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PRE- AND POSTHARVEST MEASURES FOR LONG-TERM STORAGE OF AVOCADOS

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INTRODUCTION

In recent times, the avocado has become well-known in the industrialised areas of North America and Europe, changing from a little-known exotic, to a major commodity. The United States, Israel and South Africa are at present the major exporting nations, accounting for 90 per cent of world trade and marketing the product remote from the production areas.

Trade with distant markets requires the production of high quality fruit and an efficient transport system in order to land fruit in a sound condition. There are, however, many references to chilling injury in the literature (Chaplin, Wills and Graham, 1982) which have been attributed to long periods of cold storage (Couey, 1982) during transport. The use of low temperature is, however, the major means by which the physiology of the highly climacteric and rapidly softening (once harvested) avocado fruit can be slowed down, to arrive at the market with sufficient shelf-life to allow for sale. Assuming that the rate of softening can be controlled by temperature, the most important non-pathological problem facing the avocado exporter, becomes that of physiological disorders. This paper, therefore, deals primarily with physiological disorders after long periods of shipment and the measures required to minimise them.

PHYSIOLOGICAL DISORDERS

Physiological disorders are common in many crops, particularly where storage at low temperature for long periods is required. The major disorders in avocados were described in South Africa by Swarts (1984). Two types of symptoms were described, that of pulp spot and mesocarp discolouration.

Pulp spot is a blackening of a region surrounding cut vascular bundles and is usually localised in nature. Severe cases present unattractive fruit flesh. This disorder is usually most prevalent early in the harvest season.

The second disorder, mesocarp discolouration, is often referred to as chilling injury (Eaks, 1976). It is an overall grey to brown flesh discolouration, most intense in the distal half of the fruit. The symptom is predominant towards the end of the normal picking season, thus increasing as fruit maturity increases.

Primary causes of flesh discolouration

Before discussing the means by which physiological disorders can be minimised, it is necessary to examine the basic cause of the flesh discolouration.

The reactions involved in the disorders cause tissue browning. This means that the enzyme polyphenol oxidase (PPO) is involved (Kahn, 1975). PPO on its own, however, does not cause browning. A group of chemical compounds known as phenolics, together with oxygen, must also be present. Under these conditions, the phenollcs become oxidised to form dark coloured pigments, hence the appearance of physiological disorders. A further important aspect is that PPO and phenolics must come into contact with each other for the browning reaction to occur. In a normal cell, the PPO is found in the chloroplasts (Tolbert, 1973), while the phenolics are in the vacuoles. In order to come into contact with one another, physical cell damage must occur.

Overall, symptom development is determined by:

1 High PPO activity (the higher the activity the more intense the browning) and/or

2 High phenolic concentration and

3 Tissue damage.

The degree to which fruit cells can withstand postharvest stress such as low temperatures, without becoming damaged, will therefore be a determining factor in the development of disorders.

Factors inducing physiological disorders

It Is clear that low temperature postharvest storage does not constitute the only important factor in the development of disorders. Bezuidenhout (1983) ascribed the reasons for physiological disorders to pre-harvest orchard factors as well as postharvest aspects such as storage temperature, period of storage and storage atmosphere, Bower and Van Lelyveld (1985) added a third dimension, the Interaction between pre- and postharvest factors.

Pre-harvest factors

As previously indicated, the ability of fruit to withstand postharvest stress, depends to a large degree on the characteristics of the fruit at the time of picking. A factor of considerable importance is calcium, although other factors, such as water stress at critical times during fruit development and fruit maturity, have been shown to play an important role. These will be discussed in more detail later.

Calcium

The pre-harvest factors affecting postharvest characteristics are particularly important during the early cell division stage of fruit development, when structural characteristics of cell components, such as cell walls and membranes, are determined (Bangerth, 1979). It is also known that calcium plays a role in the maintenance of cell stability, particularly membranes, under stress conditions such as postharvest, low temperature storage (Roux and Slocum, 1982). The more stable the cell membranes are, the less likely it is that cell damage resulting in browning, will occur.

