Proceedings from Conference '97: Searching for Quality. Joint Meeting of the Australian Avocado Grower's Federation, Inc. and NZ Avocado Growers Association, Inc., 23-26 September 1997. J. G. Cutting (Ed.). Pages 14-37.

AVOCADO QUALITY ASSURANCE: WHO? WHERE? WHEN? HOW?

D. L. Milne
Merensky Technological Services, P. O. Box 14, Duivelskloof, 0835, South Africa

Abstract

Avocado quality control is dealt with as a total process, commencing with an understanding of the physiological attributes of the fruit itself, including respiration, ethylene production, transpiration and the effects of step-down temperatures and time on quality. Orchard factors that may affect fruit quality are discussed briefly. These include factors such as irrigation, nutrition, mulching, fruit-maturity, diseases, picking and transport to the packhouse. This is followed by an analysis of packhouse factors, including grading, temperature control, waxing, vapour pressure, packaging and marking of cartons. Control of the cold chain during road transport, at the docks and during sea transport is emphasised and the interrelationship between time and temperature and their effect on quality is again emphasised. The potential for using CA and MAP is discussed.

Systems for the quality evaluation of fruit on overseas markets are described, together with definitions of some common types of external cold injury. Ethylene 'triggering' or ripening is mentioned as an important factor in marketing.

Emphasis is placed on the role of grower organisations in ensuring that controls are implemented at each point of the production and marketing chain so as to guarantee satisfied customers and therefore the grower's own economic success.

Keywords: *Persea americana,* fruit physiology, cold chain

Introduction

<u>Quality: Who pays the penalty?</u>

Whether due to climatic extremes, pre-harvest diseases, bad handling during picking and delivery to the packhouse, bad handling or cooling at the packhouse, poor cooling en route to the market, whether by land, sea or air, poor storage conditions at the market, losses during ripening and prepacking, losses at retail outlets and incorrect usage by the consumer, **it is in every case the grower who pays the penalty due to losses in quality.**

<u>Quality: Who is responsible?</u>

Responsibility is allocated to a great many people and organisations in the whole process of producing and marketing avocados. These include the grower and his employees, packhouse management, transporter staff, shipping and airways staff, local or overseas wholesalers, pre-packers, ripeners, retailers / supermarkets and even the consumer.

Quality: Who is accountable?

The important thing to remember is that ultimately it is the **grower** who is accountable for quality losses. He cannot abdicate his accountability by blaming it on others. Alistair Young of 'Team Avocado' in New Zealand said 'We have learned the hard way to keep control of our product until it reaches the retailer' (Smith, 1996).

Quality: The solution

The process of achieving quality at all stages can be summarized in Fig. 1. A total quality management process is required.

(Figure missing from manuscript)

Figure 1. Quality management: The process of ensuring that quality is maintained at every step of the production and marketing process

Quality: Definitions

The basics of quality include cultivar choice, shape, external colour, freedom from blemishes and freedom from disease. Internally the fruit should be free of physiological disorders, bruising and disease symptoms and should be of reliable and excellent eating quality.

Quality certainly means different things to different people (Combrinck, 1996). To the **grower** it is perceived as the standard laid down by the industry, prescribed by the packer and export agent, and in some cases by marketing boards. In the case of the avocado, this will usually mean fruit of a specific cultivar, of the correct size, properly mature but rock-hard, free of disease and free of blemishes. The **wholesaler,** whether local or overseas, will probably have similar requirements and will expect fruit to be hard and to have sufficient shelf-life to allow time for distribution and sale at the best price. The **retailers'** needs vary, depending on whether they are selling firm, triggered, or ready-to-eat fruit. They will want the fruit to be free of blemishes with dependable internal quality and sufficient shelf-life to avoid spoilage losses.

Consumers have two moments of quality assessment, firstly at purchase and secondly during consumption. At purchase their eyes must tell them that this is a sound fruit, of the kind he or she is familiar with and preferably with a predictable waiting period before being ready to eat. It must also represent good value for money, with the **consistent assurance** that 'what you buy you can eat'.

At the time of use, consumers must enjoy the even colour, smooth texture and delicious subtle flavour of a mature and properly ripe avocado. They should at the same time, be aware of the health value of the avocado.

Quality: The live avocado

Education is a major factor required in the quality management process, particularly when it comes to understanding the nature of the avocado fruit. The avocado must be recognised by all those handling it as a **living entity.**

<u>Respiration</u>

The picked avocado fruit respires. In other words, it utilises oxygen and produces carbon dioxide. The respiration process consists of the metabolism of carbohydrates in the presence of oxygen leading to the production of water, carbon-dioxide and heat energy (Combrinck, 1996). The avocado has a high respiration rate, compared with apples, citrus, grapes or kiwifruit (Kader *et al.* 1985) and therefore generates more heat during storage than many other products. The Hass fruit has a higher respiration rate than Fuerte (Kruger, 1996).

The avocado is a climacteric fruit, meaning that its physiology is characterised by an increase in respiration with time, reaching a peak, after which the ripening and softening process occurs (Bower and Cutting, 1988). Whereas fruit continue to mature on the tree, they will not soften until picked.

Cellulase is the main enzyme involved in the softening process (Pesis *et al.* 1978). Early in the season cellulase activity is low in freshly picked fruit; however levels are higher in more mature fruit (Fuchs and Zaubermann, 1987). These authors concluded that cellulase activity and softening of fruit at 20°C are not triggered by ethylene production but rather precede is.

<u>Ethylene</u>

Ethylene plays a vital role in the avocado ripening process. It is generally recognised as one of the triggers which induce the enzyme ripening process (Tucker *et al.* 1985, Starrett and Laties, 1993). However, Zauberman *et al.* (1988) have shown that the ripening process of avocado fruit requires the continuous presence of ethylene. Gazit and Blumenfeld (1970) and Köhne (1985) have shown that immediately after harvest, fruit will not readily respond to ethylene induced ripening. They explained this response as being due to an endogenous ripening inhibitor present in fruit while still on the tree, and remaining functional for a limited time after harvest. Ethylene induces an enhancement of tissue permeability, respiration and ripening (Bangerth, 1979). Ethylene production by fruit can be increased due to mechanical injuries, disease incidence and increased temperatures (Kader *et al.* 1985).

Tingwa and Young (1974) showed that infiltration of avocado fruit with calcium in the form of $CaSO_4$ or $CaCl_2$ depressed and delayed the peak of ethylene production if applied prior to the climacteric.

Hofman *et al.* (1997) showed that the respiration rate of Fuerte fruit can be increased by levels as low as 0,01 μl^{-1} of ethylene during storage at temperatures of 10-14°C. Reduction of ethylene levels during long-term storage is therefore vitally important. Sufficient air exchanges are essential in container vessels, while under CA conditions, scrubbers will be required.

The commercial use of ethylene for ripening fruit for the consumer is discussed later in this paper.

Transpiration

Transpiration is the process of water loss by the fruit and is an important factor in determining fruit quality. The evaporation of water will be affected by temperature, relative humidity, air velocity, surface coatings such as waxes or wrappers and packaging. Rind moisture loss has been shown to have a significant effect on fruit quality and the degree of cold injury in Fuerte fruit stored at 5,5°C (Bower and Cutting, 1987; Donkin and Cutting, 1994).

