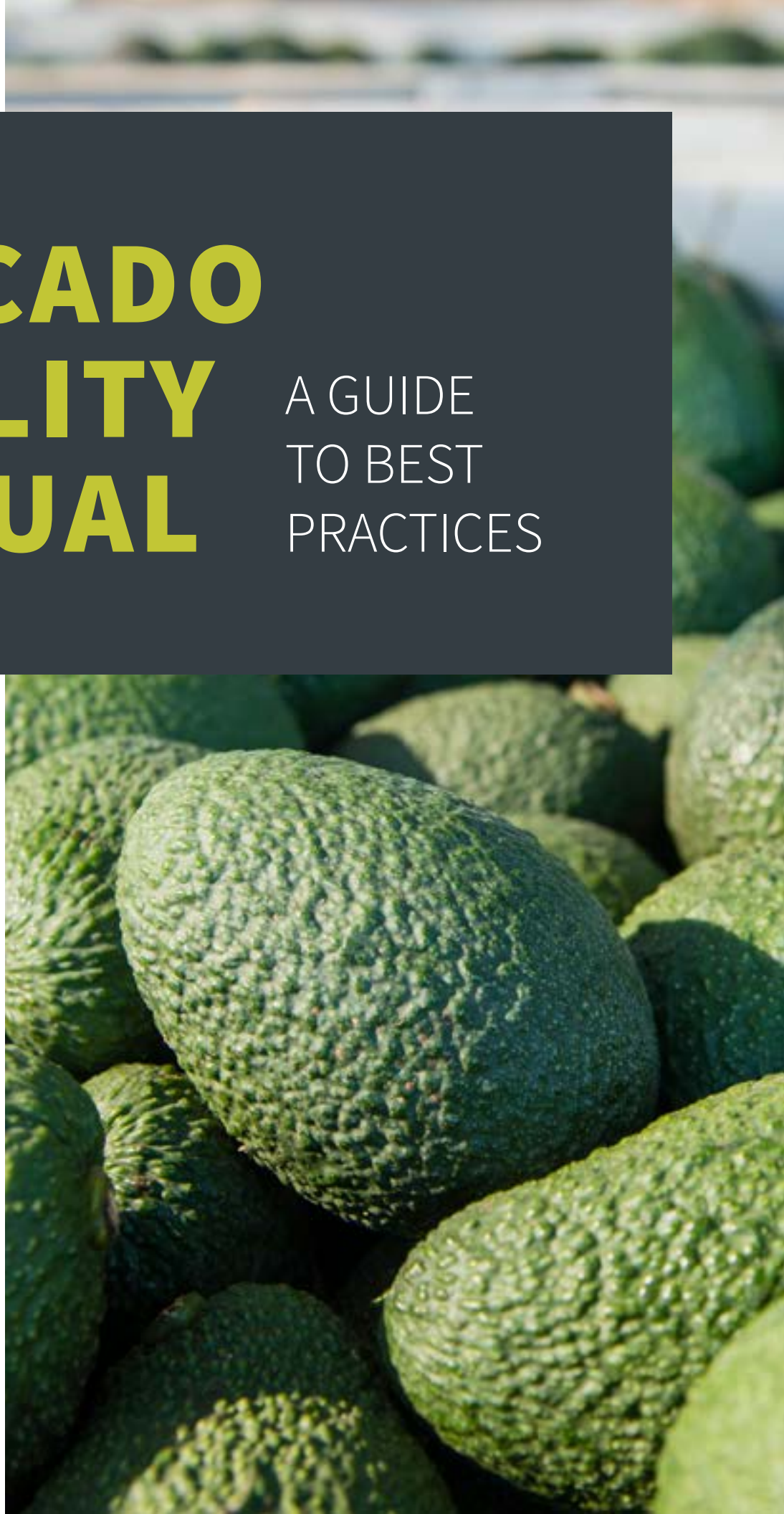
AVOCADO QUALITY MANUAL

A GUIDE TO BEST PRACTICES



HASS AVOCADO BOARD

ABOUT THIS MANUAL

To maximize avocado returns for growers, packers, shippers, processors and final sales outlets, fruit needs to be supplied to the consumer with both internal and external quality acceptable to the consumer. Fruit needs to be handled throughout the supply chain to maintain external defects at the level within tolerance set by the market standards and expectations, and internal defects at the lowest possible level.

The supply chain within the USA is complex, and depends on the fruit origin (Californian produced and packed or imported), and final destination as well as intended use of the fruit (food service, processing or fresh, pre-ripened or not) has tremendous impact on how fruit is handled or should be handled in the chain. In addition, the physiology of the fruit changes with increasing maturity, and therefore will react differently within the supply chain. In order to deliver fruit at final destination with the quality desired by the market, it is necessary to handle the fruit through the supply chain in the manner which is best for that particular fruit, within the constraints of practicality. This includes adherence to legal and quality management protocols such as the Food Safety Modernization Act (FSMA) and Hazard Analysis and Critical Control Point (HACCP).

The intention of this manual is to assist operators within each of the supply chain steps to choose protocols which are appropriate for the fruit origin, maturity level, destination and intended sales format. However, it is also very important to note that the overall quality of the fruit at final sales point is dependent on multiple steps within the supply chain. Each step has an influence on the quality. It is therefore not sufficient to only consider protocols and parameters within each sector of the supply chain. The entire supply chain should be seen in a holistic manner, taking into account the actions at any one point on the other components of the chain.

As temperature is the most critical aspect of the supply chain in relation to fruit quality, this will be a major focus of protocols, but will need to be interpreted with other storage, handling, and transport protocols at each step.

A fruit quality management system does not only consider protocols to implement within the supply chain, but also management of the entire system. This requires adherence to a number of factors to be successful. The most notable are:

- A total management acceptance of the need for an integrated quality management system. This philosophy needs to be accepted for all parts of the supply chain, including packing houses, transport companies, distribution centers, processors and re-packers as well as final retail sales points, though the main focus of the supply chain participants should be one step back and one step forward from their position in the chain. The management of each individual sector needs to appreciate the required quality parameters of fruit on arrival, and protocols to implement to maintain the required quality until the next step in the supply chain. Any deviations need to be fed both back and forward so that appropriate actions can be taken. The critical specifications for each consignment that are required at any point in the supply chain need to be known, and the parameters need to be known not only by management, but also by operational staff, otherwise defects will not be recognized.