If calcium physiology is of vital importance for the maintenance of fruit quality, then the factors affecting the pre-harvest uptake, movement and deposition of calcium will be important, as the grower must ensure that the fruit obtains the maximum amount of calcium at the most critical time of fruit development. Figure 1 indicates the pattern of calcium concentration change after fruit-set. It is clear that the calcium concentration peaks early in fruit development, and coincides with early cell division. The grower must therefore ensure that conditions for uptake, during this early period of fruit development, are ideal.

A schematic diagram of calcium movement in the avocado tree and the role in fruit physiology is shown in Figure 2. Although there are many complex interactions, there are only a few important aspects over which the grower has control.

The initial entry of calcium into the plant is influenced by functional root area, soil moisture and ion exchange, where the ammonium ion is particularly important (Fukumoto and Nagai, 1983). Fertiliser applications must be made with this in mind.

Once calcium has entered the plant, it moves with the transpiration stream towards the leaves and fruit. Therefore, water stress due to poor irrigation or harsh environmental conditions, will cause slow movement of calcium and less availability to fruit (Hanger, 1979). However, a further factor of considerable importance, is the influence of the leaf:shoot ratio. Kirkby and Pilbeam (1984) showed that calcium movement was strongest towards terminal buds. Thus, new leaf growth can be expected to compete with fruit for calcium. New work has shown that rapidly dividing cells play a vital role in calcium uptake into an organ. Such cells produce the growth regulator indoleacetic acid (IAA).

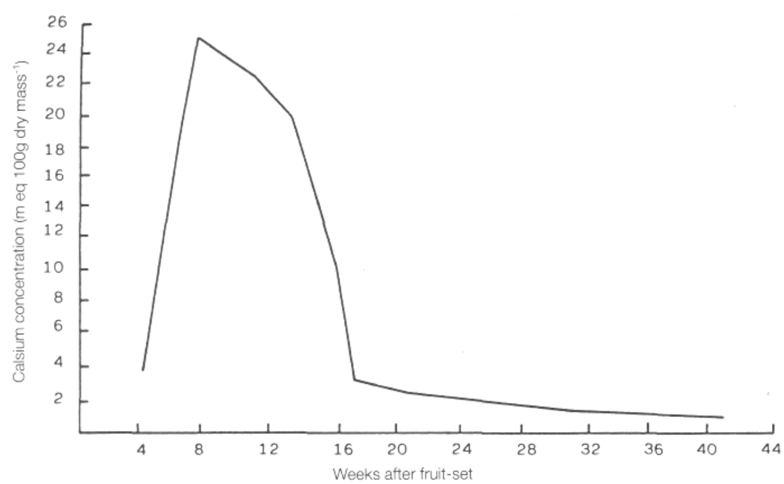

Fig 1 Fuerte avocado fruit calcium concentration changes during development.

