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IMPROVED SHELF LIFE OF AVOCADO FRUITS

Y AHARONI

DEPT OF FRUIT & VEGETABLE STORAGE, ARO, THE VOLCANI CENTRE, BETDAGAN, ISRAEL

OPSOMMING

Die invloed van die samestelling van atmosferiese gasse en temperatuur variasie op avokadovrugfisiologie en rakleeftyd word bespreek.

SUMMARY

The effect of atmospheric composition and temperature variations on avocado fruit physiology and shelf life is discussed.

INTRODUCTION

Improving the shelf life of a fruit is, in most cases, a result of improving its storage life. To achieve this goal there is a need to study the physiological processes occurring in the fruit. Intensive studies on the avocado fruit have started in the 50's and 60's and have been carried on since then in California, Florida, Israel, South Africa, Australia and other countries. Thanks to the scientists involved, we now know much about the life cycle of this unique fruit, rich in oil and other components.

Ward law and Leonard in 1935, were the firsts to report on an increase in carbon dioxide (CO_2) production in the avocado fruit, leading to a climacteric peak and thereafter to a decline and senescence. Later it was found that the increase in respiration coincided with an increase in production of ethylene, which is considered to be the ripening hormone. On comparative basis, the avocado is physiologically more active than most other fruit. For example in the apple, melon and the peach the increase in the respiration rate from the minimum to the maximum during ripening is about 2 fold, in the banana 3 fold, while in the avocado it is more than 4 fold (Fig 1). This high metabolism at ambient temperatures leads to rapid ripening and deterioration. Studies have been initiated to find effective methods to control ripening and delay senescence in avocado fruit, without causing physiological disorders and increased rate of decay. The main factors involved are: temperature, changes in storage atmosphere and fruit exposure to sub atmospheric pressures.

TEMPERATURE

The application of refrigeration is a method commonly used to increase storage and shelf life of fruit. However, reducing the temperature during prolonged storage periods is limited by the susceptibility of the fruit to chilling injuries. There is a safe range of temperatures for each particular fruit. Exposure to temperatures outside this range for *a* sufficient length of time causes injuries and abnormal ripening. For avocado fruit this range is between 5 °C and 30 °C. At 30 °C as well as below 5 °C, the fruit does not ripen properly and the tissue darkens. Experiments conducted in Israel indicated that it is possible to store avocado's at temperatures as low as 0 °C, 2 C°, and 4 °C for short periods of 7, 14 and 14 days, respectively, with no injury (Table 1). Storage at 6 °C more than doubled their storage life.

CHANGES IN THE ATMOSPHERE SURROUNDING THE FRUIT

Early studies with Fuerte avocado's showed that storing them in an atmosphere with oxygen (O_2) lower than in air resulted in a lower respiration rate. Increasing the concentration of CO_2 in the storage atmosphere also reduced the respiration rate and delayed the climacteric rise. A combination of elevated CO_2 and reduced O_2 levels in the storage atmosphere was more effective in delaying ripening than each gas by itself (Fig 3). More studies have shown that the best conditions for prolonging storage and shelf life of avocado fruit are storage in 2% O_2 + 10% CO_2 at a temperature of 5.5 °C. However, for Florida avocados 'Lula' and Booth', which are more susceptible to chilling injuries, a temperature of 7,2 °C is safer.

When dealing with storage of avocados, one must consider the effect of ethylene, the ripening hormone, which is produced by the fruit and may accumulate in the storage space. A concentration of ethylene as low as 0,1 ppm has been reported to initiate the ripening process in avocado fruit. Research conducted in Florida showed that concentrations of ethylene of 12, 18 and 29 ppm were found in chambers with avocado fruit at 10 °C and an atmosphere of 2% O_2 + 10% CO_2, after 30, 45 and 60 days respectively. Removal of the ethylene from the chambers by activated aluminium (Al_2O_3) impregnated with potassium permanganate ($KMnO_4$), extended shelf life of the fruit, but not markedly. (Table 2). Fruit stored in chambers without ethylene softened 0.4, 0.5 and 0.2 days later than fruit stored in chambers with ethylene, after storage of 30, 45 and 60 days respectively. It is assumed that this system is not able to withdraw all the ethylene in the internal tissue of the fruit. Exposing the fruit to sub atmospheric pressures may affect ethylene concentrations within the fruit.

The system consists of a strong metal chamber connected to a vacuum pump. Air flow under sub atmospheric pressure is continuously introduced into the chamber. Experiments have shown that by using this method it was possible to prolong storage life of avocado fruit more than by storing them in controlled atmosphere. 'Hass' avocados were stored at 6 °C under various sub atmospheric pressures during periods of 35, 50 and 70 days (Table 3). Control (air) fruit were soft after 35 days while fruit stored at 200 mm Hg pressure softened after 50 days and fruits stored at 100 mm Hg softened after 70 days. The experiment was terminated after

70 days of storage. At that time fruit at 80 and 60 mm Hg pressures were still firm and softened 3 days later upon removal to normal atmosphere at 14 °C. The inhibition of ripening under sub atmospheric conditions can be attributed to reduction of O_2 partial pressure in the storage chamber and the acceleration of the outward diffusion of ethylene from the fruit. Using this method it is possible to extend markedly the storage and shelf life of avocado fruit.

