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POST HARVEST PHYSIOLOGICAL PROBLEMS OF AVOCADOS

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The dominant factor responsible for keeping quality of the avocado fruit is the genetic characteristic of the specific cultivar. The purist argues that plant breeding is the only way to satisfactorily overcome the numerous post harvest physiological problems. The development of new and successful cultivars is a very slow process and while it should always receive concerted attention it does not lessen the urgent need to continue and even increase research in an effort to counter the numerous post harvest physiological problems.

Optimum keeping quality is not only dependant on the cultivar but also on correct farming practice which encompasses many aspects e.g. soil, rootstocks, health of nursery stock, fertilizers, irrigation, maturity stage at harvesting etc.

Climate and specifically pre-harvest orchard temperatures have been shown to influence post harvest behavior of fruits in some unusual ways. Mellenthin (1966) from the Oregon State University has worked assiduously in this field since the 1960's. While his work was mainly on pears, the techniques he used are worth noting. Of special interest is the development of a portable limb enclosure for temperature modification of tree fruits. (Mellenthin & Bonney, 1972).

Work in the South African avocado industry on the influence of climate on post harvest chilling injury is of great importance and should result in landing firmer fruit on the overseas market. (Swarts, 1982).

Maturity

Picking at the correct stage of maturity is a very important operation in an export chain aimed at landing high quality climacteric fruit on distant markets. There are two aspects that call for attention: (i) prediction of when different stages of maturity are reached and (ii) maturity assessment at harvest time.

Firmness

The measurement of firmness is successfully used as a maturity index for many kinds of fruit. Firmness alone has proved a very reliable index for pears in all pear producing countries. The penetrometer used in the deciduous fruit industry cannot easily be used for avocados even with conical plungers. The firmometer developed by Swarts (1979) is a non-destructive method for measuring pressure. It has been shown to realiably measure softening during ripening and is extensively used in most South African maturity and other avocado post harvest studies. This is a big step forward compared with subjective scoring for softness as used in many post harvest research studies.

The avocado does not ripen on the tree. This was demonstrated by Swarts (1979) where he shows the firmometer reading remained at 18 from January to September. This means that firmness just after harvesting is of limited value. Its value is assessment of softening after the avocado has been held under different conditions from harvesting until ripening.

Oil Concentration

Oil concentration as a maturity index for avocados is used with success in California, South Africa and Israel. In California a minimum value of 8,0% has been promulgated for all cultivars. The use of a single oil concentration for all avocados grown is seriously questioned by Reid (1980). He maintains that the minimum value may lead to some cultivars being unacceptably immature when the quality is judged on organoleptic standards. South African cultivars exported at an oil concentration of 8,0% when ripened did not attain optimum dessert quality and this was cause for concern. (Lund, personal communication).

This investigation on rate of oil concentration development throughout 1980, 81 and 82 showed oil concentration to be a reliable maturity index despite differences in fruit set times. The rate determined per cultivar enabled predictions to be made concerning the date of commencement of harvesting.

Doubt has also been expressed by Smith and Huisman (1982) that a minimum 8,0% oil concentration is acceptable for all cultivars. The high incidence of shrivel and abnormal ripening found in certa in lots of Edranol avocados from some Letaba growers may possibly be due to harvesting at too immature a stage. It is suggested that a minimum concentration of 14,0% oil should be used for Edranol.

Maturity standards in Florida USA

Several studies have been undertaken in Florida USA to find suitable indices for avocado maturity evaluation (Anonymous, 1954). The work by Hatton Harding *et al* (1963) covered a 7 year period and looked at a large number of factors such as fruit dimensions, abscission, seed coat colour, specific gravity, oil content, total soluble solids etc. Picking date, fruit mass and diameter correlation and oil content were found to be reliable avocado maturity indices. The Florida standards are dependant on different minimum mass and diameter specifications set for four periods. These; specifications diminished as the season advanced and are waived after the fourth period. It is then accepted that irrespective of size all the avocados are fully mature.