- Potential hazards, or causes of protocol defects should be considered ahead of time and remedial actions specified.
- Management needs to have a plan of action in place should any protocols be found to be incorrect or quality parameters not in accordance with specifications.
- The plan of action needs to specify actions to prevent a recurrence of the problem if possible, as well as planned courses of action to take to both remedy, or at least minimize the current issue at hand and to notify the proper participants in the supply chain of the discovered breach.
- Staff training is of the utmost importance. Operational staff need to appreciate the need for maintaining the desired quality specifications, and the need to apply required protocols, as well as reporting and remedial actions should any consignments be found to not be within specification. This requires some understanding of the avocado fruit as a product, the need to adhere to certain protocols and the implications of not adhering to the required protocols and specifications. A lack of adequate understanding of the product and the implication of handling practices at the operational level can nullify otherwise good intentions to maintain good fruit handling practices.
- It is essential to the success of any fruit handling system, especially one as complex as the avocado packing, shipping and marketing to different retail outlets and in different final sales forms across the USA, to have a well-developed record keeping and tracking system that not only flags any deviations to protocols or specifications, but also triggers action to be taken. Every staff member of all sections of the supply chain needs to know what to report, how to report and to whom to report.
- The entire operation, from packing a consignment to final sale, needs to be coordinated. This will be discussed further under the section concerning packing houses.

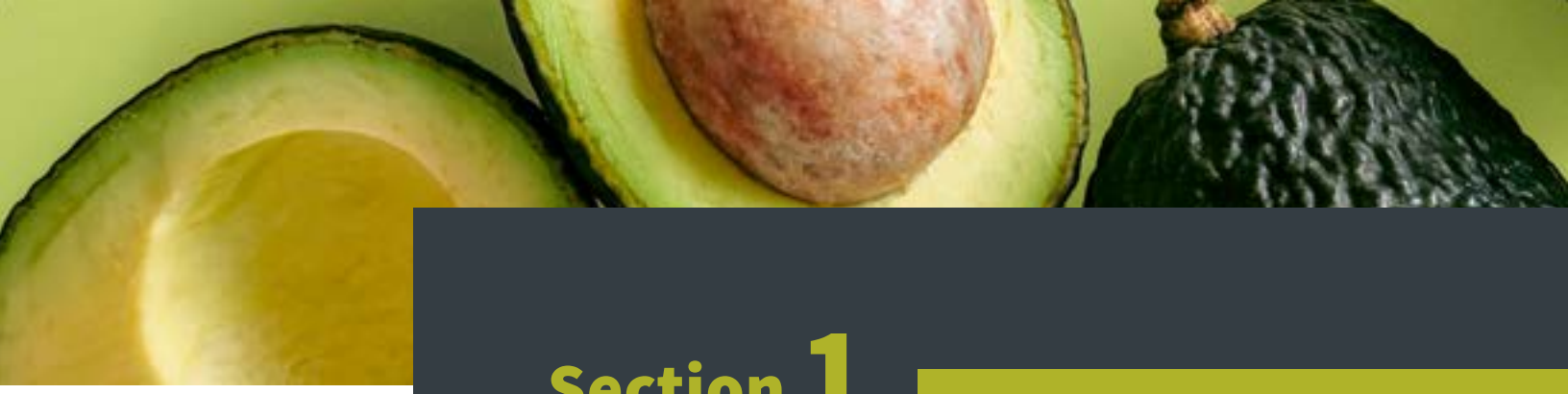
HOW TO USE THIS MANUAL

There are many choices that can be made in the handling protocols of avocado fruit, as well as numerous steps in the supply chain. The layout of the manual is based on each step in the supply chain, so that operators within that step can easily access suggested protocols. The manual also uses the principles embedded in quality management systems such as ISO systems, where each step in the supply chain takes account of the previous operations as well as the following operations, and is able to flag and feed back and forward any quality non-conformity.

The manual is not designed to replace detailed packing house operations protocols or the protocols required for food safety certifications or specialized market place certifications, but could be used to aid these requirements. The purpose of the manual is to flag and emphasize issues of particular importance to the maintenance of fruit quality through the entire distribution chain, so that operators can include critical aspects in their own detailed operations protocols. It will also help to remove ambiguity, where different companies may be using different protocols within the same distribution chain.

Where specific defects are noted, causes and potential mitigating treatments are included as an aid to identifying deficiencies and taking remedial action within the supply chain.

Our gratitude to Dr. John Bower for providing the technical writing for this manual.



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PACKING HOUSE CALIFORNIA

HARVESTING AND TRANSPORT TO THE PACKING HOUSE

Although the harvesting of fruit is not a direct packing house operation, it is sometimes controlled by the packing house. In some instances, picking teams are operated by the packing house, and in most instances the decision to pick as well as what fruit to pick (complete crop or only certain sizes), and how much to pick per day is dictated by the packing house which needs to plan packing on the basis of incoming fruit, capacity and customer demands. The packing house therefore does have a role to play in harvesting.

In addition to playing a role in overall delivery of fruit for packing, which affects the through-put of the packing operation, the eventual fruit quality can be considerably affected by fruit attributes at the time of harvest, as well as the harvest process.

Although fruit from Californian packing houses is mostly for internal USA consumption, and even the longest shipping distances to the East Coast are not longer than a few days, storage potential for marketing purposes and ripening physiology are nevertheless important. Certain quality aspects can be determined prior to harvest which may indicate potential for storage, the risk of chilling damage, shelf life and ripening physiology.

It has been shown that an analysis of fruit mineral constituents, especially nitrogen and calcium, is a useful tool to predict post-harvest shelf life, as well as possible development of internal disorders such as grey pulp, and resistance to chilling injury. It would be a good idea to have analysis from early in the season to the time of picking, to see the trends in changes as well as actual levels. However, an analysis for each orchard at least one month before minimum maturity is advised. Levels of nitrogen at less than 1% and showing a decreasing trend, plus calcium at 0.05% or higher, would indicate good quality fruit. Using this information, packing houses are able to determine risk for internal or external disorders, as well

as shelf life and ripening behavior. Lower calcium will cause faster ripening, higher ethylene evolution, higher fruit respiration and therefore higher risks for quality defects. These factors can be included in the packing house marketing and distribution plans, with higher risk fruit going to closer markets, short storage periods or food service where fruit are to be ripened and used within a short time.

At certain times of the year, and in certain orchards, especially in cool coastal areas, fog or rain may be present at the time of picking. This leads to fruit having a high turgidity, and the lenticels may be very easily damaged during picking and transport to the packing house. This leads to lenticel damage resulting in black spots on the fruit surface after packing. If fruit are to be stored for some time, the areas of damage may appear similar to chilling damage. These areas of the fruit surface appear to become more sensitive to low temperatures. Wherever possible, do not pick wet fruit. It is also advisable to cease irrigation at least one day prior to harvesting.

There is also the probability that weather conditions can be very hot and dry at the time of harvesting. While it is not practical to stop picking on such days, the high temperatures and low relative humidity will affect fruit quality and shelf life by increasing post-harvest water loss and maintaining high fruit respiration. The Q10 principle implies that for every 10 degrees increase in temperature fruit shelf life halves. If it can be arranged, picking during cooler times of day or even at night, can substantially help decrease the effects of hot and dry conditions. Fruit should also be kept as cool as possible, and transported to the packing house as soon as possible.

The picking operation is very important, and the first point in the supply chain where fruit damage can occur. Packing houses should check the protocols of picking companies to ensure that fruit will incur as little damage as possible. If packing houses are responsible for picking, it is essential that good protocols and supervision of the picking operations is undertaken.