Using controlled atmosphere or sub atmospheric pressure it is possible to ship avocado fruits over long distances using sea transportation and bring them in good condition to far markets. However, these methods are still too costly to be used commercially.

At the Dept of Fruit & Vegetable Storage, ARO, The Volcani Center, Israel, experiments have been conducted to find less costly methods for prolonging the storage life of avocado fruit. The main export season of avocado fruits to Europe is between November and April. The average ambient temperature is about 17 °C at that time. When the boat leaves the harbor in Israel on its route to England for example, the fruit is exposed to gradually decreasing temperatures along the Mediterranean sea and the Atlantic ocean: 17 °C for 2 days, 14 °C for 2 days, 12 °C for 4 days and to 8 °C until the fruit arrives and sold. Experiments were conducted to study storage and shelf life of avocado fruits exposed to such temperature conditions. Fig 3 presents the respiration rate of 'Fuerte' avocado fruit stored at gradually decreasing temperatures (GOT) compared to respiration of fruit stored at constant temperatures of 17 °C, 12 °C and 8 °C. At GOT the respiration rate of the fruit was lower compared with fruit at 17 ° and 12 °C, but somewhat higher than of fruit stored at 8 °C. However, the fruit at GOT started to soften 15-16 days after harvest too short a time for export to Europe (Table 4). Sealing the fruit in a polyethylene bag markedly increased its storage and shelf life. The atmosphere inside the bag changed, creating modified atmosphere of 6.4-7.9% CO_2 and 7.8-5.0% O_2. The bags were removed from the fruit when first signs of softening appeared, thus they were removed after 14 days from fruit at 17 °C, and after 23 days from the other fruit. The total period from harvest to edible condition for the wrapped fruit stored under GOT was 26-28 days — a sufficient period to transfer the fruit from Israel to the European market with no refrigeration. However, the buyers refused to buy wrapped avocado fruits, because of the labor involved in removing the bags from the fruits upon arrival.

CONCLUSION

Methods are now available to markedly prolong storage and shelf life of avocado fruit. However, these methods need further development in order to reduce the high cost of using them, especially during transportation.

The problem of postharvest fruit decay is on its way to being solved, as South African researchers and others are progressing using new fungicides.

It is believed that in the near future, it will be possible to ship avocado fruit over long distances by sea transportation at a reasonable cost, so that the consumer will pay a reasonable price for a high quality fruit.

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TABLE 1. Safe storage periods and shelf life of Fuerte avocado fruit stored at low temperatures (0 °, 2 °, 4 ° and 6 °C) for 1-6 weeks and transferred to 14 °C.[z]

Temperature (°C)	Safe storage Days	Shelf life (14 °C) Days	Total Storage Days
0	7	8-15	15-23
2,4	14	8-15	22-29
6	42	2-14	44-56

[z] From Zauberman et al 1972.

TABLE 2. Effect of ethylene on the time for Lula avocados to soften in air at 70 °F after storage in controlled atmosphere[z]

Storage atmosphere	Average time to soften after storage for			Total range
	30	45	60	
	Days	Days	Days	Days
Air	1.4 e	0 f		0-2
2 % O_2 + 10 % CO_2 with ethylene[y]	3.1 d	3.6 bc	3.5 c	3-4
2 % O_2 + 10 % CO_2 without ethylene	3.5 c	4.1 a	3.7 b	3-5

[z] Data were based on acceptable fruit only. Data followed by different letters were significantly different at the 5 % level.

[y] Chambers contained 12, 18, and 29 ppm ethylene after 30, 45, and 60 days, respectively. (From Hatton and Reeder, 1972).

TABLE 3. Effect of sub-atmospheric pressures at 6 °C on storage life of Hass avocado fruit[z]

Days in storage	Atmospheric pressure (mm Hg)	Fruit firmness[y] (kg)	Fruit condition
35	760	2.0	soft
	200	—	firm
	100	—	firm
	80	—	firm
	60	—	firm
50	200	2.5	soft
	100	9.3	firm
	80	10.1	firm
	60	11.5	firm
70	100	1.9	soft
	80	3.9	firm
	60	7.0	firm

[z] From Apelbaum et al 1977.
[y] Fruit firmness at harvest time was 12.5 kg.

TABLE 4. Storage and shelf life periods (until edible) of 'Fuerte' fruits, unwrapped and wrapped with polyethylene bags (0.025 mm thick), and stored under gradually decreasing temperatures (GDT), and constant temperatures of 17 °, 12 ° and 8 °C.