Water loss is certainly one of the important factors leading to overseas 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 and Cutting, 1987). The relative humidity in the storage atmosphere therefore plays a vital role. Cutting *et al.* (1992) have shown that more mature fruit are less subject to moisture loss than relatively immature fruit.

A basic rule in heat dynamics is that the greater the temperature gradient (*T*) and the less the volume of air in the system, the higher the moisture loss will be from the fruit. By decreasing the volume of air (i.e. by using a cooling system with a bigger capacity) and restricting *T,* moisture loss can be limited. The design of the cooling system in a packhouse therefore plays a major role in preventing water loss from fruit and in final fruit quality (Vorster *et al.* 1990).

Temperature

Temperature is the most vital factor when planning long term storage of avocados. However, it is not just temperature *per se*; it is the **maintenance** of the cold chain, right through to the consumer that is of equal importance. The impact of a break in the cold chain was clearly shown by Swarts (1981) who demonstrated that the later in the cold chain such break in cooling occurred, the greater the increase in softening of fruit.

It is therefore clear that a total management strategy in which time and temperature are both controlled is necessary if a good outturn of fruit quality is to be achieved.

After problems were experienced with South African fruit arriving soft in Europe, a detailed analysis of seasonal data was made by Bezuidenhout (1992). He showed that a deviation in holding temperature 1°C higher than recommended, for a 22-day transit time, increased the softness of fruit from a firmometer reading of 25 to 35. Furthermore, a similar increase (1°C) over a total transit period of 28 days caused an increase in softness from 32 to 46 on the firmometer (Table 1).

The rate of development of external cold injury of Fuerte avocados at various temperatures below 5°C, overtime, was clearly, demonstrated by Swarts (1980). See Figure 2.

The relationship between ethylene production, the climacteric, and ripening of Hass avocados at various temperatures, was shown by Eaks (1983). Bezuidenhout (1983) drew up a climacteric model for Fuerte fruit and was able to establish that excessive cold prior to the climacteric is favourable for chilling injury and pulp-spot to develop once the climacteric has passed, temperatures can be lowered. He also found that large Fuerte fruits are more susceptible to physiological disorders than small fruits. Pulp-spot susceptibility drops later in the season, whereas grey pulp increases steadily, especially if high temperatures occur in the post-climacteric phase (Bezuidenhout, 1983).

Table 1 **The influence of fruit age and temperature deviations on fruit firmness on arrival in Europe (after Bezuidenhout, 1992)**

FRUIT AGE DAYS	TEMPERATURE DEVIATION	FIRMOMETER READING
22	NIL	25 (hard)
22	1°C	35 ('breaking' to soft)
28	NIL	32 (firm to 'breaking')
28	1°C	46 (soft)

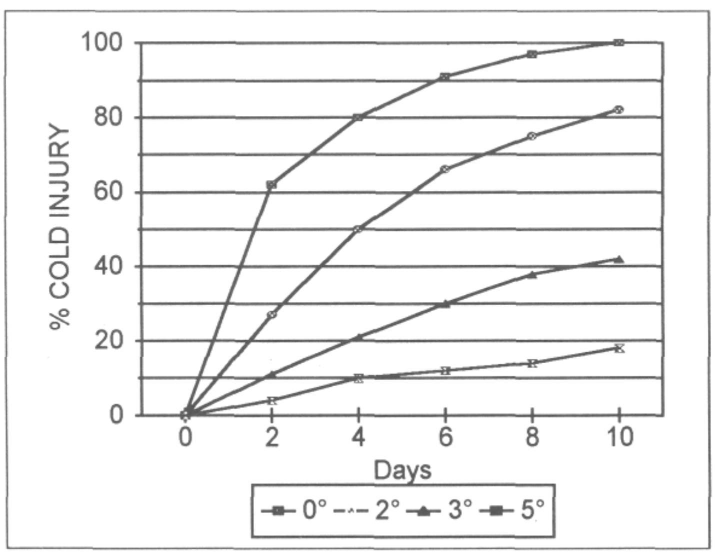

Figure 2 **The incidence of cold damage in Fuerté avocados stored for various periods and at various cold temperatures (after Swarts, 1980)**

Vorster *et al.* (1987) carried out trials in which the schedules proposed by Toerien (1986) were evaluated on various cultivars. Early season Fuerte fruit were found to be very sensitive to external cold injury, and the use of 7,5°C as storage temperature for the first week, followed by 5,5°C for two weeks and 3,5°C for one week, was found to reduce the incidence of early cold injury during the first half of the season, when compared with the standard of 5,5°C for four weeks. The step-down temperature also resulted in a significant reduction in pulp-spot symptoms. These authors proposed a **step-down temperature program,** not only during the storage period, but also throughout the season (Vorster *et al.* 1987, Eksteen and Bester 1987).

By 1990 a more sophisticated schedule of shipping temperatures, based on the moisture content of fruit had been developed (Vorster *et al.* 1990) (Table 2).

Table 2 **Temperature guidelines for export of avocados from South Africa (after Vorster *et al.* 1990)**

% MOISTURE	COLD ROOM °C	ROAD TRANSPORT °C	PORT STORAGE °C	VESSEL 1ST WEEK °C	LAST WEEK °C
78.5 - 80.0	7.5	7.5	7.5	7.5	5.5
77.5 - 78.4	7.5	7.5	7.5	6.5	5.5
76.5 - 77.4	7.0	7.0	7.0	6.0	5.5
75.5 - 76.4	6.5	6.5	6.5	6.0	5.5
74.5 - 75.4	6.5	6.5	6.5	5.5	5.5
73.5 - 74.4	6.0	6.0	6.0	5.5	5.5
72.5 - 73.4	6.0	6.0	6.0	5.5	5.5
71.5 - 72.4	5.5	5.5	5.5	5.5	5.5
69.5 - 71.4	5.5	5.5	5.5	5.5	4.5
69.4 & Less	5.5	5.5	5.5	5.5	3.5

Note: The above temperatures are air delivery temperatures and the temperature regimes are best suited to Fuerte, Hass and Ryan avocados.

Interestingly, this stepped down schedule of cooling was found to be unnecessary for Fuerte fruit grown in Kwazulu-Natal, where continuous storage at 5,5°C was found to be satisfactory in terms of external quality and internal physiological disorders (Donkin *et al.* 1995).

Various authors (Zauberman and Jobin-Decor, 1995; Jessup, 1991) have shown the potential of storing Hass fruits at temperatures as low as 2°C, however at 1°C severe chilling injury was found to occur (Vuthapanich and Hofman, 1997). The pre-conditioning of Hass fruit to induce tolerance to low temperatures (Woolf *et al.* 1995, 1996) is dealt with elsewhere in this conference.

<u>Time</u>

Swarts (1979) has shown the relationship between time and storage temperature and how chilling injury increases with reduced temperatures and longer time (Table 3).

Table 3 **The influence of low temperatures on the development of cold injury in Fuerté avocados which were stored for various periods (after Swarts, 1979)**

STORAGE TEMPERATURE	STORAGE PERIOD	% COLD INJURY
3,3°C	15 days	12,5
	28 days	66,0
	34 days	82,0
4,4°C	15 days	3,6
	28 days	26,0
	34 days	43,3
5,6°C	15 days	0,0
	28 days	10,2
	34 days	20,2
6,7°C	15 days	0,0
	28 days	1,9
	34 days	1,9
7,6°C	15 days	0,0
	28 days	0,0
	34 days	0,0

Vorster *et al.* (1988) have also shown that dramatic increases in external cold injury in Fuerte occur if the time of storage is extended from 21 to 28 days. Similarly, grey pulp increases in both Pinkerton and Hass as the storage period is extended. Bower (1988) also found that total postharvest disorders increased from 14% after 21 days to 30% after 30 days and to 58% after 44 days.

