

Susceptibility to Chilling Injury of Three Avocado Cultivars at Various Stages of Ripening¹

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Abstract. Response of 'Ettinger', 'Fuerte', and 'Nabal' avocados (*Persea americana* Mill.) to 0, 2, 4 and 6°C at various stages of ripeness was tested. No damage appeared during cold storage and shelf-life when firm avocado fruit was stored at 0, 2, 4 and 6° for 1, 2, 3, 4 and 6 weeks, respectively. Fruit placed in cold storage when semi-firm or soft was more tolerant to low temperature than firm fruit. There was no relation between the duration of cold storage at 0, 2, 4° and subsequent length of self-life at 14°; on the other hand, the longer the storage at 6°, the shorter the shelf-life. Chilling injury, although initiated during cold storage, did not become apparent until during the post-storage shelf-life period. 'Nabal' was more tolerant to low temperature than 'Ettinger' and 'Fuerte'.

Susceptibility to chilling injury is known to vary among avocado cultivars. Climatic conditions play an important role in cultivar susceptibility.

There is a quite general belief that avocado cultivars of the West Indian race are more sensitive to low temp than those from the Guatemalan and Mexican races. Differences in tolerance to cold storage among different avocado cultivars are cited for Florida by Hatton and Reeder (3), for Puerto Rico by Pennock (4) and by the present authors (7) for Israel.

Susceptibility to chilling injury is apparently affected by the local climate where grown as well as the region from which the cultivar was derived. 'Pollock', a West Indian cultivar, was found to have a quite high tolerance to low temp when grown in Puerto Rico (4), but a considerably less when grown in Florida (1). Furthermore, in some fruit, e.g. bananas (2) and mango (8), it has been shown that susceptibility to chilling injury varies with ripeness.

This study was aimed at determining the effects of ripeness and of differences among cultivars with regard to susceptibility to chilling injury of some avocados grown in Israel.

The tolerance of avocado to low temp was tested in fruit at 3 different stages of ripeness after harvest: firm fruit, semi-firm fruit (i.e., responsive to hand pressure), and soft fruit suitable for consumption. In order to obtain semi-firm and soft fruit, for these experiments avocados were stored after harvest at 25 °C until they reached the desired stage of ripeness.

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'Ettinger' (local seedling from 'Fuerte'), 'Fuerte' and 'Nabal' were stored at 0, 2, 4 or 6°C for different periods of time, and then held at 14° until soft. The semi-firm and soft fruits were stored at these low temp for 4 weeks only; firm fruit (placed in storage 1 day after picking) was stored for 1-6 weeks.

The fruit was wrapped in paper and packed in cartons. Each experimental group consisted of 4 cartons, each containing 10 fruits. The experiment was repeated in 3 consecutive years, 3 times in each year, at the beginning, middle and end of the customary picking seasons for each cultivar: 'Ettinger' from Oct. to Nov. 'Fuerte' from Jan. to Feb., and 'Nabal' from Feb. to March.

The fruit was examined while in cold storage, on the day of removal from cold storage, and during the post-storage holding period. External and internal signs of injury were recorded, as well as the degree of softening and the rate of rotting.

The effect of low temp on the avocado fruit was basically similar in all 3 years. Low temp injury was not apparent in the fruit during the cold storage period; injury appeared only after the fruit was transferred to shelf-life condition. The lower the storage temp, the shorter the period during which fruit could be stored without damage.

The symptoms of cold injury also differed among cultivars. In 'Ettinger' damage was manifested by a yellowing of the peel and at a more advanced stage by browning of the peel from the bottom in the direction of the stem-end. In 'Fuerte' and 'Nabal', the damage appeared as sunken, dark brown spots on the peel, and at an advanced stage all the peel turned dark brown. The pulp of 'Ettinger' and 'Fuerte' fruit took on a gray color, while the pulp of 'Nabal' became brown.

No rot developed during cold storage; the incidence of rots caused mainly by the fungus *Colletotrichum gloeosporioides* Penz. that subsequently developed at 14°C was not affected by the different temp of cold storage.

Firm fruit. The differences in sensitivity to low temp among the cultivars was evident at 2 and 4°C, where chilling injury developed during shelf life only after cold storage periods longer than 2 weeks in 'Ettinger' and 'Fuerte', and longer than 3 or 4 weeks in the 'Nabal' (Fig. 1). Fruit of all 3 cultivars stored at 6° showed no cold injury throughout the 6-weeks of cold storage and subsequent shelf-life. In all cases, fruit removed from cold storage was still firm. Shelf-life, from removal from cold storage until fruit softened, ranged from 8 to 15 days for the 3 cultivars stored at 0, 2 and 4°. The shelf-life of fruit stored at 6° was 2-14 days; the shorter the cold storage period, the longer the shelf-life.

