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Prolonging Storage Life of Avocado Fruits by Subatmospheric Pressure[1]

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Abstract. **Reducing the atmospheric pressure in the refrigerated storage chamber at 6°C markedly retards avocado fruit ripening. This effect is more pronounced when the pressure is reduced below 100 mm Hg. Fruit stored at 760 and 200 mm Hg ripened after 35 and 50 days, respectively, while fruit stored at pressures below 100 mm Hg remained unripe for 70 days in storage. The best storage pressure tested for avocado fruits was found to be 60 mm Hg. The inhibition of ripening under these conditions is explained by the lower oxygen partial pressure which retards respiration and ethylene production, and by the acceleration of the outward diffusion of ethylene from the tissue which lowers its internal level.**

Avocados are a perishable commodity having a high rate of metabolism at ambient temperature and atmospheric air, leading to rapid ripening and deterioration. The application of refrigeration is a method commonly used to increase the storage life of this commodity (12). However, reducing the temperature during prolonged storage periods is limited by the susceptibility of fruit to chilling injuries (14) and abnormal ripening (13). A combination of refrigeration and modified atmosphere was found to extend fruit storage life further (8, 9). Under these conditions, however, the accumulation of ethylene in the storage atmosphere could hasten ripening and deterioration (9, 13).

Subatmospheric pressure storage of perishables, a method introduced by Burg and Burg (5), combines refrigeration, controlled atmosphere and constant ventilation of the commodity. The method has been found to extend storage life of several commodities substantially (1, 2, 5, 7, 10). Burg and Burg (5) have indicated that storage of avocado fruits can be prolonged under reduced atmospheric pressure. Spalding and Reeder (11) failed to show any beneficial effect at low pressure for storage of avocados. The aim of the present work was to study the effect of

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subatmospheric pressure on the ripening processes and storage life of avocado fruit in order to determine the proper conditions which will enable a successful application of this storage method to avocado fruits.

Mature 'Hass' avocado fruits were harvested in a local plantation. Fruits were selected for size and uniformity and placed in 50-liter steel storage chambers maintained at 6°C. Each chamber contained 100 fruits. The chambers were ventilated continuously with moisturized air at a rate of 1 air exchange every 2 hr. Subatmospheric pressure was achieved by continuous evacuation of the storage chambers by means of a vacuum pump. A vacuum regulator, Matheson No. 49, installed at the inlet of the chamber, maintained the selected pressure. The air flow through the system was measured using a rotometer attached to the inlet of the regulator.

Four levels of subatmospheric pressure were selected for this experiment: 200, 100, 80 and 60 mm Hg. Fruits stored at atmospheric pressure (760 mm Hg) and 95% relative humidity were used as controls. The storage chambers were opened periodically and fruit samples consisting of 20 fruits each were taken for observation and analysis. One half of each sample was checked immediately after removal from storage and the other half was placed in atmospheric pressure at 14°C for evaluation of ripening potential; these fruits were analyzed after ripening. Fruits were checked for weight loss, general appearance, skin damages, firmness, ethylene evolution, respiration rate, pulp color and taste.

Fruit firmness was measured on unpeeled fruits by a Chatillon penetrometer equipped with a conical tip. Rates of CO_2 and ethylene evolution from fruits were measured by enclosing individual fruits in sealed jars for 1 hr and analyzing air samples withdrawn from the jars. Quantities of ethylene and CO_2 were determined by gas chromatography.

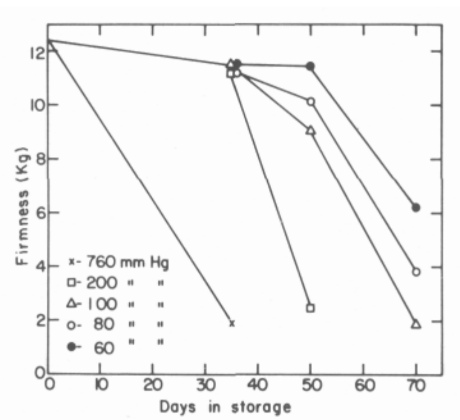

Fig. 1. Effect of storage at subatmospheric pressure and 6°C on avocado fruit firmness.