'Brown cold damage' (see p 24) definitely appears to be correlated with age of fruit (after picking) and this, coupled with low temperature storage for long periods, appears to aggravate the problem. For example, fruit placed at ambient temperature on arrival in Europe (22 days after packing) showed no symptoms. However, after a further 10 days of cold storage, the symptoms clearly developed after holding the fruit for two days at ambient temperature. Once again, this malady appears to be time x temperature related. Desiccation may however, also plays a role (Milne, 1994).

What can be done about quality?

<u>In the orchard</u>

To produce a fruit with adequate storage capacity it is essential to manage all the factors that influence the **inherent** physiological characteristics of the fruit. This is described as the pheno-physiological approach. Some seasonal factors such as low or very high rainfall, hail, excessive winds or extremely low temperatures cannot be controlled by the grower and furthermore the area of production can have a significant impact on shelf-life and postharvest diseases (Vuthapanich *et al.* 1995). However there are many aspects that do require grower management inputs.

Correct **irrigation** scheduling, with the use of tensiometers or other monitoring systems is essential in order to achieve fruit of optimum size and free of physiological disorders. In a trial carried out by van Eyk (1994) in South Africa, irrigation of Hass to field capacity (-15cb) gave superior yields of larger fruit than irrigation according to phenological demand.

Similarly, in trials carried out on seven-year-old Hass trees Vuthapanich *et al.* (1997) showed that well-watered (20kPa) trees in Queensland had twice the yield of the least watered trees (70kPa) mainly due to more consistent yields and greater fruit numbers. Postharvest characteristics of these fruits were not found to differ between irrigation treatments. However Bower (1988) found that water stress during the first 3-4 months after fruit set in Fuerte affects the activity of abscisic acid and of the browning enzyme, polyphenol oxidase. These in turn adversely affected fruit quality during storage (Bower and Cutting, 1987). Akkaravessapong *et al.* (1997) investigated the effect of water deficit on ripening time of avocados. The fruit harvested at night, between 20h00 and 05h00 had a significantly higher water potential than those harvested during the day. The fruit harvested during the day (07h00 to 15h00) were found to ripen a day earlier than those harvested at night. There are further papers dealing specifically with irrigation during this conference.

Nutrition plays an important role in determining fruit quality, particularly with regard to storage ability. Nutrition research of avocados was first explored in detail by Embleton and Jones (1964) and was reviewed by Bower and Cutting (1988). Whiley (1994) has recently, demonstrated that the application of nitrogen before flowering together with foliar sprays of PBZ applied at mid-anthesis, led to significant increases in Hass fruit size, total yield and II shelf-life.

It is beyond the .scope of this paper to review the literature on nutrition, but it is recommended that growers remain abreast of recent trends and make use of consultants or extension staff where possible.

Mulching was investigated by Moore-Gordon and Wolstenholme (1996) as a possible method of increasing Hass yield and fruit size through improved root activity and reduced tree stress in a field trial in Kwazulu-Natal. Feeder root growth was greatly increased throughout two seasons by the application of coarse composted pine bark mulch beneath the tree canopy. Over two seasons, the mulch treatment resulted in a significant 11,8% increase in mean fruit mass, in spite of 16,7% more fruits per tree. The combined effect was a 30,4% greater yield. The probable explanation for this increase is that mulching ameliorates overall plant stress.

Maturity of the fruit prior to harvest plays a major role in fruit quality and this relates mainly to the lipid or oil-content of the fruit. Percentage dry matter in the fruit is directly related to oil content and the total oil and moisture contents are reciprocal and generally sum to a constant for each cultivar (Swarts, 1978).

It is important for the grower to monitor maturity trends prior to the start of picking, to ensure that each cultivar has reached the required standard. Maturity will vary within a single tree, due to multiple fruit-set periods, so selective picking is recommended.

During the extremely high rainfall which occurred in 1996 in South Africa, following two years of drought, the higher soil-moisture levels were found to accelerate the production of oil in Hass fruit (Kruger and Claasens, 1997).

Diseases such as anthracnose, *Pseudocercospora* (black spot), sooty mould, stem-end rots and sooty-blotch, should be kept under continuous control in the orchard. Sprays of copper-oxychloride are generally used for this purpose.

Integrated fruit production using production methods in balance with nature, should be the norm aimed for.

Picking is a process which can greatly affect post-harvest quality, whether mechanical pickers or pole-pickers are used. It is generally accepted that Fuerte pedicels should be manually clipped, whereas it has been found that Hass can be snap-picked without detrimental effects on fruit quality (Köhne and Kremer-Köhne, 1995).

It is essential to avoid mechanical injury in the picking and handling process. A survey has shown that 49% of the decay occurring in apples stored for long periods, could be ascribed to infections arising from mechanical injuries (Combrink, 1996).

Temperature already plays an important role during the picking process and in the potential for creating physiological disorders. Measurements made on cherries, picked into lug boxes in the United States, showed that if fruit was stored in the sun, pulp temperatures at the top of a lug could reach 38°C (with an air temperature of 27°C) while fruit at the bottom of the lug were at 16°C. However if fruit were stored in the shade, the maximum temperature reached was 24°C (Kader *et al* 1985). Avocado fruit should reach the packhouse within two of hours of picking.

Although Darvas (1982) reported an increase in fungal stem end rot induced by a *Dothiorella* and *Colletotrichum* complex when fruit were harvested wet, this was not confirmed in later studies by Duvenhage (1993). However the latter author found that wet picked Fuerte fruit had a significantly higher incidence of black cold damage during early picking, which may also be ascribed to the low storage temperature of 5,5°C. Lenticel damage of wet picked Fuerte fruit was also significantly higher during early picking when compared to dry picked fruit. In general the incidence of lenticel damage was high for all fruit early in the season.

Although pulp spot incidence in the trials was significantly higher for wet picked Fuerte fruit than for dry fruit, it occurred at an extremely low level and could not be considered a commercial problem.

Although wet picked Hass fruit had a significantly higher incidence of lenticel damage during early picking, this may not pose a problem due to the darkening of Hass fruit on ripening. Incidence of vascular browning in Hass fruit picked wet during late picking dates increased significantly when compared to dry picked fruit. For this reason, wet picking of Hass late in the season, is not recommended (Duvenhage, 1993).

Late picked fruit tend to ripen much faster, particularly when grown in warmer areas (Vuthapanich *et al.* 1995).

Whether plastic lug-boxes or large wooden crates are used for picking, hygiene is important and the picking containers should be regularly washed, preferably using a fungicidal sterilant such as sodium or calcium-hypochlorite, copper sulphate or quaternary ammonium compounds.

Transport to the packhouse should be by means which minimise fruit vibration. Zauberman *et al.* (1969) noted that the main cause of fruit injury during transport was contact with the sides or the bottom of the bins. Therefore, the percentage of injured fruits in bulk bins (13.6%) was less than in field boxes (33.4%) as relatively fewer fruits were in contact with the sides and bottom of the bulk bins. Injury incidence was reduced by 50% when bins were lined with canvas.