Pickers need to be trained to handle the fruit very carefully, and understand the consequences if fruit is damaged. Finger nails of all pickers need to be cut very short, as finger nails can easily damage fruit. When placing fruit in picking bags, it must not be rubbed against the side of the bag and must be placed carefully in the bag. No fruit should be allowed to fall on the ground, and any fruit that does must not be included.

When emptying the fruit from the picking bag into the bulk bin, fruit must be placed carefully so that as little damage as possible is done. The supervisor needs to keep a check of this.

In order to decrease the potential of stem end rot, the picking clippers should be cleaned with a sterilizing compound at regular intervals. When a picker empties the picking bag is a good time to do this.

On arrival in the orchard, the bulk bins must be checked that they are clean and free of sand, leaves or any branches. There should be a soft, sponge base in the bins. The bins must be placed on a wooden pallet when delivered to the field. This is to stop sand accumulating on the base, which will fall into other bins and damage fruit when the bins are loaded for transport to the packing house. Sand in the bins will also fall onto the pack line when the fruit is dumped, and will cause damage to the fruit. The same arrangement will be needed at areas where the bins may be accumulated before transport to the packing house. While bins are being filled, as well as when waiting for transport to the packing house, they should be placed in the shade or under a shade structure if large numbers are to be accumulated before transport to the packing house. When full, the bins can also be covered to keep fruit out of direct sun. For convenience, the cover can be the same as used in the bottom of the bin.

Full bins should be transported to the packing house as soon as possible, especially if conditions are hot and dry. For good fruit quality the fruit should lose as little water as possible after harvest. Only if conditions are cold and wet, should bins be left in the orchard for more than a few hours. In the latter case, if it is necessary to pick, fruit can stand in the orchard to lose some turgidity before transporting them, to decrease the chance of lenticel damage.

It is expected that once harvested, fruit will be transported to the packing house, graded and packed in accordance with the individual packing house protocols and market requirements. Thereafter, pallets need to be cooled or pre-cooled prior to transport. This is a critical component of the supply chain, and is therefore included in the manual.

The temperature for the cooling protocol is chosen based on fruit maturity and market intentions.

MATURITY DETERMINATION

Fruit maturity is based on dry matter of the fruit. The dry matter is determined using the method outlined in the California Food and Agriculture Code of Regulations Article 11 Avocados section 1408.3. The minimum dry matter is taken as 20.8%, and in addition fruit size, fruit weight and date of release is imposed.

However, although the Agricultural Code of Regulations forms the legal basis for measuring the dry matter of avocados, and helps to define the minimum starting date for harvest, it alone does not necessarily provide the information needed for best practices leading to ideal fruit quality in all markets.

LOGISTICS PLANNING AS RELATED TO DRY MATTER

Packing houses need to be aware of the maturity of fruit on a fruit size basis as well as the variability, especially near the start of the season, for each consignment of fruit arriving from the field. This is especially important where packing houses are packing fruit from a number of producers with variable tree age and condition. This is particularly important for making decisions concerning fruit cooling and for marketing to determine the optimal shipping destination. Therefore, it is recommended that on arrival at the packing house, if the dry matter of the consignment is not already known, samples should be taken and tested. These results will help to determine the correct temperature for cooling the fruit as well as shipping.

When planning packing for the following week, it is helpful if the packing house makes arrangements to receive fruit in batches of similar dry matter to enable as much consistency as possible within pallets for cooling in each cooling chamber. It is very important to try as best possible, not to have mixed maturity fruit within a box, pallet or consignment. The ripening characteristics will be different, and mixed maturities will result in checker board ripening if within a box, and create great difficulties for correct choice of cooling, as well as downstream for fruit ripeners, re-packers and within the retail sector. The objective of pre-planning as described, is to decrease errors in choosing suitable cooling regimes, as well as ensuring as uniform a pack as possible. If the fruit packed is very variable in maturity, a higher incidence of mixed ripening will occur, which creates considerable problems at retail level and if fruit is to be pre-ripened before sale.

THE PACK LINE

There are many different combinations of equipment on the pack line, with variations in washing, brushing, drying, grading and packing. There is no single best practice. However, it is essential to ensure that minimal fruit damage occurs on the pack line. Because of the generally rough nature of Hass fruit (compared to most other avocado cultivars) the potential for damage, and in particular, lenticel damage, is high. Damaged lenticels cause increased water loss, as well as result in notable blemish at destination. In addition, it is possible that damaged lenticels will increase the possibility of chilling damage.

It is suggested that the pack line be regularly checked for the potential to damage fruit. Each section of the line should be checked separately, to isolate any areas causing damage. Fruit can be removed from the line and carefully checked for damage. Another very simple technique, is to wrap a number of fruit in thin aluminum foil, and place them on the pack line amongst other fruit. At the end of each section (for example brushes) remove the fruit from the line and inspect for any damage of the aluminum foil. Damage is a good indication of a problem within that section. See also section on packing house cleaning.

FRUIT COOLING

Dump

Wash

Grade

Sticker

Pack

Stack

Fruit cooling is probably the most important operation within the logistics chain, as this sets the parameters for fruit quality, by being the major controller of fruit physiological changes from harvest to sale. This will dictate the rate of ripening, as well as shelf life, and influence the potential for post-harvest defects. The cooling parameters set at packing, as well as the degree to which these have been effectively implemented, are critical to the success of the entire cold chain.

The temperature to which fruit is to be cooled depends on:

- Dry matter
- Distance to destination
- Potential storage requirement
- Picking season, early or late for the particular fruit origin

Based on dry matter, approximate temperatures are:

- Dry matter < 23% use 45°F
- Dry matter 23-26% use 42°F
- Dry matter >26% use 40°F but as dry matter approaches 30% this can be decreased to 39°F. Late season high dry matter fruit with a short supply chain including fruit from Mexico may be shipped at a temperature as low as 38°F

Do not adjust low dry matter fruit (<23%) or early season fruit to a lower temperature than stated above, as chilling damage may occur in fruit stored for longer than 2 weeks. At low dry matter the temperature indicated will not result in premature ripening provided there are no significant cold chain breaks. The closer the market or shorter the intended storage period, the more flexibility there is for cooling fruit to a slightly higher temperature than those shown.

There are three potential cooling points in the packing house cooling operations.

REMOVAL OF FIELD HEAT ON ARRIVAL AT PACKING HOUSE

The first point is on arrival of fruit from the field. Packing houses have different operations at this point. However, it is necessary to ensure that the time between arrival and final cooling is as short as possible. The faster that field heat can be removed the better the potential for extended shelf life and the slower the subsequent quality deterioration. Packing houses have a number of options for temperature control of fruit on arrival.