Exogenous ethylene and maturity

Avocado respiratory investigation in Israel, Zauberman and Fuchs (1973) and California Eaks (1976) led to the finding that the ripening response of the avocado to ethylene applied after harvest may be used as an indication of fruit maturity. Both these studies started with very immature avocados (1,5% oil) and continued until oil concentrations were 21% for Fuerte and 16% for Hass. Both these cultivars were found to reach the mature stage at 10,0% oil.

The ripening response of exogenous ethylene on the respiration curve can however only be looked upon as a research tool.

South African maturity standard

The Republic of South Africa regulation No R 928 of 28 March 1980 (Anonymous, 1980) lay down that Class 1 avocados must be mature and not have more than 80% moist u re but shall be firm and show no signs of softening. Mature is defined as a stage of development of the avocado to a degree ensuring the proper completion of the ripening process. This standard is based on the work done by Swarts (1982). The oil contents derived from the 80% moisture standard are Fuerte 9,8%, Edranol 10,9% and Hass 7,8%. There is little doubt that all these avocado cultivars will soften. The question posed is whether they will all measure up to the definition of mature on the basis of Eaks (1980) C_2H_4 response requirement or Reid's basis which required the attainment of acceptable organoleptic quality. (Reid, 1980).

Dessert quality evaluation

Post-harvest research fruit should be backed up by a dependable taste panel. The factors being measured by panel members are subjective but they must be guided by means of aspects to judge by, like ripeness, palatability, texture and tastiness.

Cut off harvesting date

The acceptable maturity index laid down is largely aimed at deciding on an opening date when the fruit condition is such that it will be able to be delivered to markets in a sound condition and ripen evenly after retail marketing. It is important to have knowledge of the harvesting quality in relation to harvesting date. A study undertaken during 1982 (Smith, 1982) on external and internal quality analysis of avocados during simulated export conditions showed that the incidence of grey pulp tended to increase the longer the fruit from 3 to 4 cultivars remained on the tree. With vascular browning the increased incidence in relation to tree storage time was found for two out of four cultivars.

Another factor which differs according to tree storage time is the ripening rate of the avocado. Swarts (1979) showed the earlier the fruit was picked the longer the shelf life.

The Fuerte avocados harvested in February and held at 20ºC required 15 days to ripen where as the August harvested fruit was edible after 6 days. When the fruit was exported the February fruit ripened in 9 days while the September crop was edible after 3 days at 20ºC. These findings are confirmed by Eaks and Zauberman & Fuchs (1972).

A rapid ripening time means a short shelf life. This and the fact that late harvested fruit tends to be more susceptible to both physiological disorders and fungal decay means that consideration should be given to limiting the time that the fruit is stored on the tree. This could be done by laying down a maximum oil concentration per cultivar.

Regional Laboratories

The determination for date commencement and ending of harvesting will obviously differ from areas as well as for individual farms and even groves. The ideal is to have regional laboratories run by the industry or co-operatives. This system has been developed in the apple industry and is in operation on a commercial scale in the USA Olsen 1982. A regional laboratory has been developed in the South African Apple Industry (Eksteen, personal communication). It has been in operation for two seasons and while it has already been of much value to the industry a further season or two is necessary for fixed opening and closing harvesting dates to be laid down. The laboratory is run by the South African Apple Producers Organization but has the full co-operation of the Department of Agriculture Fruit Research Institute and the Deciduous Fruit Board. The rates of change of the various important physiological and chemical changes are monitored at regular intervals and the dates for commencement and closing dates determined.

Samples are also stored simulating sea shipment or for long storage. This operation provides valuable seasonal data. Reference to the USDA's work reported in Florida and the FFTRI's information bulletin on determination of apple maturity is valuable in assessing the possible establishment of a similar facility for the avocado industry. (Olsen, 1982).

Shipping temperature

Once an avocado has been harvested at the correct maturity it must be rapidly cooled, held at the optimum storage temperature and shipped in the appropriate transport to arrive at the market in a sound and attractive condition.

The avocado, like many other sub-tropical fruits is subject to chilling injury when held at temperatures approaching zero ºC. Wardlow (1 939) in Florida USA determined that 5,5ºC was a good compromise temperature for avocados as it provided three weeks storage with an acceptable amount of chilling injury.