At the packhouse

The first step to be taken at the packhouse is to collect a **representative sample** from each grower's fruit, preferably on an individual orchard basis. This sample should be carefully evaluated for damage, including wind-damage, hail damage, sunburn, the presence of diseases, insects or insect-damage and mechanical damage incurred in the picking or transport process. This analysis should be reported immediately to the grower and/or picking team, so that corrective action can be taken where necessary. The presence of pathological problems on fruit on arrival at the packhouse, is usually a fair indication that orchard practices are not being well managed.

Whether the packhouse is your own or not, ensure that **packhouse hygiene** is rigorously applied. This includes personal hygiene of staff as well as regular sterilising of cold rooms, packing-equipment, etc. Any fruit falling on the floor or rejected for disease should be disposed of far from packing facilities and orchards.

At Westfalia Estate in South Africa, representative samples of export fruit are held back under simulated sea-shipment conditions, representing each vessel's fruit. In this way differences between **inherent** problems in the fruit and actual commercial storage, can be evaluated. Corrective action can then be taken.

Monitoring of **temperatures** in the packhouse is of vital importance. Packers and transporters should not rely solely on temperature dials and electronic devices. Conventional mercury thermometers should be used in an ice / melted-ice mixture to calibrate at 0°C. Such a thermometer can then be used to evaluate measuring equipment. It is not uncommon to find equipment that reads up to 2°C off the actual temperature. Such a deviation is not acceptable in avocado storage. Note that hand-held electronic probes may give different readings when the instruments themselves are in a warm or a cold environment.

The Perishable Products Export Control Board (PPECB) in South Africa, applies a **grading system to the cooling facilities** in packhouses. If the minimum standards are not met, the packhouse may not pack for export. On arrival at the packhouse, if the fruit is not packed immediately, it should be pre-cooled to approximately 16°C in order to remove field heat. Lower temperatures may result in condensation during packing.

Waxing is commonly used for export fruit in order to improve appearance and also to increase shelf-life. The European Union has currently placed a restriction on the use of polyethylene waxes and allows the use of natural waxes only. Kremer-Köhne and Duvenhage (1997) have demonstrated that 'Stafresh', a natural wax emulsion containing shellac and carnauba wax, gave results equivalent to or better than polyethylene wax ("Tag") in terms of physiological disorders, external appearance and shelf-life. Boonyakiet (1997) has also had success in storing avocados under ambient conditions using edible coatings.

Grading is carried out according to local or international standards. The Organisation for Economic Co-operation and Development (OECD) has produced a booklet (Anon. 1995b) giving standards according to cultivar, size, shape, colour and blemishes.

Packaging used will vary according to market requirements. However, adequate ventilation is the basis of being able to hold all the fruit at the correct storage temperature. Ventilation holes should register, i.e. be continuous throughout a pallet stack, and should comprise approximately 8 to 9% of the vertical surface area (Boelema, 1987). Where link-sheets are used to stabilise pallet loads, these must also register with the ventilation holes in the cartons. Boelema (1987) also conludes that a space of 5mm between the fruit and the lid of the carton is desirable. However, the trend today is towards open-top cartons.

Carton markings have now become international practice, where cultivar, class, exporter, country of origin and average fruit mass must be recorded on the carton. Most exporting countries now also use grower codes (in order to monitor potential problems arising from specific producers), packer codes (in order to monitor quality, productivity and accuracy) and date codes. Packing dates or date codes are essential in monitoring the time x temperature chain involved in export of fruit. When sea transport is used, the date of packing should be used for setting cut-off dates after which fruit can not be successfully exported. Date codes are also of vital importance in monitoring the movement of fruit through the marketing chain (see Overseas Technical Officer).

After packing, **fruit temperatures** should be reduced to the final storage temperature as soon as possible, especially if long term storage is required. This is often achieved by placing the cartons in a standard cold room. The refrigeration capacity required in a cold room for cooling of fruit is influenced by the temperature of the fruit entering storage, the throughput of fruit, the ambient temperature and the desired rate of cooling (Hardy *et al.* 1995).

Rapid and uniform cooling can be achieved with forced-air or pressure cooling. An air pressure difference is produced between opposite faces of the pallets, which forces air through the packaging and carries heat away. Watkins and Ledger (1990) report that avocados can be forced-air cooled to storage or transport temperatures in 8 to 12 hours with air flows of 1.0 and 0.5 litres sec^{-1} kg^{-1}, respectively. Faster cooling times are not practical as the pressure drop across the pallet required for higher air flows is very high, and when low temperatures are used early in the season, chilling injury can occur. It should be remembered that the air velocity needed for cooling is greater than that needed for storage, therefore fruit in the cooling room will tend to lose water faster than under storage (Anon, 1997).

Vapour pressure

The rate of moisture loss from avocados is primarily controlled by the difference in vapour pressure between the air in the intercellular spaces of the fruit and the air surrounding it. Vapour pressure increases as the air moisture content and air temperature increase. The air in the fruit is nearly saturated or, in other words, is close to 100 percent relative humidity. Therefore, the humidity ratio of this air is determined solely by the temperature of the fruit. From a psychrometric chart it can be shown that low temperatures result in low humidity ratios and high temperatures cause high humidity ratios. (Kader *et al.* 1985).

The difference in humidity ratio between the air in the fruit and the storage air is significantly more when the fruit is not precooled than when it is cooled and put in unsaturated storage air. Dessication of fruit in refrigerated storage can be reduced by decreasing the difference in humidity ratio between the air in the fruit and the air surrounding it. Both temperature of the fruit and humidity ratio in the surrounding air must therefore be controlled (Kader *et al.* 1985).

Fruit respiration patterns were monitored in response to rates of water loss in Hass avocados by Akkaravessapong *et al.* (1995) who demonstrated that the lower the relative humidity the greater the percentage weight loss and the faster the fruit ripened.

All fruit destined for export is inspected at packhouses in South Africa, using PPECB inspectors. It is their duty to reject consignments of fruit that do not meet the industry-established standards of quality or that have not reached the correct temperature for transport. Fruit destined for export are currently required to have a pulp temperature not exceeding 13°C at the time of packhouse inspection.

Temperature recorders are seen as an essential part of the process of monitoring the cold chain. In South Africa, 'Ryan' recorder instruments are positioned in one pallet out of every ten during palletisation. It is necessary at the outset, to enter the name of the packhouse, the vessel for which the consignment is destined and the pallet number on the chart. The position of the recorder must also be clearly marked in the pallet, for ease of recovery. The Ryan recorder will reflect the air temperature surrounding the fruit at a particular point, and has been found to provide valuable information in cases where the cold chain has been broken. This applies whether the consignment has been sent by sea or air. "Squirrel" data loggers may also be used, the advantage being that they electronically record fruit pulp temperatures at various points in a consignment. Miniaturised data loggers are now also available for this purpose.

Rapid feedback to the Grower / Packer / Exporter of temperature data is essential so that adjustments can be made where necessary.