The data presented are averages of 3 replicated experiments with the 'Hass' cultivar. Similar results were obtained in other experiments with 'Fuerte' and 'Nabal'. Reducing the atmospheric pressure in the storage chambers markedly retarded fruit softening (Fig. 1). This effect was found to be inversely related to the pressure. Fruit firmness at harvest time was 12.5 kg. All fruits stored at the various levels of reduced atmospheric pressure remained firm for 35 days in storage. In contrast, control fruits stored at atmospheric pressure softened rapidly and the firmness recorded was 2 kg. At the end of a 50-day storage period, the fruits stored at 200 mm Hg became soft (2.5 kg) while those stored at 100, 80 and 60 mm Hg were still firm, registering 9.3, 10.1 and 11.5 kg, respectively. After 70 days in storage the fruits stored at 100 and 80 mm Hg became soft: 1.9 and 3.9 kg, respectively. However, fruits stored at 60 mm Hg remained relatively firm (7 kg). In all cases fruits stored at subatmospheric pressure became soft and edible several days after being transferred to atmospheric pressure at 14°.

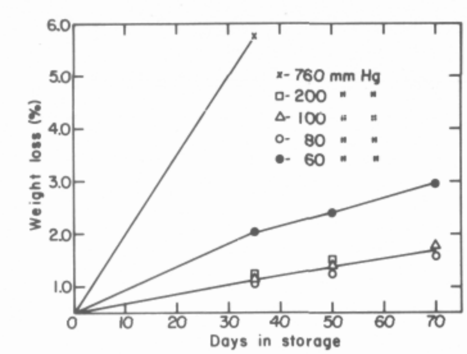

Fig. 2. Weight losses in fruit stored at atmospheric and subatmospheric pressure at 6°C.

During 35 days of storage (Fig. 2), control fruits stored at 760 mm Hg lost 5.7% of their weight, but fruit stored at reduced atmospheric pressure lost only 1.2%. The latter fruits exhibited low rates of weight loss throughout the entire storage period and after 70 days fruits stored at 100, 80 and 60 mm Hg lost 1.7, 1.7 and 3.0% weight, respectively.

At the end of a 35-day storage period control fruits were at the post-climacteric ripening stage. At 24 hr after transfer to 14°C, there was a low rate of ethylene evolution, 2 µl/kg-hr, (Fig. 3), and a high rate of CO_2 evolution, 120 mg/kg-hr, which decreased rapidly thereafter and reached the lowest rate within 4-5 days (Fig. 4). In contrast, all fruits stored at subatmospheric pressure for 35 days were at the pre-climacteric ripening stage and exhibited low rates of CO_2 and ethylene evolution; 24 hr after fruit transfer to atmospheric pressure and 14°C, the rate of ethylene evolution ranged from 3 to 8 µl/kg-hr and the rate of CO_2 evolution ranged between 55 and 80 mg/kg-hr. A climacteric peak of ethylene evolution was recorded 3-4 days after these fruits were transferred to atmospheric pressure, ranging from 15 to 20 µl C_2H_4/kg-hr (Fig. 3). A peak of CO_2 evolution in these fruits was observed after 4-5 days at atmospheric pressure, ranging from 110 to 120 mg CO_2/kg-hr (Fig. 4). All fruits stored at the various levels of subatmospheric pressure for 35 days softened within 5 days after transfer to atmospheric pressure and 14°C. At the end of a 50-day storage period (Fig. 5, 6) the fruits stored at 200 mm Hg were close to the climacteric peak; 24 hr after these fruits were transferred to atmospheric pressure and 14°C, the rate of ethylene evolution was 15 µl/kg-hr and dropped thereafter, reaching the lowest rate within 4 days (Fig. 5). CO_2 evolution reached a peak on the 3rd day after fruit removal from storage (Fig. 6). A peak of ethylene evolution was recorded 3-4 days after removal from storage of fruits stored at 100, 80 or 60 mm Hg, attaining a rate of evolution ranging between 13 and 16 µl C_2H_4/kg-hr. Coinciding with the peak of ethylene evolution, a peak of CO_2 evolution was observed in these fruits ranging between 83 and 100 mg CO_2/kg-hr. At the end of a 50-day storage period the fruits stored at 200 and 100 mm Hg softened 3 days after transfer to atmospheric pressure and fruits stored at 80 or 60 mm Hg softened 3 days later.

