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Temperature management of avocados — an integrated approach

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ABSTRACT

Research into post-harvest management aspects of export avocados has shown that the following factors are paramount in the concept of temperature management:

Early season fruit is more sensitive to low temperatures than late season fruit. The optimum temperature and storage conditions for avocados vary between cultivars. Optimum temperatures and storage periods vary with both maturity and the stage of fruit development. Higher temperatures during the early stages, and lower temperatures during the later stages of storage tend to decrease physiological disorders. Later set avocados are much more sensitive to low storage temperatures than earlier set fruit. The time / temperature relationship is an important factor determining fruit quality. The quantity of wax used influences the shelf-life of avocados.

Based on the above principles, a proposal on the temperature regime for South African export avocados is presented.

Strict maintenance of the cold chain and the time-temperature relationships are the most important factors determining fruit quality.

The importance of humidity in the design of cooling systems is also discussed.

INTRODUCTION

The South African Avocado Industry is based primarily on export and consistent high quality is of vital importance. The avocado industry relies on export for a large part of its sales and long distances must be covered in the process.

Proper post-harvest handling procedures physical principles and mechanisms of cold storage and effective post-harvest management. Temperature management forms an integrated part of this concept.

Storage Temperatures

While the ideal is to export firm fruit with no external cold damage and no physiological or pathological disorders, a fine balance between firm fruit and external cold damage exists. Transport temperatures which are too high will result in soft fruit on arrival while temperatures too low will result in fruit with external cold damage and pulp spot.

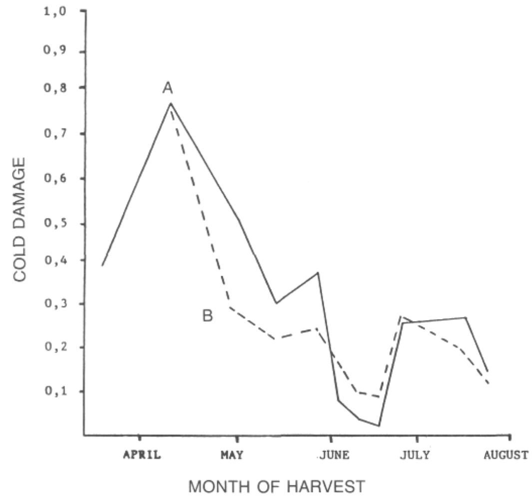

Fig 1 External cold damage in Fuerte avocados as observed at two different storage temperature regimes during one picking season:

A 5,5°C for 28 days (________).

B 7,5°C for seven days; 5,5°C for 14 days; 3,5°C for seven days (------------).

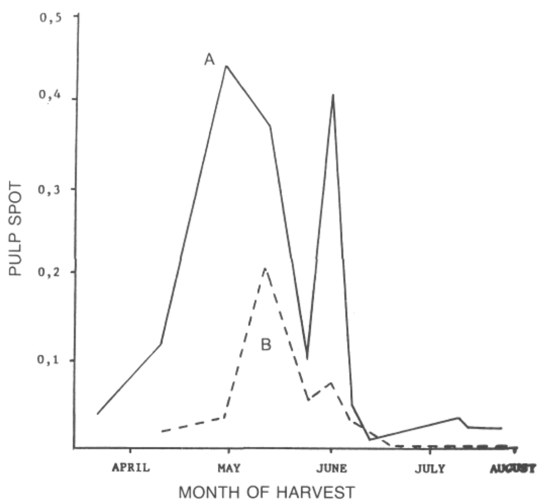

Fig 2 The incidence of pulp spot in Fuerte avocados at two different temperature regimes:

A 5,5°C over the total storage period (________).

B 7,5°C for the first week; 5,5°C for two weeks; 3,5°C for the last week of storage (------------).

Considerable differences in sensitivity to low temperatures have been observed during different stages throughout the avocado season (Vorster, Toerien & Bezuidenhout, 1987). Figure 1 shows a definite decrease in external cold damage of Fuerte avocados towards the end of the picking season.

Early season Fuerte (moisture content 77,5%) is sensitive to a storage temperature of 5,5°C over a period of four weeks. Storage at this temperature will result in cold damage. Later in the season storage at the same temperature will result in soft fruit, if avocados are stored over the same period.

Toerien (1986) proposed the concept of a declining temperature regime.

Early season fruit is more sensitive to low temperatures than late season fruit (Toerien, 1986). Because of this, adaptation of temperatures throughout the season is necessary. Optimum temperatures and storage periods vary with the stage of fruit development (Bezuidenhout, 1983). Kosiyachinda & Young (1976) found that chilling sensitivity of Fuerte and Mass avocados was highest during the climacteric rise and peak. The least sensitive stage is the post-climacteric stage.