Semi-firm and soft fruit. Semi-firm and soft fruits were more tolerant to low temp storage than was the firm fruit, and did not differ (between semi-firm and soft) in their response to low temp. Fruit placed in cold storage (0-6°C) when semi-firm had a subsequently short shelf-life of 2-6 days when removed from cold storage, and soft fruit had almost no shelf-life after removal from cold storage (Fig. 1).

Of the cultivars tested, 'Ettinger', 'Fuerte' and 'Nabal', showed a fairly high tolerance to low temp; 'Nabal', a Guatemalan, was somewhat more resistant than the Guatemalan-Mexican 'Fuerte' and 'Ettinger'. All 3 cultivars showed no chilling injury when stored at 6°C for 6 weeks, or for shorter periods of time at lower temp. On the other hand, Thompson et al. (5) found chilling injury after 13-16 days in a West Indian seedling

avocado grown in Trinidad and stored at 10°C, and even at 13° for fruit grown in Granada, illustrating how a large variation in response to low temp exists among various avocado cultivars.

Moreover, 'Fuerte' fruit grown in Puerto Rico was classified by Pennock (4) as resistant to low temp. At his lowest temp, 43°F (6.1°C), these fruits could be stored without damage for 4 weeks; however, 'Fuerte' grown in Israel could be stored at 6°C for 6 weeks without any sign of chilling injury.

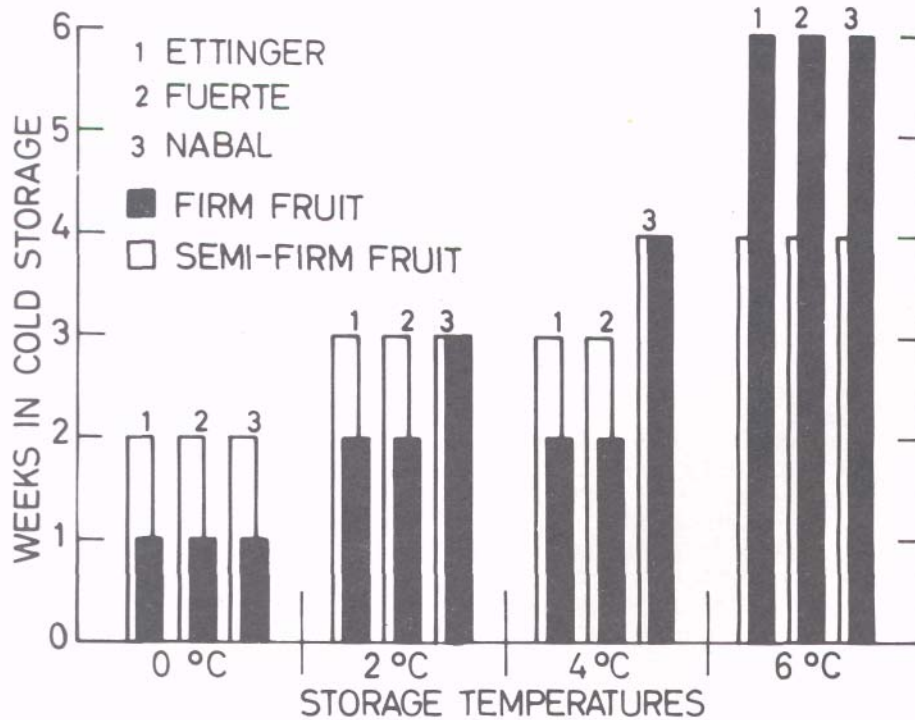


Fig. 1. Storage period at low temp (without injury at time of removal from storage and during subsequent shelf-life) of avocado cultivars at different stages of ripening. (Firm fruit was stored for 6 weeks. Semi-firm fruit was stored for 4 weeks.)

Length of exposure to low temp may affect the period required by fruit to ripen, after it is removed from cold storage to shelf-life. In our study, storage at various cold temp had varying effects on the period of shelf-life. For fruit stored at 6°C, the longer the fruit was kept at this temp, the shorter was the period until softening during shelf-life (140C. On the other hand, for fruits stored at 0, 2 and 4°, the duration of shelf-life was not markedly affected by the length of the storage period at these temp. This may indicate that during cold storage at 6°, contrary to that at 0-4°, some internal ripening results in a shortened shelf-life. Similarly, Tomkins (6) found for tomato stored at 2° that increasing the time of exposure to the low temp increased the time required for ripening at 180.

A similar relationship between prestorage ripeness and sensitivity to low temp has been reported by Furlong (6) for 'Lacatan' and 'Gros Michel' bananas. Fully ripe, yellow bananas were less sensitive to low temp than were green bananas at the harvest stage. Similarly, 'Haden' mango at the beginning of ripening, when green in color, showed chilling injury when stored at 12°C, whereas fully ripe, yellow fruit did not show any

injury when stored at 10° (8).

The determination of the duration of tolerance of avocado cultivars to low temp and the possibility established of storing semi-firm or soft avocado for certain periods at low temp may be useful in marketing.

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