The earliest storage work in South Africa was by Boyes (1953). His work was done on avocados grown at Bien Donne near Paarl. His findings agreed closely with those of Wardlow (1939). Swarts(1979) reported that 7,0ºC was a maximum shipping temperature that could be used but that softening of the fruit en route to overseas markets was a serious hazard at this temperature, and also recommended 5,5ºC. Swarts in 1982 reported that the chilling injury temperature parameters changed as the season advanced. He found that the avocado became less susceptible as the temperature in the avocado groves dropped to below 17,0ºC for several hours two to three days before harvesting.

This work by Swarts (1979) was enlarged on by Smith and Lunt (1984). Their recommendations were that if the night temperatures were below 17ºC for 5 hours or less and the oil content was 16,0% or less a safe storage temperature would be 6, 5°C. When the night temperature is below 17ºC for 10 hours and more a storage temperature of 5,5ºC is considered safe. The shipping temperature can be dropped to 4, 5ºC when the number of hours below 17ºC is 15 and the oil content 20% and more. This information has been put into practice on a small scale. While a shipping temperature of 7,0ºC early in the season may be regarded as relatively safe there was feed back during 1 984 that some of the fruit showed signs of softening. This could be linked with a seasonal effect.

The answer to overcome this problem is to utilize the temperature tolerance to chilling injury findings determined by Swarts (1980) which established the avocado could be at 5^{o}C, 4^{o}C, 3^{o}C and 2^{o}C for 3, 2, 1 and ½ days respectively without a danger that chilling injury would develop. The fruit at 7,0^{o}C could therefore be lowered to 5,0^{o}C about 7 days from the port of discharge. The 7 days period permits two days for a gradual lowering of the temperature to 5,0^{o}C.

Personal communication with Lunt in 1984 was that further work on the relationship between night temperature and susceptibility of the avocado to chilling injury was required. The present results were based on two seasons work and the more extensive study (Smith & Lunt, 1984) was only done on fruit grown on dry land and in a season of low rainfall.

Precooling

The success of storage of avocados is based on the rapid removal of the field temperature from the fruit and then holding the fruit at the optimum storage temperature. The rapid removal of the field heat is termed pre-cooling. The technique of pressure cooling developed by Guillo, Mitchel & Parsons (1972) resulted in speeding up of the rate of cooling and ensuring an even temperature distribution throughout a stack. It is used on a large scale for pre-cool mg of fruit and vegetables prior to transport. The avocado temperatures of many consignments en route to Cape Town have in the past been found to be above the required 5,5ºC with many instances with maximum fruit temperatures at 9,0ºC and even higher at the time of shipping Ginsburg (1984). In a very recent unpublished report to the DFB, Bester (1 984) stresses that the ships refrigeration capacity is designed for storage and excess capacity is limited in most ships refrigeration systems. This means that all the fruit exported on pallets must be at the required shipping temperature when loaded into the container. The major function of the ships refrigeration system is to hold a temperature and not to pre-cool. The use of pressure cooling was introduced into the cold storage facilities of some avocado packing sheds. A very disturbing result was reported on the quality of avocados when subjected to very rapid cooling by means of pressure cooling Slabbert &Toerien (1984). The increased rate of cooling increased the severity of the chilling injury. It did not lead to any increase in any of the other post harvest physiological disorders. This finding has led to a return to *a* passive cooling (room cooling) system for the pre-cooling operation.

Passive cooling means a lower rate of cooling but also a greater temperature difference between the external and internal position in the pallets. Slower cooling and different fruit temperatures in the stack leads to softening en route and uneven ripening at the retail point. Both these aspects are problems that call for attention. The authors of this paper on rate of cooling do stress the need for more research in this field. Facilities must be available to measure water gauge pressures between outer and inner faces of the stack, the air speeds etc. It is important to find parameters such as delivery temperature and air speed, carton design and stacking patterns to allow pressure cooling to be used with safety.