Higher temperatures during the early stages, and lower temperatures during the later stages of storage tend to decrease physiological disorders when compared to a temperature of 5,5°C for the total storage period (Vorster *et al,* 1987) (Figure 2). Based on this, the concept was developed to place less stress on the early stages and a lower temperature during the later stages of storage.

Bezuidenhout (1983) formulated a climacteric model. The time to the climacteric is a function of temperature and fruit maturity. Oil content was used as an index of fruit maturity and the correlation with the time to the climacteric was formulated as follows:

$$Tc = C1 - OL\ C2/Te - C3/T$$

With
Tc = time to the climateric in days
T = Temperature in °C
OL = % oil content
e = exponential constant 2,7183
C1 = 150
C2 = 1,3
C3 = 1,625

Historical data shows that the average time taken for Westfalia Estate avocados to arrive overseas was 24 days.

By making use of a moderate temperature during the early stages of storage and a lower temperature during the later stages, the climacteric can be reached after approximately 24 days. This resulted in a firm fruit with little or no cold damage. This principle was evaluated on an experimental basis and storage temperatures (Table 1) were consequently proposed to the South African avocado industry. This should be seen as a flexible tool in the concept of temperature management.

Recommended temperatures are air temperatures and it can be assumed that fruit temperatures in a commercial system will be 1-2°C higher than air temperature (Boelema, 1987).

By using the above principles, Fuerte avocados with a firmness of less than 35, as measured by firmometer (Swarts, 1981), and with the minimum amount of cold damage, can be expected if the storage period does not exceed 28 days.

Optimum temperature and storage periods of avocados vary with the different cultivars (Vakis, 1982; Vorster, *et al,* 1987). Form experiments conducted and literature cited it is clear that Hass and Ryan are less sensitive than Fuerte to a temperature of 3,5°C for up to 21 days. Early season Hass and Ryan held at a temperature of 5,5°C will result in firm fruit on arrival, whereas lower temperatures can be considered for more mature fruit.

Time Temperature Interaction

The time / temperature relationship cannot be over-emphasised in the effort to improve fruit quality on overseas markets. Significantly (P = 0,05) less external cold damage was observed on fruit harvested (for one vessel that was monitored) on the last day of picking, in comparison with the first fruit picked (Figure 5). Deadline fruit was significantly (P = 0,05) more firm than fruit picked on the first day of picking for this particular vessel. Results (Figure 5) showed a drastic increase in physiological disorders, the longer the fruit was stored (Figure 3). Thus it is clear that time is of the utmost importance in determining fruit quality.

The avocado industry must accept that there is a time constraint and should therefore minimise the period of post-harvest handling.

Selective Picking

On a Fuerte avocado tree it is quite easy to distinguish between at least three periods of fruit set before picking starts. It is logical to expect that fruit from the first to the later sets will differ in maturity. It is generally agreed that the optimum temperature and storage periods vary with the stage of fruit development (Bezuidenhout, 1983) as has been shown by experiments conducted (Figure 4).

Fuerte avocados were selectively picked, based on fruit set. First and later fruit sets were distinguished. The fruit was processed through the commercial packing line at Westfalia Estate, where it was stored for 28 days at two different temperatures: 5,5°C for the total storage period, and 7,5°C for three weeks followed by 5,5°C for one week. Thereafter the fruit was left to ripen at ambient temperature, after which it was inspected both internally and externally for physiological and pathological disorders.

First set avocados are less sensitive to low temperatures than fruit from the same trees, but from a later set. Significantly (P = 0,05) less external cold damage was observed on the more mature fruit. However more cold damage was observed on fruit stored at 5,5°C for the total storage period when compared with fruit stored at 7,5°C for three weeks followed by 5,5°C for one week (Figure 4).

A temperature regime suitable for the first set could therefore cause a lot of external cold damage on the less mature fruit of the later set. The principle of selective picking during the early season is therefore critically important in the implementation of post-harvest temperature management.

Cooling

The physical mechanism of cold storage is an important factor in temperature management and the following principles are vital:

* Well ventilated cartons.
* Configuration of cartons in pallets so as to promote optimum air flow.
* Effective utilisation of air in the cold room.
* All pallets must receive the same amount of cold air.
* A controlled air flow pattern.

The above factors will bring about maximum contact between air and the product and will result in more homogeneous cooling.

Carton Design

Investigations by Haas & Ferguson (1985) on the cooling rate of avocados, packed in cartons in a windtunnel, indicated that there is no significant gain in increasing the free flow area (total area of openings as a percentage of carton area) perpendicular to the direction of openings of air flow, beyond a certain value. Cooling rate seldom improves above 9% free flow area. The cartons which are being used at Westfalia Estate have a free flow area of 8,5% in the direction of vertical air flow (refrigerated truck and container), which is close to the ideal percentage. In the direction of horizontal air flow, this percentage was in excess of 11,4%.