During road transport to the port or market

The following advice is given to ensure adequate cooling, especially over long distances using road transport (RT) (Eksteen and Robinson, 1996):

Temperature control thermostats must be operating correctly and recording instruments must be functioning accurately. The RT must be set at the correct temperature and be precooled to that temperature for three hours prior to loading the fruit. The temperature-control thermostat should be set to measure delivery air temperature. In the case of top-down cooling sufficient space should be allowed above the load to allow for adequate air circulation. All fruit should be precooled to the required carrying temperature **prior** to loading and at least one pulp temperature per pallet must be recorded during loading. This data should be retained by the transporter for delivery to the receiving depot at the port (Eksteen and Robinson, 1996).

Only RT's with well-insulated and well sealed compartments should be used. Road temperatures can reach more than 80°C and this radiated heat can cause heat build-up in palletised fruit. It is also essential that pallets are aligned in such a way as to allow adequate air-flow through the load.

The Grower should know how his fruit is being handled and has the right to request feedback of temperature data.

<u>At the docks</u>

Road transport loads must be monitored for temperature deviations on arrival at the docks or container-depot. This is generally done by using probe thermometers. However thermocouples placed in fruit in the centre of pallets at the time of palletisation can be used specifically to monitor pulp temperature at possible 'hot-spots' deep within the pallet. Depending on the process involved at the specific harbour, fruit can generally be held under effective cooling in a holding store or container terminal prior to loading aboard a vessel. It should be noted however, that breaks in the cold chain can and do occur during this process. The 'Ryan' or other recorders should facilitate pinpointing of problems of this nature, which can be followed up with the relevant authority. Fruit should not be loaded aboard the vessel unless it is within 0,5°C of the required carrying temperature.

In addition to accurate monitoring of arrival temperatures at the docks, it is essential to record the **age** of fruit (i.e. from the date of packing, based on the date-code). The South African industry has a cut-off date of 12 days after packing. Older fruit will not be allowed for export and must be disposed of on the local market.

It is important for growers to be aware of the time taken for the exporter or agent to get their fruit to the port, as this can significantly affect outturn quality.

<u>During sea transport</u>

Eksteen (1995) has summarised South African recommendations for controlling time and temperature during sea export to Europe. In porthole container vessels it is essential to maintain a continuous record of delivery air temperatures (DAT) and return air temperatures (RAT). DAT's are adjusted according to the differential between DAT's and RAT's. If the RAT is more than 1,5°C higher than the DAT, this is an indication that the cooling process is not coping with the heat generated by the fruit. A downward adjustment of DAT is therefore made. This decision, based on reliable facts, is taken by an industry Temperature Committee, which responds rapidly to data radioed to shore by the ship's engineer on a regular basis. In the case of integral and CA containers, temperature data is not normally available on a day-to-day basis and correct loading temperatures therefore become even more critical.

In studying shipping conditions in terms of age and temperature of fruit in relation to outturn fruit quality, Eksteen *et al.* (1995) showed that fruit firmness decreased with an increase in fruit age, particularly in the case of Fuerte and Edranol, which should therefore not be stored for longer than 25 days. 'Black cold' and 'grey pulp' also increased significantly with time. Although 'black cold' has little or no effect on internal quality, it is strongly rejected by the trade. Lenticel damage increased with fruit age but was also found to correlate with specific growing areas. Deviations in temperature (higher) during loading of sea containers was found to be strongly correlated with fruit softness on arrival. Delays in re-cooling during loading also had a significant effect on fruit firmness on arrival.

Two factors are of great importance here. Firstly, communication and response must be extremely rapid if corrective action is to be taken and secondly, any deviations from the norm must be linked to specific quality outturn on arrival.

Controlled Atmosphere (CA)

Truter and Eksteen (1982) showed that a mixture of 10% CO_2 and 2% O_2 extended the shelf life of Fuerte, Edranol, and Hass avocados while reducing grey pulp and virtually eliminating pulp-spot. However, an increase in anthracnose was observed.

This work was followed up by Truter and Eksteen (1987) who found that a 25% CO_2 shock treatment applied one day after harvest also gave very good results in reducing physiological disorders, without the concomittant increase in anthracnose.

Faubion *et al.* (1992) indicated that Hass avocados could be stored successfully for up to 60 days, using a CA of 5% CO_2 and 2% O_2. Similar results have been obtained with Hass avocados by McLauchlan *et al.* (1992), Jordan and Barker (1992) and Meir *et al.* (1995).

During the 1996 and 1997 seasons, South African exporters resorted to CA export of many sea containers of avocados to Europe, due to the inherent vulnerability of the fruit resulting from excessive rains. The results were monitored by shipping CA and conventional containers from the same sources at the same time, and evaluating them overseas. It was found that in general, both Hass and Fuerte fruit arrived much firmer under CA, with up to a week of extra shelf life. In addition CA fruit had a lower incidence of postharvest diseases such as anthracnose and stem-end rots *(Dothiorella / Colletotrichum* complex). In some cases external cold injury of Fuerte was higher under CA and, as expected, CA was not a cure-all for age-related symptoms such as grey-pulp. Nor did CA have any impact on uneven colouring of Hass (R. Nelson, personal communication, 1997).

Controlled atmosphere containers have less cooling capacity than porthole containers and loading temperature is therefore even more critical (Eksteen, 1997). However, because respiration rates are reduced by CA, and therefore heat of respiration is less, less cooling is required in such containers.

Modified Atmosphere Packaging (MA)

Passive atmosphere modification uses the respiration rates of fruits and vegetables to consume the oxygen and produce carbon dioxide and water vapour in the pack. If the respiration characteristics of the commodity can be accurately matched to the permeability of the film used for packaging, a favourable modified atmosphere can be created passively within the package when an equilibrium concentration between the oxygen and carbon dioxide is reached (Combrink *et al.* 1996).

In a preliminary study, Boon-Long and Achariyaviriya (1994) prepared a mathematical model for determining film-permeability characteristics for the MA storage of tropical fruit.

It is reported that Mission Produce from California has expanded its ability to precondition fruit through a modified atmosphere program. The program allows avocados to remain in storage an additional two weeks. The process requires an extra refrigeration step after fruit is hydrocooled and ripened with ethylene gas. The remaining gases are removed from an airtight carton, which is then kept at a constant temperature of 4,5°C (Anon, 1995a).

<u>On arrival at the discharge port</u>

It is the responsibility of the exporter to ensure that his agent applies the correct procedures at the discharge port. Recooling (using clip-ons, a cold-wall or cold store) must be applied within two hours of unloading, using the same delivery air temperature as that applied by the vessel prior to discharge. Air vents of ducted containers must be kept open during transit to prevent build-up of heat and carbon dioxide (Eksteen and Robinson, 1996).

Ryan recorders or other recording equipment should be retrieved by the importer and the charts returned to the exporter and or packer as soon as possible. This data should then be correlated with fruit quality in the same consignment.

The South African industry makes use of an Overseas Technical Officer (OTO) who is stationed in Europe during the avocado season (April to September). His task is to monitor fruit arrivals and to give feedback on all quality parameters to the exporter / packer. Fruit is evaluated first on arrival and is then held for ripening, at which time a second evaluation is carried out. The following parameters are evaluated using a rating system where relevant:

Exporter	Firmness (using Densimeter, Köhne *et al.*, 1997)
Packer	Black cold
Grower	Brown cold
Container no.	Dusky cold
Vessel no.	Lenticel damage
Ryan recorder(s)	Mechanical damage
Pallet no.	Stem-end rot
Cultivar and count	Anthracnose
Date code	Sooty-mould
Age of fruit	Cercospora spot

On ripening, shelf-life (days to ripen) and internal disorders such as pulp-spot, grey pulp and vascular browning are also recorded. (The colour of Hass skin does not necessarily correspond to its ripeness and fully coloured, rock-hard fruit can sometimes be found on the tree. Ledger and Barker (1995) showed that fruit firmness is a much better indicator of Hass ripeness. If fruit are only sold at the completely black stage, many of the fruit may be overripe and post-harvest diseases will consequently increase significantly).

