EFFECTS OF GRADUALLY DECREASING TEMPERATURES AND POLYETHYLENE WRAPS ON THE RIPENING AND RESPIRATION OF AVOCADO FRUIT

By

Y. Aharoni, Mina Nadel-Schiffmann and G. Zauberman*

Avocado fruit stored at gradually decreasing temperatures (2 days at 17°, 2 days at 14°, 4 days at 12° and then at 8°C until the termination of the experiment) passed through the climacteric stages and ripened normally. The climacteric peak and the softening appeared at the same time as in fruit stored at 12°, but prior to fruit stored at 8° and later than that stored at 14°, 15° and 17°C. Wrapping the fruit in polyethylene bags caused a decrease in the rate of the external level of CO_2 evolved by the fruit through the bag, and a delay in ripening. Fruit wrapped in polyethylene bags and stored at gradually decreasing temperatures, 8° or 12°C, did not soften by the end of the experiment (23 days in Fuerte and 46 days in Nabal). Some of the wrapped fruit stored at 14°, 15° and 17°C softened, and rotting appeared on many of the fruits.

INTRODUCTION

In most respiration studies of stored avocados, the fruit was stored at constant temperatures, or first at low temperatures for a certain period and later at higher temperatures (2, 3, 5, 6). The fruit from Israel which is exported to northern Europe in winter in unrefrigerated ships, leaves the port at a temperature between 15° and 20°C; during the journey of 2–3 weeks the temperature gradually declines and the fruit arrives at its destination at temperatures between 6° and 10°C (9, 10). It was deemed of interest to check respiratory activity of the fruit under these special conditions.

Laboratory experiments of storage under gradually decreasing temperatures, and experiments with shipping in unrefrigerated ships have shown that the fruit softens within 2–3 weeks, and a substantial part of it arrives at market in an over-ripe condition; however, wrapping the fruit in polyethylene bags greatly delayed softening of the fruit for 1–2 additional weeks (7, 8, 9, 10, 11, 12).

The aim of the research presented below was to determine the course of respiration of wrapped and unwrapped fruit under gradually decreasing temperatures, as compared to fruit stored at constant temperatures. The relationship between the course of the respiration and the length of the period from harvest to softening was also sought.

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* Div. of Fruit and Vegetable Storage, The Volcani Institute of Agricultural Research, Rehovot.

MATERIALS AND METHODS

The experiments were carried out with the Fuerte and Nabal varieties of avocado during the winter of 1961/62. The fruit was picked in the groves of Qvuzat Schiller near Rehovot, Israel, from adult trees. In the first experiment with Fuerte, the fruit was picked on Dec. 17, 1961, and in the second on Jan. 22, 1962, each experiment lasting for 23 days. In the experiment with Nabal, the fruit was picked on March 4, 1962, and the experiment lasted for 46 days. Immediately after harvest, the fruit was placed in 13–liter glass containers, 20 Fuerte or 15 Nabal fruits per container. Air was continually passed through each container at a rate of 200 ml per minute. The average Fuerte fruit weight was 270 g/fruit in the first experiment and 317 g/fruit in the second experiment. The average weight of the Nabal fruit was 494 g.

In all experiments the respiration rate of fruit stored at gradually decreasing temperatures was compared with that of fruit stored at various constant temperatures. The rate of respiration was measured by the amount of CO_2 evolved by fruit according to the method described by Biale and Shepherd (4) and modified by Biale (3). Measurements were usually made daily, and occasionally at two-day intervals. In the first Fuerte experiment the concentrations of oxygen and carbon dioxide inside the polyethylene bags (stored at gradually decreasing temperatures) were measured by a micro-Orsat instrument four times during the experiment.

The conditions of gradually decreasing temperatures were: two days at 17°, two days at 14°, four days at 12° and then at 8°C until the end of the experiment. The constant temperatures used in the first Fuerte experiment were 12° and 17°C, in the second Fuerte experiment 8° and 14°C, and in the Nabal experiment 8° and 15°C. Six containers of fruit were used for each temperature regime, with three containing non-wrapped fruit and three containing polyethylene-bagged fruit, with each fruit wrapped separately in a 0.025–mm thick bag.

The stage of fruit softness was tested by carefully pressing every single fruit with the fingers.

RESULTS

The results of the respiration determinations of the non-wrapped fruit are shown in Fig. 1, and the external levels of CO_2 evolved by the wrapped fruit are given in Fig. 2.