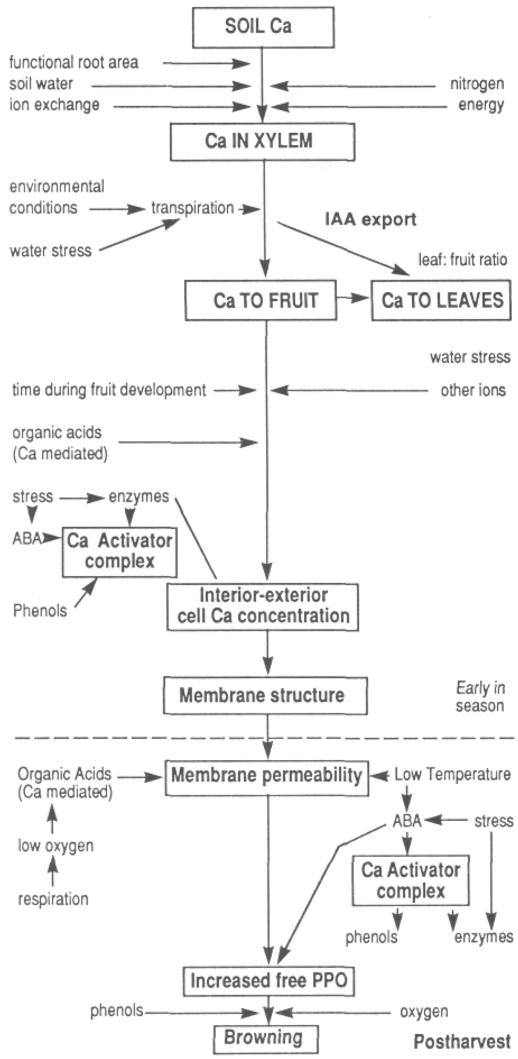

Fig 2 Schematic representation of possible interactions between calcium and other plant and environmental factors in the determination of fruit quality.

The export of this substance results in the uptake of calcium (Banuelos, 1986). Fruit production of IAA matches the pattern of calcium concentration change shown in Figure 1 (Cutting, 1984). A strong fruit calcium sink exists for only a short period. Unfortunately, in the case of the avocado, the early stage of fruit development coincides with the spring growth flush, which is often distal to the fruit. Competition therefore exists between the fruit and the developing leaves, with calcium movement predominantly towards the developing leaves (Kirkby and Pilbeam, 1984). Witney, Wolstenholme and Hofman (1986) confirmed this, by showing that non-vigorous trees had fruit with a higher calcuim content than those from vigorous trees, Cultural practices should, therefore, be arranged to ensure as small a spring flush as possible, Timing and rate of nitrogenous fertilisers should be looked at with particular care. Growth retardants may also play a role in the future,

Water stress

In most commercial avocado growing areas, water stress will result if supplementary irrigation is not applied. The period during which water relations are most critical, occurs during the first three to four months after fruit-set. The effects of stress at this time affect many aspects of fruit physiology, which can not be rectified by more satisfactory conditions later in fruit development, This situation was adequately illustrated by a long-term irrigation experiment in South Africa. A frequent, moderate and infrequent irrigation schedule was used, based on soil moisture tension. Water stress directly affected the activity of the browning enzyme PPO in ripe fruit after storage (Figure 3).

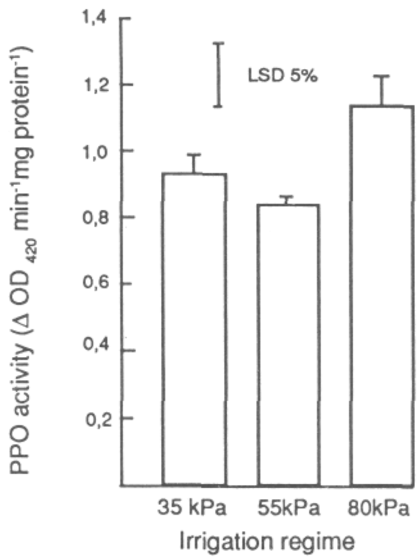

Fig 3 Effect of long-term irrigation regime (irrigation at soil moisture tensions of 35 kPa, 55 kPa, or 80 kPa) on browning potential as shown by PPO activity in soft Fuerte fruit stored for 30 days. Bars indicate SE of means, 10 samples per mean.

This implies that should postharvest cell damage occur, the likelihood and intensity of fruit browning as a result of increased PPO activity, will be higher In fruit from trees with a history of water stress. Care must be taken, however, to ensure that irrigation is not too frequent, as this may stimulate vegetative growth. The optimum irrigation regime in the experiment was found to be one of rewetting the soil profile when the moisture tension reached 55 kPa.

Fruit maturity

Analysis of fruit throughout the harvesting season, showed a rapidily increasing browing potential (as evidenced by PPO activity), with increasing on-tree maturity. In an analysis of fruit from five harvest dates (Figure 4), spread over the normal packing period for the area, a rapid increase in browning potential occurred from mid-May onwards, This correlated well with an increase in physiological disorders. The most desirable final packing date will, however, depend on the environmental characteristics of the area and the cultivar. This will have to be determined on an individual area basis.