- Picking bins or boxes are off loaded into a holding area before moving into the packing house. The holding area is simply a shaded area. This is the least satisfactory situation, as field heat is not substantially removed before final cooling, and a cooling delay of up to 24 hours is often recorded, especially during peak packing periods. For best practice, fruit should be moved into the packing house as soon as possible, and not longer than 24 hours.
- A cooled area. The temperature of this area is best at approximately 56°F to 59°F.
- Some packing houses use hydro cooling of fruit as soon after arrival as possible. Fruit are best hydro cooled to a temperature of 56°F to 59°F. Fruit should be packed as soon as possible after hydro cooling or held in a temperature controlled area at approximately the same temperature as stated above. If fruit are hydro cooled, precautions are needed to ensure the water which is re- circulated is clean and free of potential pathogens. This would constitute a Hazard Analysis and Critical Control Point (HACCP). Fruit should be moved into the packing house for packing or stored at the same temperature as target fruit temperature after hydro cooling.

The most effective packing house entry point cooling system is hydro cooling.

Fruit should not be held for more than 24 hours in any system before final cooling.

FORCED AIR COOLING AFTER PACKING

The second point of cooling is after packing and palletization. The purpose of this cooling point is to cool fruit to the temperature of shipping.

When loading pallets into forced air cooling chambers, ensure that as far as possible, only the same box type are loaded, because the air flow characteristics may otherwise differ, and cooling will not be even. Also ensure that there are no gaps between pallets within each pallet row (normally two rows of pallets with a tunnel or plenum between them approximately the width of a pallet), and have an even number and height of pallets as far as possible. If there are incomplete pallets due to a lack of boxes of a size at the end of the packing day, it is probably preferable to cool these rather than leaving them for another 24 hrs. before cooling. However, these pallets should be almost complete, and placed at the back (cold tunnel door side) of the line of pallets, so as to disrupt air flow as little as possible. To ensure that air is pulled through the pallets, ensure that the top and back (door end) of the pallets is adequately covered by a tarpaulin, so that air is pulled by the fan only horizontally through the sides of the pallets.

Do not attempt to cool too rapidly, as wind chill damage may occur on the surface of the fruit. As a guide, it is likely that cooling will take approximately 7 or more hours for 20 pallets, although the starting temperature of the fruit will greatly influence this. Sufficient temperature sensors should be placed in the fruit pulp both inside the rows of pallets and outside, at the front, center and back of the row of pallets to monitor the cooling, so as to ensure that pulp temperature reaches the desired point within all pallets. An approximate guide to the air flow rate required is 1 l sec^{-1} kg^{-1}. However, this is only a guide and the actual air flow rate will depend on both the design of the cooling equipment and the type of packing material used for the fruit, with some boxes having greater air flow through them than others. The change in pulp temperature of the fruit should be monitored. The rate of cooling between the back and front of the pallet rows will differ slightly, so the sensors will not reach the objective temperature at exactly the same time, but the cooling rate is correct when all sensors reach the set objective temperature at approximately the same time. It is particularly important that some sensors do not show a temperature considerably below the set temperature, as chilling damage may then occur to some of the fruit. This would be an indication that the rate of cooling is too rapid. It is also particularly useful to check the differential as well as rate of temperature change between fruit on the outside and inside of pallets. If fruit temperature on one side of a pallet is considerably different to the other, and one side is decreasing much more rapidly than the other, it is a good sign that air flow is too rapid. This could lead to chilling damage on one side of the pallets or inadequate cooling on the other. Air flow rate should then be decreased. When setting the air delivery temperature, do not set the temperature lower than 1°F (0.5°C) below the intended target fruit pulp temperature. It is particularly useful to also monitor external fruit temperature.

This can be done using an infrared thermometer, and fruit at positions similar to the pulp temperature measurements should be used. Again, the external temperatures should not decrease substantially below set temperature, otherwise chilling damage can occur. To ensure that cooling throughout the pallets has been adequate, both external (outside of the pallet) and internal (the side of the pallet facing into the plenum) should show similar fruit pulp temperatures, and that both are close to the set temperature. A variation of 1°F (0.5°C) is acceptable. Further, fruit pulp temperature will tend to be 0.5°F to 1°F (0.28°C to 0.5°C) above the set temperature.

When running the forced air cooling unit, it is preferable to always maintain the air flow in the same direction. If air flow is reversed after a number of hours to obtain the same fruit temperature on the inside and outside of the pallets, there is the possibility that fruit in the center of the pallets is not adequately cooled, without the operator realizing it.

In order to decrease the potential for fruit dehydration during cooling, which in turn will affect the rate of ripening, shelf life and external appearance, the cooling chambers should be humidified. This can be done by applying water through humidifiers attached to the heat exchanger unit, or by ensuring the floor of the cooling chamber is wet before starting the cooling cycle. It is not sufficient to just monitor cooling chamber humidity and assume that an ideal relative humidity reading of 85-95% is correct. The air loses water when it passes over the cooling coils, and this may then be replaced by water loss from the fruit, providing a false reading. The fruit contained in 20 pallets can lose as much as 20 gallons of water during a cooling cycle. Therefore, this needs to be added to the room to prevent excessive water loss from the fruit.

STORAGE AFTER COOLING

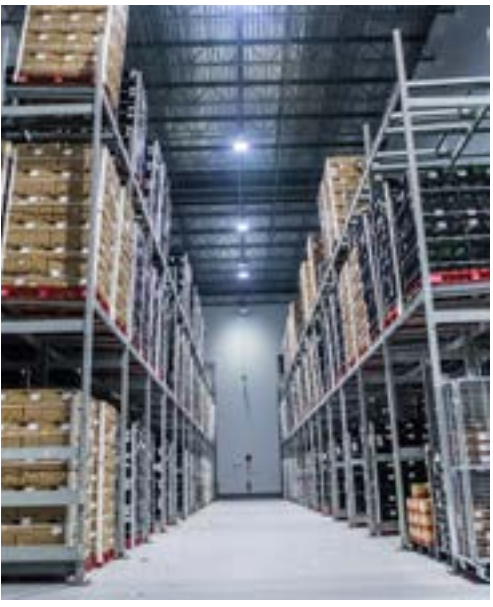
Fruit will need to be stored after cooling until shipment. The cold rooms used for storage should be set at the intended shipping temperature, and fruit stored for the shortest time possible before shipping, taking into account logistics and marketing considerations. This holding room cold area is not suitable as a fruit cooling zone, and fruit needs to be adequately cooled in forced air cooling tunnels before being placed in the cold storage chambers. The cooling in this area is static cooling, and there is a possibility that fruit on the inside of pallets will not be adequately cooled if not already cooled when placed in the holding room.

The ideal holding room will have a pre-installed stacking system where pallets may be stacked and are separated sufficiently to allow air flow between them. If not, pallets should be placed in the cold room in such a way that sufficient air flow surrounds them. A minimum of 4 inches should be maintained between pallets. The cooling system fans should be placed such that there is an even air flow throughout the room.

Air delivery in the holding room should not be set at more than 2°F (1°C) below the target fruit pulp temperature. This is particularly important when the cold room contains fruit awaiting shipment which is less mature and was pre-cooled to a temperature higher than new fruit coming into the room. For a short overlap period, the higher temperature should be used. Air temperature should be checked on a daily basis, and fruit temperatures checked on a random basis to ensure target temperatures are being maintained.

