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Storage and transport of avocados - practical considerations for the South African export situation

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SYNOPSIS
South African avocados require at least 28 days between being picked and sold. Extensive research was undertaken to understand the behaviour of locally produced avocados and also to develop transport procedures to distant markets. The relevant information applicable to the South African situation is reviewed in an attempt to formulate handling procedures and shipping conditions. A proposed temperature management system to accommodate the changing seasonal requirements of the avocado fruit is formulated.

INTRODUCTION

The main avocado production areas are in the subtropical regions of the northern Transvaal. The avocados produced in these areas are transported by road over a distance of about 2000 km to Cape Town from where they are exported. The journey with a refrigerated truck takes about 36 hours, the transfer operation into containers some 10 minutes and recooling in the refrigerated container holding store to the carrying temperature requires another 24 hours. The sea voyage from Cape Town to the UK and Continent lasts another 17 to 19 days. If accumulation for a nine-day shipping schedule and marketing period is added to the total transport period, it is clear that a total storage period of between 21 and 25 days is required.

During this long storage period at low temperatures, chilling injury, physiological disorders and pathological diseases can develop if special procedures are not applied. Temperature management according to fruit characteristics is one of the most important factors determining ripening rate and final eating quality. The effect of temperature and other factors on commercially successful storage during long distance transport is discussed in this paper.

FACTORS AFFECTING AND PROCEDURES TO IMPROVE QUALITY

Cultural and seasonal factors

Irrigation and nutrition are two very important factors affecting quality. If any one or both are not correctly applied, post-harvest quality and ripening are affected. Bower (1984) proved that moisture stress conditions during the pre-harvest stage resulted in more rapid post-storage ripening.

Fruit with a high calcium (Ca) content is less susceptible to physiological disorders (Faust & Shear, 1968; Veldman, 1983). Higher levels of Ca in fruit tissue reduce pre-climacteric, climacteric and post-climacteric respiration (Faust & Shear, 1972). Avocado fruit with a high Ca content ripens more slowly (Tingwa & Young, 1974). Variation in ripening rates can therefore also be attributed to variation in fruit Ca content.

Seasonal effects are also important when post-harvest quality of avocados is considered. Rowel & Durand (1982) reported poor quality after seasons of heavy rainfall. Anthracnose and stem end rots are major post-harvest problems (Burelli, 1982; Truter & Eksteen, 1983) which are affected by climatical conditions.

Post-harvest quality also varies between different seasons and even within a given season under relatively similar handling and transport conditions. Pulp spot and chilling injury were more severe during 1981 than during 1982 (Bezuidenhout & Kuschke, 1983). It has also been established that under simulated (Smith, 1984) and export conditions (Bezuidenhout & Kuschke, 1983), pulp spot was highest during the first part of the season and decreased towards the end of the season. This decrease in pulp spot was associated with an increase in grey spot.

PHYSIOLOGICAL AND OTHER POST-HARVEST FACTORS

Picking maturity. Oil content is regarded as the most important maturity criterium for South African avocados and Swarts (1978) has proved a direct relationship between oil and moisture content. Oil content consistently increases during the season (Smith & Huisman, 1982). Burelli (1982) indicated significant differences in oil content between large and small fruit early in the season. These differences disappeared later in the season. No relationship between oil content and chilling injury could however, be proved (Swarts, 1980).

It was established (Swarts, 1980) that chilling injury was drastically reduced as the season progressed. Swarts also proved that this was not an effect of picking maturity, but the result of a drop in the pre-harvest ambient temperature to below 17°C.

These results were confirmed by Smith (1985) and in practice this means that the storage temperature during the early parts of the season (ambient conditions still relatively warm) should be higher than later in the season. This concept was tested and proved by Vorster *et al* (1987). These authors proved that Fuerte avocados picked later in the season can be, stored at 3,5°C without the danger of chilling injury.

Physiological aspects. Van Lelyveld et *al* (1983) indicated that the enzyme phenylalanine ammonia - lyase (PAL) activity was higher in pulp spot-affected fruit than in healthy fruit. Differences in PAL activity between proximal and distal parts of the same fruit were indicated, but no seasonal variation in PAL activity was reported.