Cooling on board ship

Without doubt the carriage of fruit provides the biggest challenge to the carrier to maintain temperatures within prescribed limits. It is often forgotten that in any store whether fixed or mobile, there is a temperature range dependant upon heat leakage, heat production, and rate of air circulation.

There has been little progress to date in the control of relative humidity in ship's spaces. It has therefore been left to the packaging engineers to produce a micro climate within this fruit carton to minimize weight loss and utilize the partial effects of a form of modified atmosphere. The other main contributor to variation in product temperature is the individual fruit wrap. One also has the construction of the carton whether of the flap type or telescopic or whether or not it is ventilated.

More recently the use of palletisation for the carriage of fruit has given rise to problems where fruit is loaded above carrying temperatures. Inevitably when loading pallets on both conventional refrigerated ships and containers, there is a high air by-pass factor. The stacking of cartons to ensure a stable stow inhibits the passage of air around the outside of individual cartons unless deliberate spaces are left.

The in register stow is best for this purpose but suffers from lack of stability even when strapped. However, it should not be concluded that carriage of fruit on pallets is always difficult. Given effective precooling and prompt transfer of pallet to containers and ship's spaces, subsequent refrigeration temperatures can be held within close limits. It is important to recognize that temperature gradients will exist in cargoes and that the minimum fruit temperature is indicated by and dependant on the minimum delivery air temperature. Maximum fruit temperatures will in general be higher than the return air temperature and this should be recognized.

Respiration and ethylene

Respiration and the effect of ethylene is a subject that has been widely investigated in most important avocado producing countries. Much of this work is of a basic nature and deals with a physiological process that influences the storage life and subsequent ripening process of the fruit. The frequent reports of avocados softening during sea and land transport and even sometimes in air freighted fruit stresses the need to investigate respiration behavior and the accumulation of ethylene and its effect on ripening at different temperatures.

Work done in this field in South Africa has been more along the lines of spot tests and involved the addition of ethylene to avocados during storage as well as the iinfluence of ethylene (C_2H_4) absorbents during storage. No marked differences between the treated and the control samples were found. (Eksteen personal communication). These tests were looked at as side issues at the time and little monitoring of ethylene concentrations were recorded.

In Israel ripening was found to respond more readily to ethylene when the C_2H_4 was applied two days after harvesting compared with application soon after harvesting. The ripening influence was less effective the more mature the stored fruit was. The investigation reported by Eaks (1983) though planned specifically to investigate the influence of chilling respiration and ethylene production, provides interesting effects on the respiration rates of Hass after storage for 0, 2, 4 and 6 weeks at 10,0^{o}C, 5,0^{o}C and 0^{o}C and then ripened at 20^{o}C. The performance after storage at 10,0^{o}C and 5,0^{o}C is of special importance from a South African shipping point of view. From the respiration curves it is seen that the climacteric minimum point was reached before the end of 14 days storage at 10^{o}C. These avocados were then held at 20^{o}C and were fully ripe after 4 days at this temperature. At 5^{o}C the fruit was still in pre-climacteric stage for 4 days before the increase in the respiration rate started and the climacteric peak was reached after 6 days at 20^{o}C. Storage at 5°C for 4 and 6 weeks resulted in slight injury at 5^{o}C for storage for 4 weeks. This was recognized by a rubbery texture. Chilling injury was scored as moderate after 6 weeks storage.

This paper confirms earlier work by Eaks (1976). The basic information provided by respiration curves for storage at 10^{o}C should be looked at in conjunction with the results represented in histograms concerning the temperatures at different stages throughout the export of life from commencement of cooling until the fruit was discharged from the containers on the overseas markets. (Toerien, personal communication).

The greatly improved maintenance of the cold chain was reflected in an improved outturn condition of the avocados.

Ethylene absorption

The work done on ethylene absorption during avocado storage was of a spot nature. No gas analyses were done to either check whether ethylene was present in the storage atmosphere or to check whether the use of the absorbent reduced the level of ethylene.

There is enough experimental work done that conclusively proves that the presence of exogenous ethylene in the storage atmosphere does increase the rate of respiration and hastens the ripening rate of stored mature avocados. The converse must also be true; viz. the removal of ethylene from the storage atmosphere must increase the storage life.