Respiration of non-wrapped fruit

Fuerte and Nabal fruits stored under gradually decreasing temperatures passed through the climacteric stages. Fruit softening was normal and began with the appearance of the climacteric peak in a manner similar to that of the fruit stored at constant temperatures.

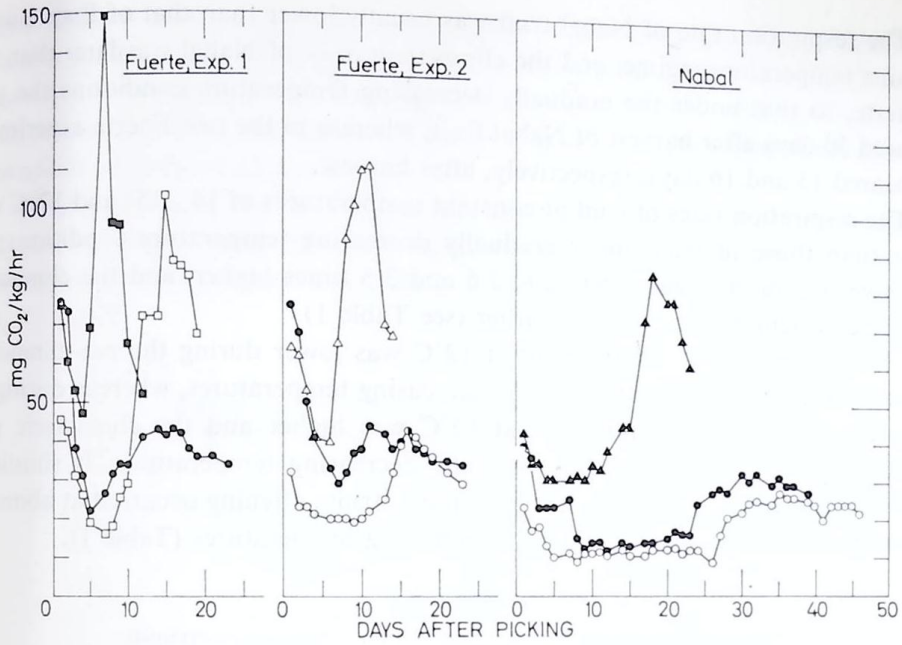

Fig. 1. Respiration rates of Fuerte and Nabal avocado fruits stored under various temperature conditions.

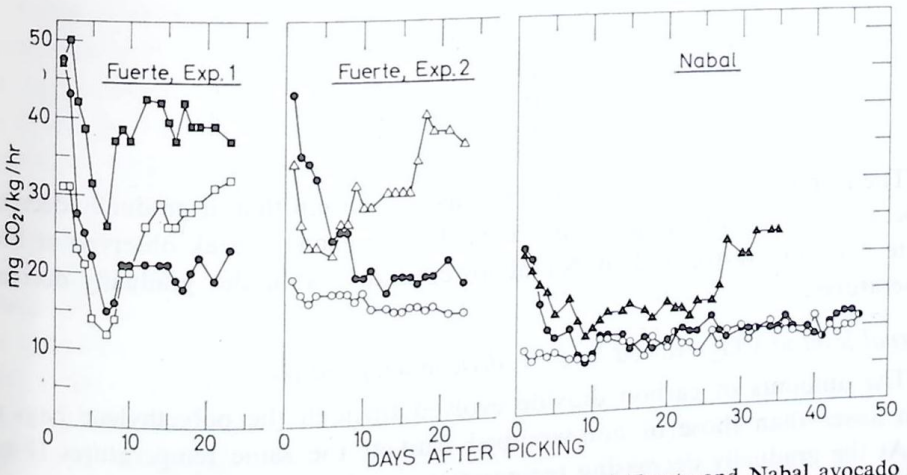

Fig. 2. External levels of CO_2 evolved by polyethylene-wrapped Fuerte and Nabal avocado fruits stored under various temperature conditions.

The respiration rate of Nabal fruit was usually lower than that of Fuerte under the same temperature regime, and the climacteric peak of Nabal was later than that of Fuerte, so that under the gradually decreasing temperature conditions the peak appeared 30 days after harvest of Nabal fruit, whereas in the two Fuerte experiments it appeared 15 and 16 days, respectively, after harvest.

The respiration rates of fruit at constant temperatures of 14°, 15° and 17°C were higher than those of fruit under gradually decreasing temperature conditions; the respective respiratory peaks were 2.6, 2.6 and 3.5 times higher, and the climacteric peaks and softening were reached earlier (see Table 1).