Cold injury definitions (after B Suter, 1997)

Black cold

A severe early cold injury resulting in shiny, black, sunken lesions with clearly defined edges. It does not penetrate below the skin. This symptom is almost always seen immediately upon arrival of fruit overseas, and is normally associated with a severe cold shock early in the cold chain, eg. in the packhouse cold stores. Such cold injury may also result from the application of too low delivery temperatures on the vessel. Black cold may also continue to develop in cold storage after fruit arrival overseas, although this is rare. All cultivars are affected, in particular Fuerte, Pinkerton and Edranol. Black cold on Pinkerton often results in internal grey pulp development.

Brown cold

A symptom which can be described as a severe, light brown discolouration on the skin of Fuerte (with defined, but not sunken edges). The lenticels remain green and healthy in the midst of a rapidly spreading discolouration. This symptom is rarely seen immediately upon arrival of fruit overseas, although old and soft fruit are more likely to display brown cold. It usually manifests itself as a result of prolonged cold storage after arrival. It may be absent on fruit just removed from cold storage, but can develop extremely rapidly (within less than one hour) once exposed to ambient temperatures. Brown cold is more common on old fruit and excessive moisture loss during transit and cold storage are thought to play a major role in the development of this symptom.

Lenticel or lenti-damage

This symptom is usually seen immediately on arrival of the fruit overseas. It involves severe injury and browning or blackening of the lenticels due to either rough handling of the fruit or too low cold storage temperatures. Fruit is also more likely to develop lenti-damage when picked during and immediately after significant rain. Hass is particularly prone to lenti-damage due to the exposed nature of the lenticels. However, the greenskin cultivars are also affected, particularly during the early part of the season. Prolonged exposure to too low storage temperatures may ultimately result in lenti-damage developing into 'black cold'.

Dusky cold

A faint sooty-brown or black discolouration, associated with cold storage of senescent fruit, especially Fuerte and Edranol. It is often correlated with internal grey pulp symptoms.

The Overseas Technical Officer's data from each consignment is faxed back to the industry office, which in turn distributes the information rapidly to exporters and packers.

These records are of vital importance to all concerned in the export process. If properly evaluated and collated they will show up orchard problems, area deviations, packer problems, shipping problems and seasonal variations. The speed of this feedback can do much to prevent recurrence of specific quality problems.

At the pre-packers / ripening facilities

The average consumer does not want to wait a week before eating the avocados they have bought. There is therefore a major trend in the United States, Australia, the UK, South Africa, and other countries, to pre-ripen or 'trigger' fruit prior to sale. This process is generally carried out by pre-packers or retailers and has become an important part of the marketing chain. However, it is also a potential disaster area where the grower may be penalised with heavy losses due to incorrect handling procedures. Because of increasing softness, pre-ripened fruit will be extremely susceptible to bruising (Arpaia *et al.* 1987).

The role of ethylene in the natural ripening process has already been discussed. However the commercial use of ethylene together with heat, to initiate or trigger ripening is now common. Hofman *et al.* (1997) demonstrated that respiration in Fuerte fruit can be increased by ethylene levels as low as 0.01 μl^{-1} during storage at 10°C. However higher levels (1.0 μl^{-1}) were required to boost respiration rates in Hass fruit held at 8°C, implying a lower level of ethylene sensitivity in this cultivar. In commercial trials carried out at Westfalia Estate in South Africa, waxed fruit was found to respond less evenly to ethylene triggering of fruit, indicating that the wax may serve as a partial barrier to entry of ethylene.

Treatment of commercial consignments with 100 μl^{-1} of ethylene at 20°C for 24 hours is generally regarded as sufficient to trigger fruit for marketing of ready-to-eat fruit (Kader, 1985). The use of non-destructive fruit firmness testers is an important part of this process, to ensure uniformity of ripening, for the benefit of the retailer and the consumer (Mizrach *et al.* 1996, Köhne, 1997, Snaddon, 1997).

It is essential for the grower to ensure that monitoring of the pre-ripening process occurs and that he is given feedback on losses occuring at this stage of the marketing chain. Where necessary, corrective measures can then be taken.

In supermarkets / retail stores

Education of the person or persons who sell to the consumer is of great importance, particularly where ready-to-eat fruit is being sold. Correct handling of sensitive fruit, an understanding of the effects of time and temperature on the fruit and the use of "best-before" or "sell-by" dates, are all part of the education process to ensure that losses do not occur at this penultimate stage of the marketing chain.

For the consumer

Just as is the case for the seller, the consumer must be educated on the correct storage procedures for the fruit they buy, whether rock-hard or ready-to-eat at the time of purchase. However all the education and promotion in the world, will be valueless if the inherent quality and reliability of the product is not there.

Quality: The role of research

Research should be aimed at three main facets:

- Production research
- The commercial process from grower to consumer
- Market research

Production research funded by the South African Avocado Growers' Association, was recently reviewed by Toerien (1997) who showed that for a grower investment **of one dollar** the return, due to implementation of research findings, is **$60.**

The commercial process from grower to consumer includes virtually all the aspects dealt with in this paper. It is the entire process of monitoring, evaluating and reporting on the quality control chain and carrying out the necessary research to solve the problems that are found to occur. This research can be of enormous financial benefit to the grower.

Market research is obviously of vital importance in order to identify what customers want and also in order to determine what customer-education is required.

Conclusion: Quality the role of grower organisations

ISO 9000 and HACCP

This paper covers many of the principles expounded in ISO 9000 and HACCP (Hazard Analysis and Critical Control Points). ISO 9000 can be seen as an internationally accepted, overall quality control system dependent on acceptance of **management responsibility,** effective documentation, entrenchment of quality control systems and regular auditing by accredited auditors, followed by appropriate and documented corrective action.

HACCP is divided into two facets, HA (Hazard Analysis) in which a total flow diagram is produced, identifying the type of hazards (whether physical, chemical or biological) which may impact on the end product; and CCP (Critical Control Points) which includes identification of the critical points in the flow chart at which quality aspects must be monitored to ensure a safe and dependable end-product. Appropriate preventative measures are then documented, applied, monitored and regularly reviewed. The HACCP process is basically the one followed in this paper.

Concluding remarks

Whether you are a member of the Australian Avocado Growers' Federation, the New Zealand Avocado Growers' Association, or Avocado Industry Council, the South African Avocado Growers' Association; whether your association is Chilean, Mexican, Californian or Israeli, it is you the grower who can and should have the greatest impact in ensuring (a) that you grow a good product and (b) that a good product arrives at the consumer. That is what this paper is about. In the end it is you who must ensure that the necessary quality control systems are in place to guarantee that your production and marketing remain profitable now, and into the future.

Acknowledgements

My thanks are due to the organisers of this conference, New Zealand Avocado Growers' Association Inc., and the Australian Avocado Growers' Federation for sponsoring this visit. My thanks also to Mrs S Cloete for her patient and effective word processing, and to Merensky Technological services, under whose auspices this paper was prepared.