As in the cooling tunnels, the holding room should be humidified. The same specifications and procedures as outlined for cooling tunnels can be used.

Before dispatch, pallets should be marked, or suitable documentation provided with the consignment, to indicate the desired temperature at which to transport and store the fruit. This will be especially useful in ensuring the fruit is handled downstream in the manner desired.



VENTILATION OF COLD ROOM AND COOLING TUNNELS

With constant usage over a number of months, there is a possibility that the carbon dioxide and possibly ethylene levels within cold rooms and cooling tunnels could increase. It is also a common practice for packing houses to hold quality control samples. These also become a source of ethylene. Ethylene build up in particular is problematic as it affects the shelf life and quality of avocado fruit. All cooling tunnels, as well as cold room storage areas and fruit transfer zones should be regularly checked (at least once per week) for buildup of gasses. Ethylene levels should not be detected. This becomes more critical later in the season when fruit is more mature and at peak times during the season when cold stores tend to be storing more fruit before dispatch.

In the case of ethylene, ethylene scrubbers are available, and are used in some packing houses to aid in ensuring there is no ethylene build-up. Regular venting of free air should also be undertaken to prevent a buildup of gasses, especially ethylene. If ethylene scrubbers are installed, it does not remove the need to vent the area with fresh air. Venting with fresh air should be done for 15 to 20 minutes with fans running. Depending on volumes of fruit moving through the cooling and holding areas, this may be needed at intervals between 2 and 6 days. Approximately 3 to 4 air volume changes may be needed to ensure gas build-up is eliminated.

To prevent rapid build-up of gasses as described, no internal combustion engine equipment should be operated in or near cold rooms. Trucks delivering fruit or at the loading docks to be loaded with cooled fruit should not be running when the loading dock doors are opened, and sufficient time after truck engines are stopped should be allowed for gas emissions to disperse.

PACKING HOUSE CLEANING

It is essential that the entire packing house, cooling tunnels, cold rooms and all packing house machinery and equipment be maintained in good condition and cleaned on a regular basis. In particular, two issues are of importance.

The first relates particularly to aspects which could damage the fruit surface, often causing lenticel damage, such as sand, leaves and deposits which form on rollers and belts in the pack line. While every effort should be made to limit the introduction of such components, it is inevitable that some field originating matter will be introduced to the packing house with the fruit. General cleaning should take place after every operational shift. Constant moving of fruit over brushes, rollers and belts, results in wax build-up (from fruit surfaces) on pack line equipment. It is particularly important that brushes be cleaned regularly, as they can become important sources of abrasion and fruit damage. The pack line should be inspected for such deposits and any defects such as broken padding on drop plates or corners, which can damage fruit, on a regular basis. A general inspection should be done daily, with a more careful inspection and cleaning if required, at least once per week.

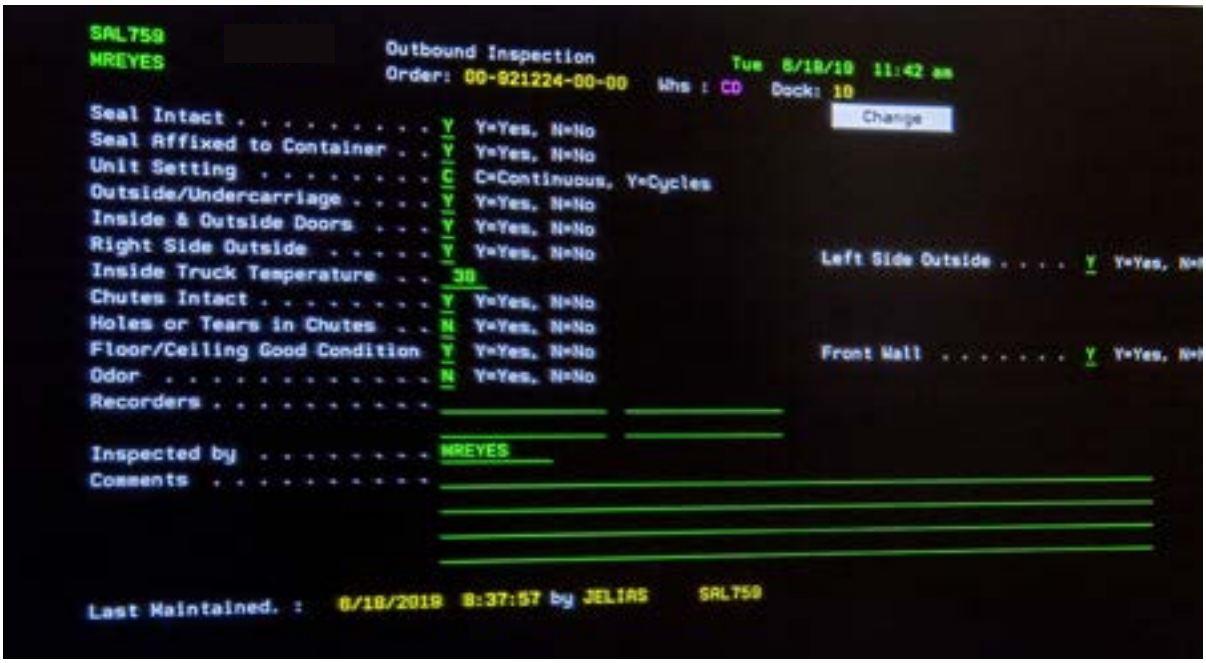
The second issue of importance relates to sanitation, and is particularly important where high humidity conditions (such as cooling tunnels and cold rooms) are present, or water is applied such as hydro cooling (if used) or fruit washing. Suitable sanitizing products should be added to any applied water for cooling or washing, and re-cycled water should be filtered to ensure not only good sanitation, but the removal of potentially abrasive particulate matter. High humidity areas such as cooling tunnels and cold rooms must be regularly cleaned with a suitable sanitizing compound.

TRANSPORT TRUCK LOADING

Correct loading of transport trucks is essential to ensure the cold chain is not broken, both at initial loading of the fruit and at the time of unloading, especially if fruit is to be unloaded at more than one destination. This aspect is discussed under the packing house section, because the operation sets the parameters for the entire transport operation.

Transport trucks should be positioned at the loading dock such that there is a good seal between the open truck and the loading dock, to minimize loss of cold air from the cold room or pallet warming during loading.

Before loading, the truck must be checked for cleanliness and operational correctness (readiness for operation) in accordance with product safety regulations. It is also essential that the truck is already cooled to the correct shipping temperature. Incorrect temperature at loading will be difficult to rectify without compromising fruit temperature.



Before loading, pallets should be checked for correct fruit pulp shipping temperature. A single fruit half way up a pallet can be used for this purpose. A hand held digital thermometer can be used, with a fruit probe inserted into the pulp of the fruit. Ideally, the position should be marked, so that the same fruit can be used for future temperature checks. The probe should be sterilized with a sterilizing agent after each reading. A temperature record needs to be kept. Fruit should not be loaded if temperature is not within the target temperature (+1°F or 0.5°C) unless approval is obtained. The temperature devices must have the calibrations checked at regular intervals to ensure correctness. Such measurements and records are essential to ensure temperature management is correct at the time of loading, and ensures correct responsibility for product care during all sectors of the logistics chain.