Further evidence to support this statement is the prolongation of the storage life of avocados when stored at sub-atmospheric atmospheres. Storage at 6,0°C at 60 mm mercury (HG) pressure compared with 760mm HG pressure more than doubled the storage period.

The inhibition of ripening was due both to the lower oxygen content which is known to reduce the rate of respiration and the removal of ethylene from the intercellular air spaces and tissue of the fruit. This does not mean shipment in hypobaric containers is recommended as the costs of such containers is very high. It does however stress the need to look for effective methods for removal of ethylene.

A very efficient method for ethylene has been developed in England and commercial units are available. It is similar to the catalytic converters used in automobiles for the cleansing of the exhaust gasses from internal petrol engines. The ethylene level stores where the atmosphere is passed over such catalysts was found to be at or below 0,25 ppm. This does enable storage trials to be done at very low levels of ethylene.

Physiological disorders

Physiological disorders are influenced by pre-harvest factors and also by the length of time from harvesting to consumption. The time between harvesting and marketing for sea shipments require 30 to 50 days and sometimes even longer. This is far in excess of the time needed by the other avocado producing countries. The avocado is a climacteric fruit and has a respiration rate far higher than found in other fruit. It is twice that of bananas and 7 times that of apples. The long shipping time and the fact that it is a sub-tropical fruit possibly accounts for the complex post harvest physiological disorders met with.

The first problem is not directly linked with the fruit but is one of terminology for all fruit disorders. Local terminology misleads others working in the same field. Calcium deficiency was recognized to be responsible for Baldwin spot. Very few initially realized that Baldwin spot was really bitter pit in Baldwin apples grown in Canada. Much time could have been gained in solving the bitter pit problem had other workers realized that it was due to a calcium deficiency in apples. The necessity for using an internationally recognized terminology for avocado storage disorders was stressed by Swarts (1984). His plea to all avocado post-harvest experts to talk the same language should not go unheeded. It is however essential that extreme care must be exercised before changing terminology. Certain disorders may well be inappropriately named but if they are accepted on an international basis it is advisable to use that terminology. The term chilling injury is a good example.

Chilling injury

Chilling injury is the internationally accepted term for injury to fruit cold stored at temperatures above their frozen point often by as much as 5^oC to 13^oC. The name clearly spells out the difference between chilling and freezing injury. It is the terminology used in America, Israel, Australia and almost all fruit producing countries. Me Glasson (1979) at a plenary session of the International Congress of Refrigeration in Venice devoted much of his time in his paper on storage of tropical and sub-tropical fruits to chilling injury. Different forms of chilling injury occur in most fruits that are stored for several weeks and longer. In citrus rind stain and rind pitting occur in oranges, in apples, superficial scald, core flush (brown core in USA), soft scald and internal breakdown. There are different kinds of chilling injury. In avocados there are two forms viz. pulp spot and skin and pulp discoloration with the pulp discoloration becoming more intense when subjected to anaerobic conditions. (Van Lelyveld & Bower, 1984).

Pulp spot

The first symptoms of pulp spot are noticed soon after the fruit is cut. The spots are initially smooth and glassy of 1,0 mm in diameter and occur along the vascular bundle. The spots discolor after being exposed to the atmosphere and are generally brown to dark brown within 30 minutes. The severity of pulp spot varies from season to season and the incidence drops rapidly as the season advances (Swarts, 1984). This is possibly due to the fact that avocados are able to withstand storage better at lower temperatures as the season advances (Smith & Lunt, 1984).

Calcium content and pulp spot

Work done at Westfalia Estate showed that fruit with pulp spot injury had a much lower calcium content (69,3 ppm) compared with fruit with sound tissue (Ca 319 ppm). This is indicative that the calcium content does play a big role in pulp spot susceptibility. The lower calcium concentrations found later in the season and the statement that pulp spot is less as the season advances does not quite marry up. This statement must be weighed against the ability of the avocado to withstand storage at lower temperatures later in the season.