The respiration rate of the fruit at 12°C was lower during the pre-climacteric stage than that of the fruit at gradually decreasing temperatures, whereas during the climacteric rise the respiration rate at 12°C was higher and the climacteric peak was 2.4 times higher than at the gradually decreasing temperatures. It should be noted that climacteric peak and the beginning of fruit softening occurred at about the same time at 12°C as under gradually decreasing temperatures (Table 1).

TABLE 1

TIME OF CLIMACTERIC PEAK APPEARANCE AND THE SOFTENING OF NON-WRAPPED FUERTE AND NABAL FRUITS STORED UNDER VARIOUS TEMPERATURES

Storage temperature (°C)	*Appearance of climacteric peak* (days after harvest)	*Beginning of softening* (days after harvest)	*Days from beginning of softening until edible*
	Fuerte		
Gradually decreasing	15, 16	15, 16	4
17	7	9	2
14	9	10	3
12	15	15	4
8	17	17	6
	Nabal		
Gradually decreasing	30	30	6
15	17	20	3
8	35	37	7

The respiration rate of fruit at 8°C was lower than that at gradually decreasing temperatures and softening began later. The climacteric peak observed at 8°C in Fuerte was similar to, and in Nabal lower than that under gradually decreasing temperatures.

External level of CO_2 *evolved by polyethylene-wrapped fruit*

The amounts of carbon dioxide evolved through the polyethylene bags were much lower than those of non-wrapped fruit at the same temperatures (Fig. 1).

At the gradually decreasing temperatures and at the constant temperatures of 8° and 12°C there was no softening of the fruit during the experiment (23 days for

Fuerte and 46 days for Nabal), and the fruit remained hard without blemishes or damage. At the higher temperatures some of the fruit softened at 17°C (Fuerte) 14 days after harvest, at 14°C (Fuerte) 17 days after harvest, and at 15°C (Nabal) 34 days after harvest; this softening was accompanied by the appearance of rot in a substantial proportion of the fruit.

Measurements of O_2 and CO_2 concentrations inside the polyethylene bags (that wrapped the fruits) under gradually decreasing temperature conditions showed that there was a significant decrease in the percent of O_2 and an increase in the percent of CO_2 (Table 2).

TABLE 2

CONCENTRATIONS OF CO_2 AND O_2 INSIDE POLYETHYLENE BAGS CONTAINING FUERTE FRUIT STORED UNDER GRADUALLY DECREASING TEMPERATURES

Days after harvest	% CO_2	% O_2
5	6.4	7.8
12	7.0	6.5
17	7.1	5.5
23	7.9	5.0

DISCUSSION

The softening of avocado fruit at gradually decreasing temperatures occurred at about the same time as in fruit stored at a constant temperature of 12°C. These results are similar to those obtained previously at these two temperature regimes (8, 10). Respiration measurements in the present work clarify the similarity of the course of softening, as the climacteric peaks under these regimes also appeared at about the same time after harvest.

From a comparison of the physiological behavior of the varieties Nabal and Fuerte, it is very apparent that the respiration rate of the former was much lower, and that softening occurred after a much longer time in storage than with the latter. The lower respiration rate of Nabal as compared with Fuerte can also be seen in the respiration curves of Pratt and Biale (6). It is possible that the longer storability of Nabal fruit is related to its lesser physiological changes, a factor which should be clarified further.

Wrapping the fruit in polyethylene bags caused a reduction in gas exchange between it and the external atmosphere. As a result of the respiratory activity there was a marked increase in CO_2 and decrease in O_2 concentration inside the bags, which in turn caused a reduction in the respiration rate of the fruit and a delay in softening. The conditions inside polyethylene bags are similar to those of controlled atmosphere storage, and the experiments of Biale (3) showed that lower-than-normal oxygen concentrations (2.5%, 5%, 10%) lowered the respiration rate of the fruit and delayed the climacteric and softening.

In this work we did not remove the polyethylene bags from the fruit, but in previous work (1, 8) it was shown that when bags are removed from the fruit even 3 weeks after wrapping, the fruit is capable of resuming the climacteric and normal softening.

The appearance of rotting on the polyethylene-bagged fruit stored at 14°, 15° and 17°C was probably due to the relatively high temperatures and humidity within the bags, conditions suitable for fungal development. Similar results were also reported by other workers (7, 8, 12), who found the major pathogens to be *Colletotrichum*, *Diplodia* and *Fusarium*.

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