Pallets should be loaded such that the last pallets scheduled to be delivered at destination are the first to be loaded, to ensure as little cold chain break as possible at destination. Pallets should also be loaded such that there are no gaps between them, to ensure adequate air movement of cold air through the pallets.

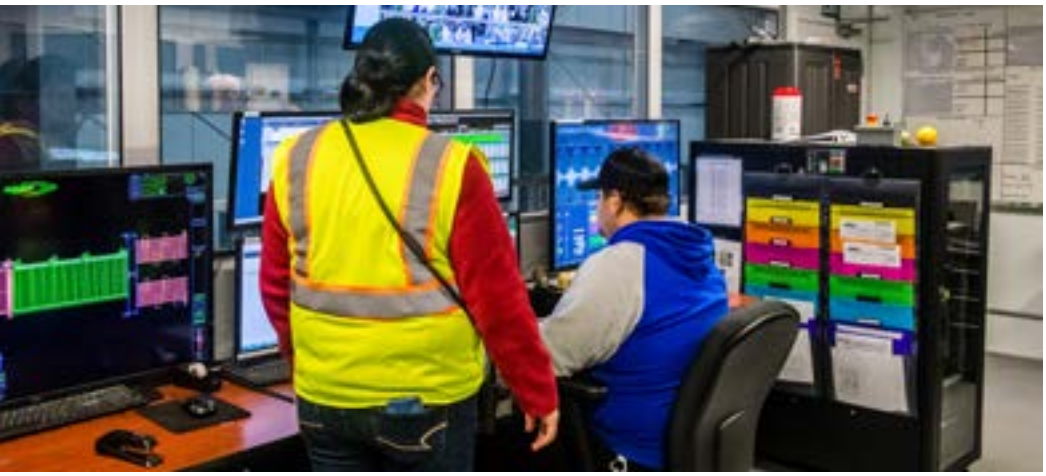
At loading, temperature tracking devices need to be inserted into boxes of pallets at the front and rear at least, of the truck. Ideally, if there is more than one consignment of fruit to be delivered (more than one destination), temperature tracking devices should be included in each consignment. The reason for this is that failure in the cold chain may occur at various points down stream, and if only one destination point is tracked, failures may occur at other points in pallets going to a different destination, without being tracked.

The type of temperature recorder used is of importance with regards to the reliability and usefulness of information collected. While a minimum requirement could be considered to be a recorder which requires removal at some point and downloading of data, with subsequent reporting of any out of protocol information, the usefulness relies on the timely actions of downstream operators, essentially at the final delivery point of the fruit. Fruit may be destined for an intermediate point, such as a regional distribution center, before further delivery. The net result of this, is that any deviations from protocol which may occur may only be found long after the event, making timely remedial action difficult or impossible. The alternative, is the use of a real-time tracking device, which can be checked by the packing house until final delivery point is reached. This allows for timely remedial action to be taken should a deviation from protocol be noted. It also allows timely checking of transport progress. At least one such device should be included in each consignment. In terms of fruit quality management, such devices allow for active temperature management and cost effectiveness.

ADMINISTRATION OF QUALITY MANAGEMENT AT PACKING HOUSE LEVEL

The packing house, as initial handler of the fruit and the entity that packs and prepares fruit with knowledge of fruit initial quality and final intended destination, should be responsible for setting protocol parameters, and tracking progress through the supply chain. Suitable check points and documentation where appropriate need to be implemented by packing house management. It is necessary for a successful quality management program that the entire distribution chain be coordinated, and the packing house is the ideal place for this, as they have contact with all components of the chain, including producers and marketers. Appropriate instructions for all parts of the logistics chain should be generated, and a copy should accompany each fruit consignment. These instructions could be linked to or attached to the bill of lading, which would make them part of the carrier contract.

It is therefore suggested that the entire quality management operation for each consignment of fruit from a packing house be controlled and monitored by a quality management specialist at the packing house.



ROLE OF CALIFORNIAN PACKING HOUSES AND IMPORTER RECEIVING FACILITIES IN RELATION TO IMPORTED FRUIT

There are some instances where packing houses in California as well as receiving facilities belonging to importers act as a distribution hub for imported fruit. The quality protocols for distribution hubs as well as those for packing houses (where appropriate) should be used.

ROLE OF CALIFORNIAN PACKING HOUSES AND IMPORTER RECEIVING FACILITIES AS RE-PACKERS

Some Californian packing houses as well as receiving facilities belonging to importers may act as re-packers for fruit from other origins than the normal fruit packed by them on the pack line in the case of packing houses, or from multiple origins in the case of importers. The quality protocols relating to re-packers as well as the packing houses themselves should be used.

ACTION ITEMS

PACKING HOUSE CALIFORNIA

- ☐ Ensure all staff members are sufficiently trained for the task as well as overall packing house objectives
- ☐ Determine dry matter and maturity level for all consignments and size categories
- ☐ Take into account field origin of fruit and fruit quality aspects e.g. fruit nitrogen and calcium concentrations
- ☐ Plan the logistics
- ☐ Determine cooling, holding and shipping temperatures
- ☐ Ensure cooling rates are appropriate
- ☐ Load cooling tunnel to ensure even cooling at appropriate rate
- ☐ Store fruit until shipment at appropriate temperature
- ☐ Check that transport conforms to requirements and temperature is correct
- ☐ Load transport to ensure temperatures are maintained
- ☐ Add temperature tracing device to fruit
- ☐ Regularly check cooling tunnels and holding rooms are ventilated and that there is no build-up of gases especially ethylene
- ☐ Check packing house equipment for cleanliness, areas of potential fruit damage and sanitize where necessary
- ☐ Track progress of each consignment, including fruit temperature
- ☐ Take appropriate actions for any items out of protocol

PACKING HOUSES OUTSIDE CALIFORNIA

The majority of Hass avocado fruit sold in the USA originates in countries other than the USA. The quality of this fruit at the point of final sale is to a large extent dependent on the entire logistics chain from field through packing house, shipment to the USA and finally within the distribution chain in the USA. It is therefore useful to consider the operations of packing houses within the major supplier countries to the USA market.

Section 1 of this manual considered handling protocols from picking to fruit departure from a Californian packing house. The majority of these protocols are generic and based on preserving the physiological integrity of the fruit, so as to create the best possible shelf life and defect free quality at final point of sale. These protocols can thus be used in any packing house, and should be referred to for any fruit origin. However, fruit from different origins may be physiologically different due to different climatic conditions during the growing season, and the shipping time and conditions from packing house to the port of arrival in the USA. Because of these differences between major suppliers to the USA, the issues of particular importance will differ. Issues of note for packing houses in Mexico, Peru and Chile are therefore outlined, to be considered in addition to the generic handling practices in section 1.