Storage temp (°C)	Storage life		Shelf life		Total period[y]	
	unwrapped	wrapped[z]	unwrapped	wrapped	unwrapped	wrapped
	Days		Days		Days	
GDT	15-16	23	4	3-5	19-20	26-28
17	9	14	2	3	11	17
12	15	23	4	3-5	19	26-28
8	21	23	6	4-7	27	27-31

[z] Polyethylene bags were removed from fruit when first signs of softening appeared, Bags of fruit at 17 °C were removed after 14 days and of the others after 23 days in storage.
[y] Include storage period and shelf life at ambient temperature.

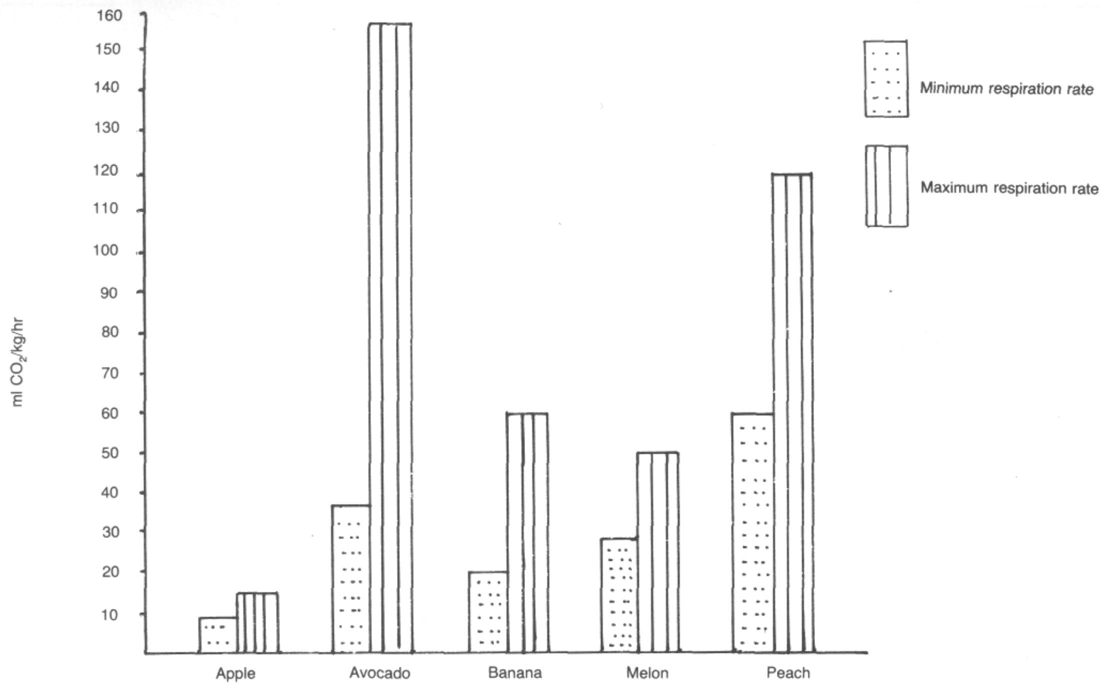

FIG 1. Minimum and maximum respiration rates of some climacteric fruits.

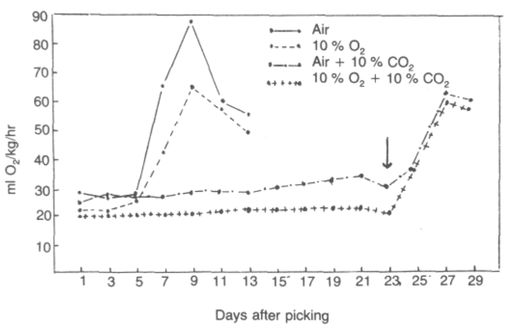

FIG 2. Oxygen uptake by Fuerte avocados at 15 °C in air, in 10 % O_2, in 21 % O_2 with 10 % CO_2 and in 10 % O_2 with 10 % CO_2. Arrow indicates transfer of fruit to air. (from Young et al 1962).

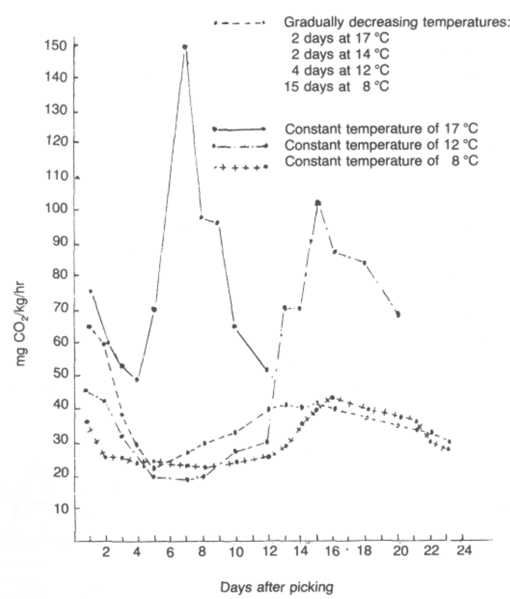

FIG 3. Respiration rates of Fuerte avocado fruits stored under various temperature conditions.