At the end of 35 days storage at 6°C and 3 days at 14°C, the control fruit stored at 760 mm Hg were somewhat overripe, the taste was poor, and in some cases, internal discoloration was observed. However, all fruits stored at subatmospheric pressure displayed, after ripening, excellent texture and taste. After 50 days in storage the fruits at 200 mm Hg had poor texture and taste, while those stored at 100, 80 or 60 mm Hg had excellent texture and taste. After 70 days in storage, fruits stored at 100 and 80 mm Hg still exhibited good taste while those stored at 60 mm Hg were excellent. No skin damage or decay was observed in fruits stored at subatmospheric pressure throughout the entire storage period.

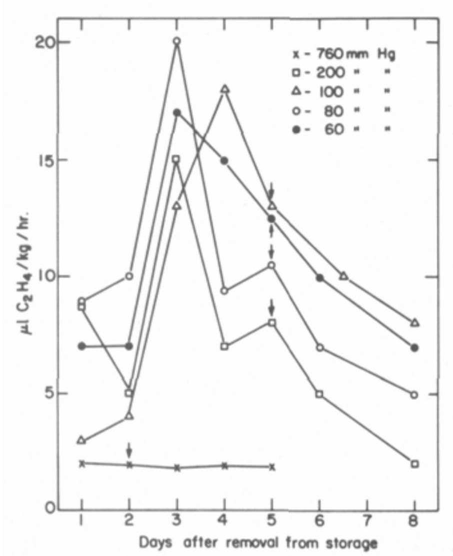

Fig. 3. Ethylene evolution from fruits after 35 days' storage at atmospheric and subatmospheric pressure. Measurements were taken 24 hr after fruits were transferred to 760 mm Hg and 14°C. The arrows point to the day when the fruits became soft and edible.

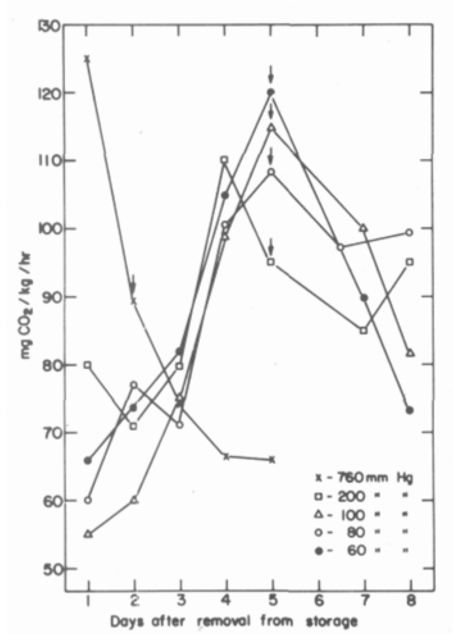

Fig. 4. CO_2 evolution from fruits after 35 days' storage at atmospheric and subatmospheric pressure. Measurements were taken 24 hr after fruits were transferred to 760 mm Hg and 14°C. The arrows point to the day when the fruits became soft and edible.