Grey spot is associated with senescence (Eksteen & Truter, 1983) and factors such as advanced picking maturity, slow cooling, high storage temperatures and long storage periods will increase the incidence of this disorder. This was confirmed by Slabbert &

Toerien (1984) who reported less grey spot with fast cooling of late season fruit.

Cooling rate. Slow cooling drastically reduces internal discolouration of avocados (Pantastico *et al,* 1975). There is also a strong correlation between chilling injury, pulp spot and grey spot of avocados. Bezuidenhout (1983) indicates that an increase in chilling injury results in an increase in pulp spot. It is known that early season fruit is much more susceptible to chilling injury than fruit picked later in the season (Smith & Hunt, 1984). It can therefore, be stated that the high incidence of pulp spot during the early parts of the season may indirectly be the result of too fast cooling.

This relationship between chilling injury and other physiological disorders may however not always exist. Slabbert & Toerien (1984) reported a significant increase in cold injury with fast cooling, but did not find any effect on pulp spot, grey spot and vascular browning. It is clear that other factors also play an important role in the development of physiological disorders (water stress, maturation etc).

Storage temperature and period are two very important post-harvest factors affecting the quality of South African avocados on distant markets. Smith (1985) identified three different phases during maturation of avocado fruit and indicated different storage conditions for each phase. These phases are:

Phase 1:
With orchard temperatures less than 10 hours below 17°C and oil content less than 16 per cent, a storage temperature of 6,5 °C is recommended.

Phase 2:
With orchard temperatures of at least 10 to 15 hours below 17°C and oil content above 16 per cent, the storage temperature can be reduced to 5,5°C without the risk that chilling injury may affect market quality.

Phase 3:
With orchard temperatures for longer than 15 hours below 17°C and oil content above 20 per cent, the storage temperature can be reduced to 4,5°C.

The findings of Smith (1985) were verified and confirmed by Vorster, Toerien & Bezuidenhout (1987). These authors recommend lower storage temperatures as the season progresses and even propose a storage temperature of 3,5°C for shorter periods later in the season. This concept was tested on export fruit during the 1986 season and a substantial improvement in quality was achieved (PPECB and Westfalia unpublished results). The procedure will have to be refined during the 1987 season before a general industry recommedation can be finalised. Of particular importance is the correct and accurate definition of the different phases.

The storage temperature also affects the total storage and shelf-life period, but the time between picking and marketing is very critical. An improvement in quality can be achieved by reducing the average storage period of 24 to 29 days even by only two days (Smith, 1982). For this reason fruit should be picked as close to shipping as possible and there should be a minimum delay in transportation to Cape Town and in

transfer to containers and the ship (Smith, 1982).

Packaging, ventilation and *en route* cooling are factors that can assist in maintaining good temperatures and to reduce storage (shipping) period. Cartons which allow positive vertical air circulation can ensure effective cooling and even temperatures (Toerien,1986). Fruit picked up to four days before shipping can be cooled in the production area before being transported to Cape Town.

Effective cooling *en route* and completion of cooling after containerisation in Cape Town prior to shipping can effectively reduce total storage period. This is because fruit from the last day's pickings will be at the correct temperature at the time of shipping. This can only be achieved if the following conditions are met:

1. The field heat must be removed so as not to exceed a pulp temperature of more than 16°C at the time of loading.

2. The structure of the mechanical refrigerated truck must be properly cooled down to 5,5°C and this temperature should be accurately maintained during the approximately 36 hours transit period to Cape Town.

3. Sufficient air circulation should be maintained throughout the journey which means that the circulation fans should be operated at full speed all the time. A circulation of at least 40 air changes per hour based on the empty volume of the truck is required.

4. The cartons should be designed to allow maximum air circulation. This is essential because the coolant (cold air) must make direct contact with the product. If the above requirements can be met, effective further cooling *en route* is possible as can be seen from Table 1.

5. Quick transfer from the road unit to the shipping container in Cape Town and immediate continuation of cooling in the Cape Town holding store.