References

Akkaravessapong, P., Smith, L.G., Joyce, D.C., Simons, D.H., Horton, I.F., and Beasly, D.R. (1995). Increasing rates of postharvest water loss hasten ripening and alter respiration rates of avocado fruit. *Proceedings of the Australasian postharvest horticulture conference 'Science and technology for the fresh food revolution,'* Melbourne, Australia, 25-28.

Akkaravessapong, P., Joyce, D.C., Simons, D.H., Horton, I.F. (1997). Diurnal water potential changes and avocado fruit ripening. Abstract: Workshop on 'Disease control and storage life extension in fruit,' Chiang Mai, Thailand, 24.

Anon., (1995a). Modified atmosphere packaging extends shelf-life. *Talking Avocados,* 6 (1), 8.

Anon., (1995b). International standardisation of fruit and vegetables: Avocados. Organisation for Economic Co-operation and Development, Paris, 67pp.

Anon., (1997c). Postharvest handling of avocados. *RAP Postharvest Bulletin* No. 6, 8pp.

Arpaia, M.L., Mitchell, F.J., Katz, P.M. and Mayer, G. (1987). Susceptibility of avocado fruit to mechanical damage as influenced by variety, maturity and stage of ripeness. *South African Avocado Growers' Association Yearbook* 10, 149-151, 3.

Bangerth, F. (1979). Calcium related physiological disorders of plants. *Annual Review of Phytopathology,* 17, 97-122.

Bezuidenhout, J.J. (1983). Die voorkoms van mesokarpverkleurings by Fuerte avokado's op die Rungis mark gedurende 1982. *South African Avocado Growers' Association Yearbook* 6, 24-27.

Bezuidenhout, J.J. (1992). Analysis of transit temperature and fruit condition of South African export avocados. *South African Avocado Growers' Association Yearbook* 15, 39-40.

Boon-Long, P., and Achariyaviriya, S. (1994). Mathematical modelling of modified atmosphere conditions. In: Johnson, G.I., and Highley, E. ed. Development of postharvest handling technology for tropical tree fruits: A workshop held in Bangkok, Thailand, July, 1992. ACIAR Proceedings No. 58, 63-67.

Boonyakiet, D. (1997). Performance of bananas and avocados coated with edible coatings under commercial conditions. Abstract: Workshop on disease control and storage life extension in fruit, Chiang Mai, Thailand, 9.

Bower, J.P. and Cutting, J.G.M. (1987). Some factors affecting post-harvest quality in avocado fruit. *South African Avocado Growers' Association Yearbook* 10, 143-145.

Bower, J.P. (1988). Preand postharvest measures for long-term storage of avocados. *South African Avocado Growers' Association Yearbook* 11, 68-71.

Bower, J.P. and Cutting, J.G.M. (1988). Avocado fruit development and ripening physiology. *Horticultural Reviews* 10, 229-271.

Combrinck, J.C. (1996). Integrated management of post-harvest quality. ARC Infruitec, Stellenbosch, South Africa, 146 pp.

Cutting, J.G.M., Wolstenholme, B.N. and Hardy, J. (1992). Increasing relative maturity alters the base mineral composition and phenolic concentration in avocado *(Persea americana Mill.)* Fruit. *South African Avocado Growers' Association Yearbook* 15, 64-67.

Darvas, J.M. (1982). Etiology and control of some fruit diseases of avocado *(Persea americana* Mill.) at Westfalia Estate. D.Sc. (Agric.) Thesis, University of Pretoria, Pretoria, South Africa. 136pp.

Donkin, D.J. and Cutting, J.G.M. (1994). Rind moisture loss the cause of cold damage in harvested avocado fruit? *South African Avocado Growers' Association Yearbook* 17, 28-30.

Donkin, D.J., Mans, C.C., Slabbert, M.J., Levin, J. and Wolstenholme, B.N. (1995). "Stepped down" storage temperature regimes for Fuerte fruit grown in the Kwazulu-Natal midlands: Do they reduce the incidence of physiological disorders? *South African Avocado Growers' Association Yearbook* 18, 89-93.

Eaks, I.L. (1983). Effects of chilling on respiration and ethylene production of Hass avocado fruit at 20°C. *Horticultural Science* 18(2), 235-237.

Eksteen, G.J. and Bester, J.M. (1987). Storage and transport of avocados practical considerations for the South 'African export situation. *South African Avocado Growers' Association Yearbook* 10, 157-159.

Eksteen, G.J. (1995). Handling guidelines for avocado -1995 season. *South African Avocado Growers' Association Yearbook* 18, 111-113.

Eksteen, G.J., Bezuidenhout, J.J., Robinson, R., and Suter, B. (1995). The effect of preshipment factors on the market quality of avocados -1995 season. *Joint report by PPECB, SAAGA and Westfalia.* Cape Town, 29pp.

Eksteen, G.J. and Robinson, R. (1996). Recommended handling procedures for export of avocados by sea. *PPECB Report,* Cape Town, 20pp.

Eksteen, G.J. (1997). Loading pulp temperature: CA containers. *PPECB Circular to All Avocado Exporters.* 4pp.

Embleton, T.W., and Jones, W.W. (1964). Avocado nutrition in California. *Proceedings of Florida State Horticultural Society* 77, 401-405.

Faubion, D.F., Mitchell, F.G., Mayer, G. and Arpaia, M.L. (1992). Response of Hass avocado to postharvest storage in controlled atmosphere conditions. *Proceedings of Second World Avocado Congress,* 467-472.

Fuchs, Y., and Zaubermann, G. (1987). Physiological aspects of delayed ripening of avocado fruit. *South African Avocado Growers' Association Yearbook* 10, 132-135.

Gazit, S and Blumenfeld, A. (1970). Response of mature avocado fruits to ethylene treatments before and after harvest, *Journal of American Horticultural Science* 95, 229-231.

Hardy, J., Finnemore, H.J., Partridge, C. and Joubert, J. *(1995). SAAGA Avocado Exporters' Packing Guide,* Tzaneen, 23pp.

Hofman, P.J., McLauchlan, R.L. and Smith, L.G. (1997). Sensitivity of avocado fruit to ethylene. *Acta Horticulturas* (in press).

Jessup, A.T. (1991). High temperature dip and low temperature storage and disinfestations of avocados. *Hort Science* 26, 1420.

Jordan, R.A. and Barker, L.R. (1992). Controlled atmosphere storage of Hass avocados. *HPG Biennial Review,* QDPI, 4-5.

Kader, Adel A., Kasmire, R.F., Mitchell, F.G., Reid, M.S., Sommer, N.F. and Thompson, J.F. (1985). Postharvest technology of Horticultural Crops. *Co-operative Extension,* University of California, Davis, California, 192 pp.

Köhne, J.S. (1985). Pre-ripening of avocado fruit by postharvest treatment with ethylene. *South African Avocado Growers' Association Yearbook* 8, 81-82.

Köhne, J.S. and Kremer-Köhne, S. (195). Picking Hass avocados without pedicel. *South African Avocado Growers' Association Yearbook,* 18, 66.

Köhne, J.S., Kremer-Köhne, S., and Gay, S.H. (1997). Non-destructive avocado fruit firmness measurement. *Poster: Seventh Annual South African Society for Horticultural Science Congress,* 1997. Nelspruit, South Africa.