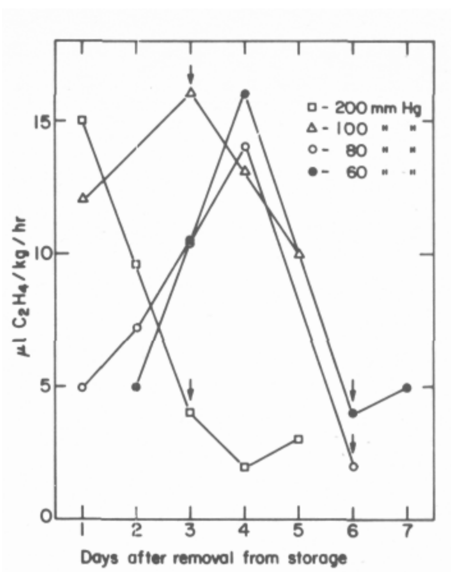

Fig. 5. Ethylene evolution from fruits after 50 days' storage at atmospheric and subatmospheric pressure. Measurements were taken 24 hr after fruits were transferred to 760 mm Hg and 14°C. The arrows point to the day when the fruits became soft and edible.

Our results do not agree with the finding of Spalding and Reeder (11); we were able to demonstrate that exposing avocados to subatmospheric conditions markedly delayed fruit ripening and facilitated prolonged storage of this commodity. These results are in agreement with those of Burg and Burg (5). However, we found that prolongation of storage life was more pronounced when the pressure was decreased below 100 mm Hg. For example, fruits stored at 760 and 200 mm Hg ripened after 35 and 50 days, respectively, while those stored at pressures below 100 mm Hg remained unripe for 70 days in storage; the best results were obtained at 60 mm Hg. Storage of avocado fruits at pressures below 50 mm Hg resulted in substantial fruit desiccation.

Ripening of avocado fruits is associated with increased ethylene evolution reaching a threshold level which triggers a climacteric in respiration (4, 6). The inhibition of ripening under subatmospheric conditions can be attributed to the reduction of O_2 partial pressure in the storage chamber and the

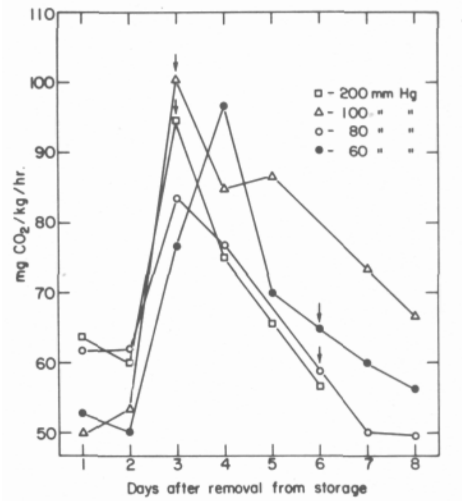

Fig. 6. CO_2 evolution from fruits after 50 days' storage at atmospheric and subatmospheric pressure. Measurements were taken 24 hr after fruits were transferred to 760 mm Hg and 14°C. The arrows point to the day when the fruits became soft and edible.

acceleration of the outward diffusion of ethylene from the fruit, both of which are inversely related to the pressure (1, 5, 7). Reducing the oxygen partial pressure affects fruit metabolism by lowering the rate of respiration (3, 6). Under such conditions the rate of production and action of ethylene are lowered (5); in addition, the constant ventilation of the commodity prevents the accumulation of ethylene in the storage chamber, which might hasten ripening even at a low temperature (14). The low rate of weight losses under subatmospheric pressure during prolonged storage was probably due to the fact that the chamber was ventilated with water-saturated air, eliminating the water vapor gradient between the commodity and the atmosphere.

Although ripening was markedly retarded under subatmospheric conditions all fruits ripened normally several days after being transferred to atmospheric pressure and 14°C (Figs. 3, 4, 5, 6). This indicates that there was no damage to the fruit tissue by the treatment, and that the fruit retained the ability to undergo normal ripening processes and develop proper texture and taste.

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