Controlled atmosphere storage and pulp spot control

Controlled atmosphere (CA) storage for 33 days at 5,5ºC resulted in elimination of pulp spot in an atmosphere of 10,0% CO_2 2,0%O_2 and 88% N_2. The high CO_2 is an important element in this control. The value of this treatment is at present negated by the increased incidence of anthracnose that results under CA storage conditions. It can also become of commercial significance when CA facilities can be introduced on ships and provided this will be at an economical viable freight rate.

CO_2 Shock treatment

Results both at the FFTRI and Westfalia Estate have shown that an initial shock treatment with high concentration of CO_2 for up to 6 days noticeably diminished pulp spot and other physiological disorders without adversely affecting the quality of the avocados.

Improved calcium content

The results of calcium content show low Ca values are associated with pulp susceptible avocados. Methods to increase the Ca uptake both in the grove and after harvesting have been investigated but as no noticeable Ca increase was achieved the value of such a treatment has not been established.

FUTURE RESEARCH 1.

Maturity cut off date

It has been proved that the respiration climacteric is delayed by keeping the fruit on the tree. Ripening, softening and other maturation processes only take place after picking. It has also been proved that these processes take place at an accelerated rate the longer the fruit stayed on the tree before picking. This means that both the cold storage and shelf life steadily decrease later in the picking season. On the other hand it may be beneficial to delay picking rather than to over store optimum picked fruit.

During both procedures quality losses take place and physiological disorders (grey spot, pulp spot, vascular browning etc) and fungal decay (especially anthracnose) increase. It is therefore of the utmost importance also to deter mi net he cut-off harvesting date for the different cultivars. This calls for intensive studies on after storage fruit quality as related to picking maturity. Because other factors may also affect quality, these studies must be done to cover all the major production areas and climatic conditions that may be experienced during the harvesting season. Parameters should be worked out to predict storage potential as the season progresses.

2. Calcium effects

Calcium plays a very important role in the stabilization of cell walls and membranes. The more calcium in the cells the more resistant the tissue to certain physiological disorders. The effects of calcium on the incidence of pulp spot, vascular browning and other disorders should be studied to lay down minimum calcium levels for optimum storage life and quality.

Although the calcium status of the tree and fruit can be improved by foliar sprays, methods should be developed to increase calcium uptake by the leaves and translocation to the fruit without spray damage. Optimum application rates and application time should also be investigated.

Foliar application of calcium is not always the ideal method of increased fruit calcium content. Factors affecting soil application, calcium uptake by the roots as affected by cultural practices and soil types should be thoroughly investigated before commercial recommendation can be made.

3. Carbon dioxide shock treatment

Avocado fruit are climacteric and therefore presents a sharp rise in respiration activity immediately prior to ripening. If respiration can be inhibited, ripening can be postponed or slowed down. Initial results proved that high levels of carbon dioxide (CO_2) can reduce respiration, extend storage and shelf life and improve fruit quality.

Basic information on time and concentration tolerances is still lacking and these studies must continue. Special attention should also be given to carbon monoxide in the atmosphere.

Shock treatments with CO_2 under commercial transport and shipping conditions should be studied. This calls for a team effort because a number of organizations may be involved. The best seems to treat the fruit en route from the production point to Cape Town, but treatment at the packhouse may give more accurate control and less variation in quality.

Controlled atmosphere (CA) storage was proved to benefit quality, but methods should be developed to apply this system on board ship if proved to be practical and passable.

4. Soil effects

Mineral nutrition plays a very important role in the growth and development of any fruit. This also determines fruit quality and storage life. A number of nutrient elements are of importance and also the balances of these elements in relation to each other. High fruit nitrogen leads to soft fruit and low calcium may result in physiological disorders.

It is important to study the uptake and translocation of especially the macro elements. This is affected by a number of factors such as soil type, fertilization and irrigation practices, rootstocks, and phytophthora and crop size. All these factors must be studied and optimum regimes for maximum quality determined.

5. Cultivars

Theoretically all the post-harvest physiological disorders can be controlled by breeding resistant cultivars. Although this is the viewpoint of the purists, much can be done to improve available cultivars. Apart from a well planned breeding programme, all growers must be on the look out for mutations on existing trees.

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