene treated avocado fruit. Each mean represents 4 determinations with the standard deviation indicated by vertical bars. Continuous ethylene flow (———), ethylene for 24 hr (– – –), and continuous air flow (– . – .).

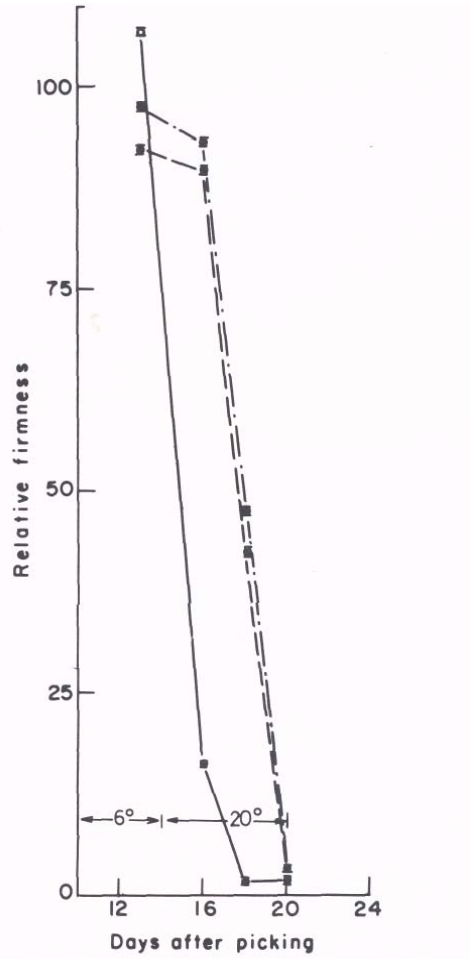

Fig. 4. Firmness of cold-stored (6°C), ethylene treated avocado fruit. Each mean represents 4 determinations with the standard deviation indicated by vertical bars. Continuous ethylene flow (———), ethylene for 24 hr (– – –), and continuous air flow (–.–.–.).

These findings are in accord with those of Hatton and Reeder (4), who showed that the removal of ethylene from controlled atmosphere storage chambers (10°C) increased the percentage of acceptable fruit at the end of the storage period. It has been reported that ethylene had an effect on apple fruits in controlled atmosphere cold storage (3). However, Blanpied et al. (2) claim that no effect of ethylene was evident in controlled atmosphere cold storage of apples. It should be noted that in this report the fruit was

kept under regular storage atmosphere containing less than 0.5% CO_2 rather than under controlled atmosphere as described in the above mentioned papers (2, 3, 4).

From the data presented in Figs. 1 and 2 it is evident that the ethylene peak did not precede the respiration peak, while in normal ripening of avocado fruit at 20°C the respiratory peak always follows that of the ethylene.

From the practical point of view it is suggested that at 10°C (4) and also at 6°C, ethylene should be avoided whenever long shelf-life of avocado fruit is desired.

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