Controlled Air Flow

For all pallets to receive the same amount of cold air a controlled air flow pattern in the coldroom is necessary. Temperature recordings of fruit in the coldroom of the packhouse at Westfalia Estate were found to show a big difference in cooling rates depending on the position of the pallet in the coldroom. In an uncontrolled configuration fruit were found to be at a pulp temperature of 9°C plus, after cooling for 24 hours at 6,5°C. However in the same uncontrolled configuration there were also fruits found which had cooled down below 9°C within three hours. It is recommended, therefore, that a controlled air flow pattern be effected.

Water Loss

Water loss is one of the most important factors leading to fruit deterioration. Increased moisture loss resulting in stress during storage, not only enhances polyphenol oxidase (PPO) activity and visual symptoms of physiological disorders, but also increases the prevalence of pathological disorders (Bower & Cutting, 1987).

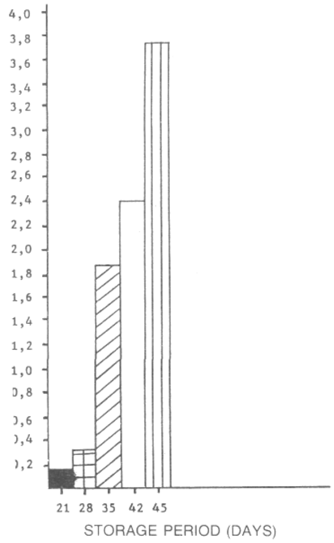

Fig 3 The incidence of grey pulp in Hass avocados after periods of cold storage varying from 21 to 45 days. A storage temperature of 5,5°C was used for the first 28 days and 3,5°C was used for the period after the original 28 days.

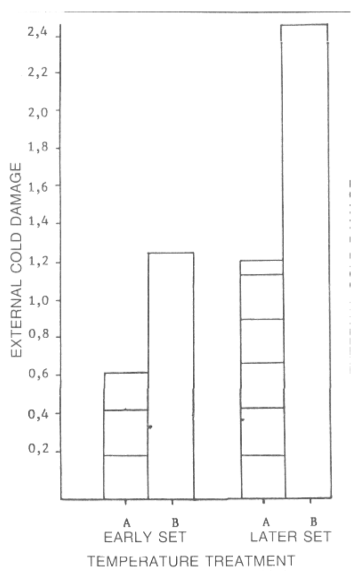

Fig 4 The incidence of external cold damage on fruit selectively picked and based on fruit set. An early and later fruit set were distinguished. Two different temperature regimes were used namely: A 7,5°C (three weeks); 5,5°C (one week). B 5,5°C (four weeks).

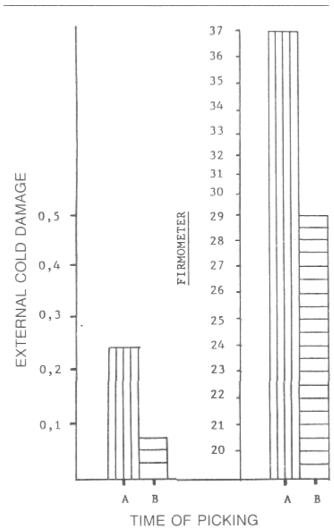

Fig 5 A comparison of fruit picked during the first pick of a vessel (Monday, 2 May 1988) (A) and the deadline picking (Friday, 6 May 1988) (B) with external cold damage and firmness of the fruit as criteria. Storage temperature: 6,5°C (one week), 5,5°C (three weeks).

TABLE 1 Proposed storage temperatures (air temperatures) for South African avocados

FRUIT MOISTURE %	COLDROOM PACKHOUSE	COLD TRUCK	HOLDING STORE	VESSEL
78,5	7,5°C	7,5°C	7,5°C	7,5°C (Last week 5,5°C)
77,5 — 78,5	7,5°C	7,5°C	7,5°C	7,5°C (Last week 5,5°C)
76,5 — 77,5	7,0°C	7,0°C	7,0°C	6,0°C (Last week 5,5°C)
75,5 — 76,5	6,5°C	6,5°C	6,5°C	6,0°C (Last week 5,5°C)
74,5 — 75,5	6,5°C	6,5°C	6,5°C	5,5°C
73,5 — 74,5	6,0°C	6,0°C	6,0°C	5,5°C
72,5 — 73,5	6,0°C	6,0°C	6,0°C	5,5°C
71,5 — 72,5	5,5°C	5,5°C	5,5°C	5,5°C
69,5 — 71,5	5,5°C	5,5°C	5,5°C	5,5°C (Last week 4,5°C)
67,5 —	5,5°C	5,5°C	5,5°C	5,5°C (Last week 3,5°C)

This recommendation is for Fuerte. Early season Hass and Ryan can be stored at 5,5°C for the total storage period. Lower temperatures can be considered for more mature fruit of these cultivars.