Kremer-Köhne, S. And Duvenhage, J.A., (1997). Alternatives to polyethylene wax as postharvest treatment for avocados. *South African Avocado Growers' Association Yearbook,* 20 (in press).

Kruger, F.J. (1996). Pilot study on the respiration patterns of the major South African export avocado cultivars. *South African Avocado Growers' Association Yearbook* 19, 96-99.

Kruger, F.J. and Claasens, V.E. (1997). What went wrong with export avocado physiology during the 1996 season? *South African Avocado Growers' Association Yearbook,* 20 (in press).

Ledger, S., and Barker, L. (1995). Hass skin colour deceives buyers. *Talking Avocados, 6* (1), 26.

Ledger, S.N. and Barker, L.R. (1995). Black avocados the inside story. *Proceedings of the Australian Avocado Growers' Federation Conference "The Way Ahead",* 71-77.

Meir, S., Akerman, M., Fuchs, Y., and Zauberman, G. (1995). Further studies on the controlled atmosphere storage of avocados. *Postharvest Biology and Technology, 5,* 323-330.

Moore-Gordon, C.S., and Wolstenholme, B.N. (1996). The Hass small-fruit problem: Role of physiological stress and its amelioration by mulching. *South African Avocado Growers' Association Yearbook* 19, 82-86.

McLauchlan, R.L., Ledger, S.N. and Barker, L.R. (1992). Simulated export of avocado by sea under controlled atmosphere. *HPG Biennial review,* 1992.

Milne, D.L. (1994). Postharvest handling of avocado, mango, and lychee for export from South Africa, in Champ, B.R., Highley, E. and Johnson, G.I., ed. Postharvest handling of tropical fruits. *Proceedings of an internatonal conference held at Chiang Mai, Thailand,* July, 1993. ACIAR Proceedings No. 50, 73-89.

Mizrach, A., Galli, N., Gan-Mor, S., Flitsanov, U., and Prigozin, I. (1996). Models of ultrasonic parameters to assess avocado properties and shelf life. *Journal of Agricultural Engineering Research,* 65(4), 261-267.

Pesis, E., Fuchs, Y., and Zaubermann, G. (1978). Cellulase activity and fruit softening in avocado. *Plant Physiology* 61,416-419.

Smith, R. (1996). Team avocado: Part of big changes in the New Zealand avocado industry. *Talking Avocados* 7(3), 24.

Snaddon, R.W.L. (1996). Nondestructive firmness testing and sorting of avocados at harvest. Presentation at South African Avocado Growers' Association Marketing Symposium. Nov. 1996.

Starrett, D.A., and Laties, G.G. (1993). Ethylene and wound-induced gene expression in the preclimacteric phase of ripening avocado fruit and mesocarp discs. *Plant Physiology* 103, 227-234.

Suter, B. (1997). Avocado symptom photographs. South African Avocado Growers' Association, Tzaneen, South Africa, 35pp.

Swarts, D.H. (1978). The no-nonsense determination of oil content for avocados. *Citrus and Subtropical Fruit Research Institute Information Bulletin* 41, 4.

Swarts, D.H. (1979). Cold injury in avocados. *Farming in South Africa: Avocado series* 1.3., 2pp.

Swarts, D.H. (1980). Die invloed van abnormale lae temperature op ontwikkeling van koueskade by Fuerte avokado's. *Subtropica* 1 (1) 16-18.

Swarts, D.H. (1980). Fermometer ondersoek by avokado's. *South African Avocado Growers' Association Yearbook* 4, 42-46.

Swarts, D.H. (1982). 'n Nuwe benadering tot die verkoeling van uitvoer avokados. *South African Avocado Growers' Association Yearbook* 4, 42-46.

Tingwa, P.O. and Young, R.E. (1974). The effect of calcium on the ripening of avocado *(Persea americana* Mill.) fruits. J. Amer. Soc. Hort. Sci. 99(6), 540-542.

Toerien, J.C. (1997). SAAGA Research Funding. *Report to South African Avocado Growers' Association Symposium,* 1997, 4pp.

Truter, A.B., and Eksteen, G.J. (1982). Beheerde en gemodifiseerde atmosfeer opberging van avokado's. *South African Avocado Growers' Association Yearbook* 5, 41-46.

Truter, A.B., and Eksteen, G.J. (1987). Controlled and modified atmospheres to extend storage life of avocados. *South African Avocado Growers' Association Yearbook* 10, 151-152.

Van Eyk, J.H. (1994). Die effek van verskillende besproeiingsregimes op opbrengs en vruggrootte in Hass avocado. Voorlopige resultate. *South African Avocado Growers' Association Yearbook* 17, 143-145.

Vorster, L.L., Toerien, J.C. and Bezuidenhout, J.J. (1987). A storage temperature regime for South African export avocados. *South African Avocado Growers' Association Yearbook* 10, 146-148.

Vorster, L.L., Toerien, J.C. and Bezuidenhout, J.J. (1988). The influence of time temperature interaction on the shelf-life and internal quality of avocados. *South African Avocado Growers' Association Yearbook* 11, 61 -64.

Vorster, L.L., Toerien, J.C. and Bezuidenhout, J.J. (1990). Temperature management of avocados an integrated approach. *South African Avocado Growers' Association Yearbook* 13, 43-46.

Vuthapanich, S., Hofman, P., Klieber, A., and Whiley, T. (1995). Improving the marketability of Hass avocado through manipulation of production practices. *Talking Avocados. 6* (1), 26.

Vuthapanich, S. and Hofman, P. J. (1997). Cold storage using lower temperatures. *Talking Avocados.* 8 (1), 23.

Watkins, J.B. and Ledger, S.L. (1990). *Forced Air Cooling, 2nd edn.* Queensland

Department of Primary Industries, Brisbane, Australia, 56pp.
Whiley, A.W. (1994). Ecophysiological studies and tree manipulation for maximisation of yield potential in avocado *(Persea americana* Mill.) Ph.D. Thesis, University of Natal, Pietermaritzburg, South Africa, 174pp.
Woolf, A.B., Watkins, C.B., Bowen, J.H., Lay-Yee, M, Maindonald, J.H. and Ferguson, IB. (1995). Reducing external injury in stored Hass avocados with dry heat treatments. *Journal American Society for Horticultural Science* 120, 1050-1056.
Woolf, A.B., Ball, S., Watkins, C.B., Spooner, K.J., Bowen, J.H., Lay-Yee, M., and Ferguson, I.B. (1996). Postharvest responses of Hass avocados to high temperature treatments an overview from New Zealand. *South African Avocado Growers' Association Yearbook* 19, 8-10.
Zauberman, G., Schiffman-Nadel, M., Yanko, U., Sarig, I. and Alper, I. (1969). Factors causing injury during transportation of avocado pears to packing house. The National and University Institute of Agriculture, The Volcani Institute of Agricultural Research, *Preliminary Report* 705 (Hebrew with English Abstract).
Zaubermann, G., Fuchs, Y., Yanko, V., and Akerman, M. (1988). Response of mature avocado fruit to postharvest ethylene treatment applied immediately after harvest. Hort Science 23, 588-589.
Zaubermann, G., and Jobin-Decor, M.P. (1995). Avocado quality changes in response to low temperature storage. *Postharvest Biology and Technology,* 5, 1235-1243.