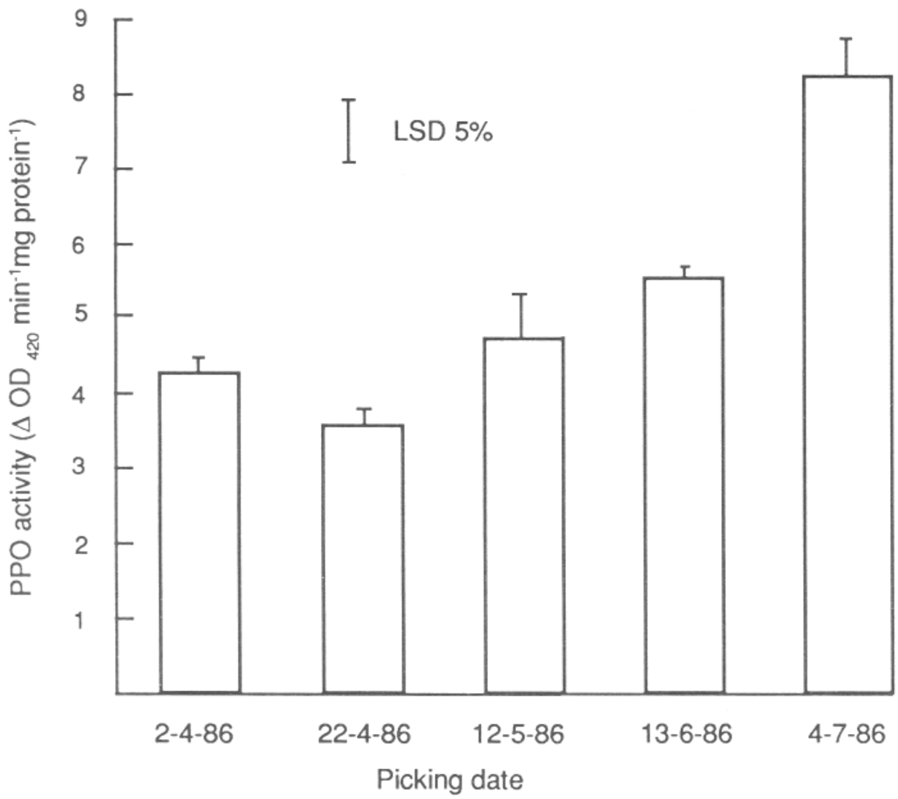

Fig 4 Change in Fuerte fruit browning potential, as indicated by PPO activity, with picking date. Bars indicate SE of means, 5 samples per mean.

Postharvest factors

Low temperature storage is the most commonly used method of extending the storage life of avocados. While most problems traditionally associated with storage have been ascribed to temperature and the period of storage (Eaks, 1976; Zauberman, Schiffman-Nadel and Yanko, 1977), experience has shown that there are a number of other factors of considerable importance to the maintenance of fruit quality in storage, The most important of the other factors involve the shipping container atmosphere, which includes oxygen, carbon dioxide and humidity.

Temperature and period of storage

In the past, the standard shipping temperature for avocados from South Africa to Europe was 5,5°C. At this temperature, a compromise between cold damage and rapid fruit softening is reached. More recent work (to be discussed later) was done in an attempt to tailor fruit quality and maturity at picking, with the ability to withstand storage conditions.

Unfortunately, at temperatures low enough to prevent softening, the period of storage becomes an important determining factor. At any temperature lower than 10°C, the length of time at this temperature together with fruit characteristics, becomes important. Low temperature decreases normal respiration, causing an alternative respiratory pathway to become predominant as an energy source. This causes respiratory by-products toxic to cells and particularly to membranes, to be produced. An example of the effect of extended storage at 5,5°C on the incidence of physiological damage, is shown in Figure 5.