6. A further 2 to 3°C temperature drop can be achieved within a 24-hour cooling period in the Cape Town holding store. This however, is only possible if a positive and even air flow can be maintained throughout the stack. With the ISO pallet (1 200 x 1 000 mm) too much air (±13 per cent) actually bypasses the load, but the non-standard (1110 x 1 120 mm) pallet presently used by some exporters, could reduce this problem. (See Figure 1 for stowing pattern.)

7. Later during the export season, fruit ripening takes place at an accelerated rate and soft fruit becomes a problem. Susceptibility to chilling injury also decreases later in the season. The shipping temperature can then be dropped to 3,5°C for the last seven days of the 21-day total transport period as tested and recommended by Vorster & Toerien (1987). Effective and positive air circulation through the pallet and carton remains a prerequisite.

TABLE 1 The extent of cooling that takes place during a 36-hour road transport period (calibrated and pre-cooled SATS truck, high-speed fans).

Pallet No	Loading temp °C	Arrival temp °C	Pallet No	Loading temp °C	Arrival temp °C
1	11,9	7,9	6	15,9	9,8
2	10,9	8,3	7	14,0	8,1
3	15,2	7,7	8	16,9	9,2
4	16,7	9,1	9	15,3	9,5
5	16,8	7,5	10	17,5	8,0

Average loading temperature at Tzaneen 13,9°C.
Average arrival temperature in Cape Town: 8,3°C

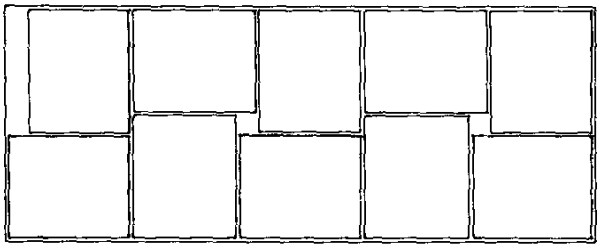

Fig 1a Loading pattern of 1 000 x 1 200 mm ISO pallets in a standard 20 ft insulated container.

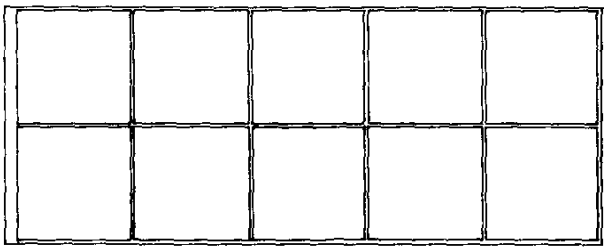

Fig 1b Loading pattern of 1 110 x 1 120 mm non-standard pallets in a standard 20 ft insulated container.

RECOMMENDED TEMPERATURE MANAGEMENT REGIME

If research findings and experience with semi-commercial export experiments are considered, it becomes clear that temperature management is absolutely essential to ensure high quality avocados on the overseas market. It has been proved that the avocado continuously changes during both pre- and post-harvest periods. It is therefore also essential to change the storage conditions to comply with the fruit requirements: a concept which has been practised for more than 50 years by the deciduous industry (Davies et al, 1935) and which may also be adopted for avocado exports to overseas markets.

Certain parameters (especially pre-harvest temperatures and oil content) will have to be accurately defined but the following recommendations based on research by Swarts (1980), Smith (1985) and Vorster, Toerien & Bezuidenhout (1987) can be made:

1. The period between picking and marketing should be as short as possible. Under local conditions this should preferably not exceed 21 days.

2. This becomes extremely difficult with a nine-day internal shipping cycle but, with intelligent temperature management, last day pickings can be shipped at higher

temperatures.

3. Removal of field heat, properly designed cartons and stacking patterns, effective transport and transfer systems to cooling facilities on land and on board ship are essential.

4. During at least the first four to six weeks of the season when the oil content is still below 14 per cent, the fruit should be kept at 7,5 to 7,2°C for seven days after picking before the temperature is lowered to 5,5°C for the rest of the voyage.

5. Storage and transport from orchard to market at 5,5°C during the middle part of the season (oil content 15 to 20 per cent).

6. During the latter part of the season (oil content above 20 per cent) ship at 5,5°C for approximately 14 days from picking before reducing temperature to 3,5°C for last seven days of voyage.

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