The period that fruit is held at each phase must be kept at a minimum.

TABLE 2 The effect of modified atmosphere (MA) on the quality of Fuerte avocados*

TREATMENT	ANTHARAC-NOSE %	STEM END ROT %	COLD DAMAGE %	GREY PULP %	PULP SPOT %	VASCULAR BROWNING %
CONTROL	0	0	5,0	4,4	2,4	0,4
CO_2 TREATMENT	1,78	0,32	0,23	3,3	0,31	1,08

Avocados were gassed with CO_2 (25%) in ship's containers and transported over a period of approximately 40 hours without any cooling. Control fruit was transported at 5,5°C in a refrigerated truck.

*Fruit evaluated by A B TRUTER.

According to Lyon (1973), chilling injury can be reduced by high humidity. This may simply suppress the expression of symptoms by reducing desiccation of necrotic tissue.

The relative humidity in the storage atmosphere therefore plays a vital role. Movement of water between a commodity and its environment is always a move towards equilibrium. Evaporation (escaping molecules) cause the water to exert a measurable pressure on the atmosphere (water vapour pressure — wvp) which is proportional to any temperature according to the net number of molecules escaping. The rate of evaporation from any plant material is proportional to the extent to which the wvp of the material and the ambient air is out of equilibrium i.e. the water vapour pressure deficit (wvpd) of the air relative to the material. The equilibrium wvp of the material depends upon two factors — the temperature and the amount of dissolved substances in the plant sap and the absorbent forces in the plant structure (Burton, 1982).

Methods that may be used to minimise evaporation loss are:

* Reduce wvpd of the environment.
* Decrease permeability of the integu ment to water vapour.
* Keep the wvp of the air as close as poss ible to the wvp of the fruit.

When lowering the temperature of a commodity with a blast of cold air the following factors must be borne in mind (Burton, 1982):

* The inlet wvpd of the cooling air.
* The extent to which this is increased by the transfer of heat to the air from the commodity and decreased by the evaporation of water from the commodity.
* The net effect of this upon evaporation.

A basic rule in heat dynamics is that the greater the temperature gradient (T) and the less volume of air in the system, the higher the moisture loss will be from the fruit. By decreasing the volume of air (cooling system with a bigger capacity) and restricting the T, moisture loss can be limited.

The design of cooling systems in a pack-house therefore plays a major role in water loss of fruit and the final fruit quality.

Controlled and Modified Atmosphere Storage

Spalding & Rheeder (1972) reported that the storage period of avocados can be lengthened by controlled atmospheric (CA) conditions (2% oxygen and 10% carbon dioxide). It has also been shown that CA storage decreases the risk of chilling injury considerably (Eksteen & Turner, 1983).

Although CA containers are available for commercial transportation of avocados, this has not yet proved cost-effective. It does, however, hold potential.

Under local conditions modified atmosphere (MA) storage (CO_2 treatment one day after harvest — 20-25% CO_2 for 36 hours) prior to, or during transportation to Cape Town, may be less expensive and more practical than the use of CA. Truter & Eksteen (1987) reported a reduction in external cold damage from 25,9% (control) to 0,5% in a CO_2 treatment, applied one day after harvest. They also reported a decrease in physiological disorders.

Promising results were also obtained by Toerien and Vorster (unpublished) in semi-commercial experiments with MA storage by making use of ships' containers (Table 2). Fruit was cooled down to an average pulp temperature of 8°C before being loaded into the containers. These containers were then gassed with CO_2 (25%) at Westfalia Estate and transported by road to Cape Town without any cooling. Control fruit was transported at 5,5°C in a refrigerated truck.

The fruit was stored at the Fruit Technology Research Institute in Stellenbosch, for a period of 28 days at 5,5°C and then for four days at 20°C. After that it was evaluated for shelf-life, external cold damage and physiological disorders (Table 2). Similar results to those of Truter and Eksteen (1987) were reported. However this system did not prove to be economically viable, due to the high cost of inland container transport.

Although there are still a few problems in the commercial implementation of these concepts, it could be expected to be of some value in the future.

SUMMARY

It is clear that the concept of post-harvest management of avocados includes various principles which start with the design of the packhouse and end with accurate feedback from overseas markets. The recommended temperature regime must be seen as a flexible tool in post-harvest management. Fruit reaction to cold storage is predetermined by orchard conditions (Smith, 1985). Because of this the sensitivity of the avocado may differ from season to season. Therefore reliable and detailed feedback from overseas markets on the firmness of the fruit, the amount of external cold damage and in-transit temperature recordings, are of vital importance in decision making and temperature management. It is clear that the total time from picking until marketing is of the utmost importance in determining fruit quality. The avocado industry must accept that there is a time constraint and should therefore reduce the total period of post-harvest handling to a minimum.

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