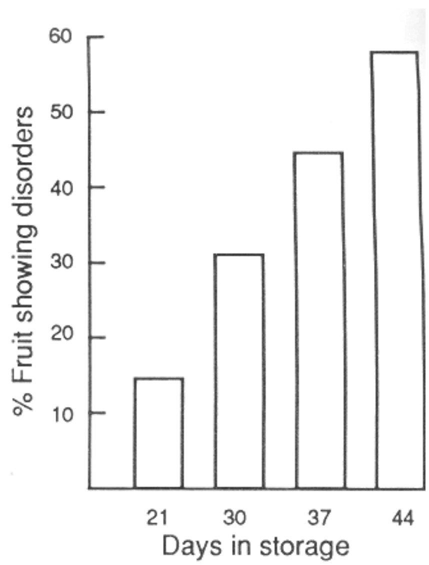

Fig 5 Effect of storage period at 5,5°C on incidence of storage disorders.

The temperature:time interaction at which fruit damage occurs, has been found to vary through the picking season, with more mature fruit being able to withstand lower temperatures. Further, Smith and Lunt (1984) found that low orchard temperatures prior to harvest can acclimatise fruit to low temperatures. It is also known that fruit temperature sensitivity alters during the ripening phase. These changes are thought to be due to changes in the saturation state of lipids within the cell membranes. These factors have led to the formulation of a temperature management approach, where fruit is shipped at a temperature of 7,5°C at the start of the picking season, and decreased to 5,5°C for the last week of the shipping period. During mid-season, a 5,5°C regime is followed throughout the shipping period. For late season harvests, the 5,5°C temperature is decreased to 4,5°C for the last week of shipping.

Container atmosphere

Coupled to the effect of temperature, the container atmosphere, especially oxygen, carbon dioxide and humidity, is important.

Oxygen

Low concentrations of oxygen, coupled with high carbon dioxide levels, have been shown to delay ripening and senescence in many fruits (Rhodes, 1981). However, care has to be taken to ensure that low oxygen levels do not occur at the end of a long storage period (for example 30 days). Van Lelyveld and Bower (1984) found that suffocation could occur, resulting in mesocarp discolouration. Oxygen concentrations of five per cent and lower are particularly dangerous. However, the quality of the picked fruit is of importance in determining the likelihood and severity of fruit damage, due to adverse conditions during storage and transport. Bower and Van Lelyveld (1985) found a clear interaction between pre-harvest water stress and low oxygen content of containers at the end of storage. Figure 6 shows that by restricting ventilation for 48 hours, a highly significant increase in browning potential, as shown by PPO activity, occurred in fruit from trees subjected to water stress, while virtually no increase occurred in fruit from non-stressed trees.

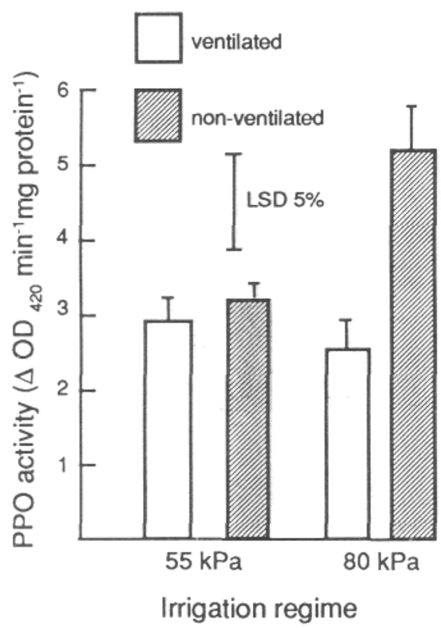

Fig 6 Effect of long-term irrigation regime and container ventilation on Fuerte fruit browning potential as indicated by PPO activity. Bars indicate SE of means, 5 samples per mean.

CO_2 shock

Research into controlled atmosphere storage of avocados has continued sporadically for the last 20 years (Ahmed and Barmore, 1980). The careful control of oxygen and carbon dioxide concentrations requires specialised containers, which are not readily available for long distance shipping at an economic tariff.