MEXICO

Mexico is in the unique position that there are a number of flowering periods (as many as four, known as flora loca, advanced, normal and marceña which span a period from summer through winter), which together with altitude differences in the major production areas, make it possible to pick and pack throughout the year. However, this also means that many packing houses will have fruit delivered from both the same and different producers which is of differing physiological maturity. This makes it more difficult to pack a consistent product and to decide on appropriate cooling and shipping temperatures. Climatically, the season, with particular emphasis on the rainfall pattern, considerably changes through the year, and with it the sensitivity of the fruit to post harvest defects such as lenticel damage and chilling injury. The following issues are highlighted as important quality affecting protocols to consider:

Harvesting

Due to the changing maturity conditions of fruit as well as weather conditions, a number of factors relating to final fruit quality should be taken into account.

The first is the effect of mixed maturities, especially notable when the fruit of one flowering period is coming to an end (with high maturity) and fruit of the next flowering period (low maturity) are picked at the same time, because fruit size is similar. If this fruit is mixed on the pack line and packed together, not only will the choice of cooling temperature likely be incorrect for some of the fruit, it is well known that checkerboard ripening is likely to occur at final destination. This is of particular problem to fruit ripeners. The best way to separate this fruit is, where possible, to start at the harvest point. Fruit harvest contractors should train the pickers to separate obviously different fruit set groups (such as can be seen by the most mature fruit starting to change color while less mature fruit is still green).

The second issue pertains to picking during periods of cold and wet weather. These conditions increase the potential for lenticel damage and as a result possible increased sensitivity to cold damage. Where it is possible, do not pick in the rain or when fruit is wet. If possible delay picking until fruit is dry, or if it is not possible to do this, delay transporting fruit to the packing house for a few hours to allow the fruit to lose some water and become less turgid and therefore less susceptible to damage during packing.

The third factor relates to the effect of leaving fruit on the trees for extended periods. It is more likely that fruit will have increased cosmetic damage, possibly decreasing packed quality as well as percentage pack-out.

Arrival at Packing House

Due to phytosanitary regulations, fruit must be delivered to the packing house and immediately stored in a holding area surrounded by and separated from the packing house entry by insect proof screens. These need to be regularly checked for damage. It is essential that the Mexican/USDA work plan (as related to article 82 of the phytosanitary regulations as signed on 17 March 2011) be vigorously followed.

If it is cold and wet, or the fruit arrives wet due to rain, it should be allowed to dry and stand for a number of hours to become less turgid before packing, to decrease the risk of lenticel damage.

The fruit arrival area should at least be shaded to reduce fruit temperature, and ideally should be cooled. If cooling is possible, a temperature of approximately 15°C (59°F) would be suitable.

If fruit of different maturities is present, dry matter testing should be done separately for each maturity so as to optimize later handling, especially cooling. Sufficient sampling needs to be done to ensure results are representative of the fruit being packed. Hand Held Near Infrared (NIR) equipment may allow for rapid non-destructive testing.

Pack Line

Where possible, fruit of similar maturity should be packed, so that low maturity and high maturity fruit is not mixed in the same boxes. If separation at picking has been done, fruit can be dumped onto the pack line in accordance with the separation. If not, it is desirable to separate such fruit on the pack line such that the different maturities end up in different pallets which where possible can be cooled differently and even sent to different markets. Where possible, more mature fruit should be sent to closer, southern USA markets while less mature fruit with a longer potential shelf life, to more distant northern USA markets.

ACTION ITEMS

PACKING HOUSES OUTSIDE CALIFORNIA

MEXICO

- ☐ Separate fruit from different flowering periods at harvest if possible or on the pack line.
- ☐ Avoid where possible picking wet fruit or allow to wait a few hours before transporting to packing house.
- ☐ Allow cold and wet fruit to dry before packing. Do not let fruit wait more than 24 hours before packing.
- ☐ The fruit arrival area should be at least shaded, and preferably cooled.
- ☐ Ensure that phytosanitary protection mechanisms are always in place.
- ☐ Avoid wherever possible, mixed maturities in both the boxes and in the same pallets.
- ☐ Treat fruit in accordance with the maturity of that fruit wherever possible.

PERU

The climatic conditions under which the majority of Peruvian fruit is produced are considerably different to most other production areas of the world. The desert climate with no or almost no rainfall is moderated by sea breezes from the Pacific ocean. During winter (picking season), these sea breezes cause heavy fog to move in over the adjacent land resulting in cool and damp conditions, and wet fruit.

The net result of these climatic conditions is that the fruit develops a very rough skin texture and lenticels which are easily damaged. The cool and damp conditions also result in very turgid fruit if picked when still wet, increasing the potential for damage during transport to the packing house and on the pack line. If lenticels are damaged, dehydration of the lenticel area can cause small black spots, which may also enlarge to form larger black spot areas after chilling and may be deemed to be chilling damage. These symptoms may be considerably decreased by careful pre-harvest conditioning, harvest and handling in the packing house.

Harvesting

Prior to harvest, especially during periods when cool, cloudy and morning fog conditions are common, irrigation should be decreased so that fruit loses some turgidity and are therefore less likely to be damaged. Irrigation should be decreased or stopped from one to two days before harvest. If the block to be harvested requires a number of days to harvest, a decreased irrigation schedule can be used until the harvest of the block is complete.

If fruit is wet due to cold foggy conditions, then where possible, harvesting should be delayed until fruit has dried. If this is not possible, then extreme care needs to be taken not to damage fruit. This can include leaving fruit in the orchard or at assembly areas for a number of hours before transport to the packing house. Fruit must be shaded during this period.

Arrival at Packing House

On arrival at the packing house, fruit should be placed in a holding area, where it may be left for not longer than 24 hours. Some fruit water loss to make the lenticels less susceptible to damage on the pack line, especially during periods of cool foggy weather is advantageous.

Ideally, the holding area should be cooled so that fruit respiration decreases. The holding temperature may be between 10°C and 15°C (50°F to 59°F) depending on environmental temperature, with the lower temperature applicable to colder environmental temperatures. This will help extend shelf life. It will also help fruit acclimatize to the lower temperatures which will be applied during cooling after packing. To control the rate of water loss, the area should ideally also be humidified.

Pack Line

The greatest problem on the pack line relates to lenticel damage. Care should be taken to eliminate as far as possible all points of potential lenticel damage. The most likely points of damage are at fruit dumping on the line and in the washing and drying section of the line. Brushes within this section are the most likely cause of damage, and should be kept to the minimum.

Containerization

The same general requirements as previously described for truck loading should be adhered to.

In addition to this, all shipping containers departing Peru for the USA use a controlled atmosphere system. A number of different systems are available. In all cases after all pallets are loaded, a plastic curtain needs to be applied at the door end of the container to ensure the container is sealed. Correct fitting is essential for operation of the controlled atmosphere system. There may also need to be other specific actions depending on container type, and packing houses need to check the requirements and certify completion.