In order to overcome the problems of controlled atmosphere storage, a second approach has recently been taken. This has been termed CO_2 shock treatment (Collin, 1984; Eksteen and Truter, 1985). Avocado fruit can withstand relatively high levels of CO_2 (20 to 30 per cent), providing oxygen is not limiting. Work is still continuing on the requirements for different cultivars, and the effect of fruit maturity and storage temperature. However, good results regarding fruit quality and rate of ripening have been obtained by packing fruit into transport containers as soon as possible after harvest, and injecting CO_2 into the container until the concentration reached approximately 30 per cent. No fresh air ventilation is applied for approximately four days (packhouse to ship loading). The use of polyethylene bags to create a similar effect by natural CO_2 build-up has been tried. Fruit suffocation is however, liable to occur if the bags are not removed timeously and this aspect is not practical.

Container humidity

Postharvest fruit moisture loss has long been known to affect fruit shelf-life after storage, with the result that fruit is waxed (Lunt, Smith and Darvas, 1981) to minimise such moisture loss. However, wax application rates must not interfere with fruit oxygen transfer, or suffocation symptoms will result. Some degree of fruit moisture loss thus still occurs.

Cooling units in both holding and pre-cooling stores, as well as during shipping, remove water from the atmosphere. This creates a moisture concentration gradient from the fruit to the atmosphere, causing moisture loss from the fruit. The higher the atmospheric temperature, such as in pre-cooling stores and where fruit is shipped at higher temperature early in the season, the more pronounced the effect will be. A means of overcoming the problem is to artificially humidify the atmosphere, thereby decreasing postharvest fruit moisture loss and stress. The principle has been tested and the fruit quality in terms of both pathological and physiological disorders evaluated for non-stressed (container humidified) and stressed (container not humidified) fruit. Results are shown in Figure 7. The incidence of both pathological and physiological disorders was lower where fruit had been less stressed. The advantages of artificial humidification of containers and storage rooms are thus clear.

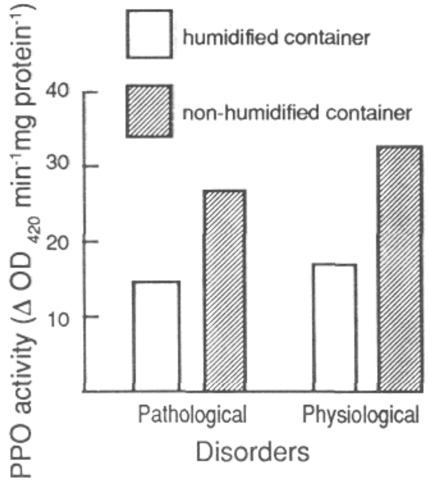

Fig 7 Effect of container humidification during storage of Fuerte fruit at 5,5°C on the incidence of pathological and physiological disorders.

OVERALL RECOMMENDATIONS FOR HIGH QUALITY FRUIT

The following is a summary of the actions which can be taken by the grower, packer and shipper, to ensure the highest possible fruit quality on the market.

Pre-harvest

(a) Ensure high fruit calcium uptake:

(i) Minimise stress, particularly during the first 16 weeks after fruit-set,

(ii) Control shoot growth in spring.

(b) Irrigation: Irrigate moderately throughout fruit growth and development.

(c) Fruit maturity: Do not pick too early or too late.

Postharvest

(a) Ensure correct shipping temperature: Use higher temperatures for early-harvested and lower temperatures for late-harvested fruit. Consider differential temperatures during shipping.

(b) Container humidity: Artificially maintain high humidity in stores and shipping containers to minimise fruit moisture loss. Particularly important in pre-cooling stores and where shipping temperatures are high at start of season.

(c) CO_2 shock: The principle of CO_2 shock can enhance fruit quality, but is still experimental.

It should be remembered at all times, that the quality of fruit in the market place begins in the orchard. Postharvest treatments can not improve poor fruit quality, but the reverse often applies. All aspects of tree and fruit treatment from flowering to market must be considered.

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