The controlled atmosphere gas settings vary slightly depending on container type used and packing house preference. There is presently no clear data to determine if any concentrations are superior in terms of final fruit quality. The choices generally used are:

- 5% O2 and 5% CO2
- 4% O2 and 6% CO2

However, some companies use other combinations within the range of O2 at 5% to 12% and CO2 at 6% to 10%.

ACTION ITEMS

PACKING HOUSES OUTSIDE CALIFORNIA

PERU

- ☐ Decrease irrigation prior to harvest.
- ☐ Where possible avoid harvesting cold and wet fruit.
- ☐ If harvest is required during cool and foggy periods allow fruit to stand for a few hours before transporting to the Packing house.
- ☐ Allow fruit to stand at the packing house for not longer than 24 hours with some water loss allowed to decrease turgidity.
- ☐ Preferably cool the holding area to 10°C and 15°C and humidify to control water loss.
- ☐ Eliminate as far as possible potential lenticel damage areas on the pack line such as during fruit dumping and washing and drying.
- ☐ Load containers correctly in accordance with CA requirements pertaining to the CA system being used.
- ☐ Set CA gas conditions in accordance with required protocols relevant to the CA system being used.

CHILE

In Chile, production occurs in a number of regions, many characterized by hot and dry summer inland valleys. Some production also occurs in milder coastal areas. Due to climatic conditions during fruit development, part of the crop is harvested during the hot and dry summer period. This requires special consideration during harvesting up to final fruit cooling.

Due to the distance from market, controlled atmosphere shipping is also used.

Harvesting

High temperature and very dry conditions during part of the fruit harvesting period require that care be taken to keep the fruit as cool as possible until arrival at the packing house. Picking bins need to be placed in the shade, and when full covered to keep the fruit out of direct sun. Fruit needs to be transported to the packing house as soon as possible. The objective is to minimize fruit water loss and reduce fruit temperature as soon as possible.

Arrival at Packing House

Due to the high temperatures prevailing during summer, fruit needs to be cooled as soon as possible. No fruit should wait in the holding area before packing for more than 24 hours, and preferably should be cooled before then.

Cooling before packing varies between packing houses. The holding area can be cooled, and at least 15°C or lower is suggested. A further option used by many packing houses is hydro cooling. Fruit should be cooled to between 6°C and 10°C and held at that temperature until packing. Cooling water needs to be suitably filtered and sterilized using an acceptable sterilant such as chlorine dioxide.

Other procedures are as required elsewhere. Controlled atmosphere procedures are also as used elsewhere. See section on Peru for CA conditions.

ACTION ITEMS

PACKING HOUSES OUTSIDE CALIFORNIA

CHILE

- ☐ Ensure fruit is kept as cool as possible after harvest.
- ☐ Transport fruit to packing house as soon as possible after harvest and minimize fruit water loss.
- ☐ Cool fruit as soon as possible after arrival at the packing house.
- ☐ Apply CA conditions in accordance with required protocols relevant to the CA system being used.

COLOMBIA

Avocado production as well as export into the USA from Colombia has increased rapidly since the USA modified phytosanitary conditions in a manner which allows producers and packers to become registered and approved for export to the USA more rapidly. However, being registered and able to export does not mean that this is a simple process. As a result of geographical, climatic and other factors, fruit physiology is not the same as that from many other producing regions, and therefore should not be treated in the same way, if consistent and acceptable quality is to be delivered to the consumers in the USA.

An important factor to take into account, is that avocados in Colombia are produced at various altitudes, ranging from 3 000 feet to 6 900 feet. This affects temperature, which in turn affects the rate of growth, physiology and maturity of the fruit. Work conducted in Colombia, has shown that the maturity standards used in most other countries are not always applicable. Other climatic conditions, especially rainfall, are further complications. Most avocados are grown in high rainfall areas and are not irrigated. The highest rainfall period also coincides with the main harvest time, and as such, the risk of both physiological and pathological disorders is increased at this time.

Once harvested, fruit needs to be transferred to a packing plant as fast as possible. This presents further challenges in Colombia, as road conditions vary considerably, and producers range from small to large, meaning that fruit can arrive at the packing plant with each consignment differing in volume, condition and physiology.

Considering all these factors, specific handling procedures for Colombian fruit are necessary, and handlers within the USA after fruit arrival need to take these factors into account.

Pre-Harvest

Because of rainfall conditions, fruit from Colombia is at high risk of infection from fungal pathogens. Before harvest, it is essential to do as much as possible to enhance the fruit resistance to post-harvest diseases and decrease internal disorders by ensuring correct fruit nitrogen (less than 1%) and calcium levels (greater than 0.05%) at least one month before harvest. Good nutrient management using leaf and fruit analysis is suggested. Calcium levels in fruit are significantly affected by tree vigor, which in turn is affected by nitrogen applications. Correct balance is essential. It is suggested that a leaf nitrogen level of

approximately 2.3% in 6 to 7-month-old spring growth leaves is ideal. In addition, the majority of nitrogen should be applied such that competition between early fruit growth and new shoot growth is limited. Further, a good pre-harvest fungicide program is needed to decrease the amount of fungi in the field. This will decrease the risk of fruit infection during development (anthracnose) and at harvest (stem end rot), which is high risk due to the rainfall in the early part of the harvest season.

Pest management and inspections are also essential, so as to comply with the USDA phytosanitary requirements. A systems approach is used to decrease risk (especially of tree borers), and risk mitigation starts in the field.

Fruit quality and shelf life cannot be improved after harvest. It is therefore essential that for the fruit to have the best possible quality potential at the time of harvest, mineral nutrition, fungal disease prevention and pest management must be effectively practiced.

Harvesting and arrival at the packing plant

Eventual fruit quality starts in the field, and the correct treatments in the packing plant, such as fruit cooling temperatures, shipping temperature and optimal destination, requires that the packing plant knows the characteristics of the fruit at the time of harvest. This is complex in Colombia, as there are many small producers who do not have their own packing plant, but pack together at packing plants within the region. For optimal fruit treatment, the packing plants should know the risk factors for each consignment, as outlined above.

Fruit is considered sufficiently mature for harvest and shipping to the USA if the dry matter is at or greater than 21.8%. However, the dry mater maturity test is an indirect estimation of oil content, which is a physiologically more accurate but difficult test for routine analysis. Oil accumulation can be affected by a number of factors. Work done in Colombia has shown that the 21.8% dry matter value is inadequate, with altitude, rainfall and sunshine hours all affecting the results. It is suggested that the oil content of fruit be checked together with dry matter to set standards for different regions. A minimum oil content of 11.2% is needed for acceptable maturity. For many areas, this occurs closer to 23% dry matter than 21.8%.

Colombian fruit appears to be particularly susceptible to lenticel damage during harvest. This damage increases the potential for greater skin damage from dehydration, resulting in black spots, and such damage also increases to possibility of anthracnose development. The problem is particularly evident if fruit is harvested when wet, and for fruit from a secondary blossom (“flora loco”). Picking teams need to be well trained, and the need for care in harvesting emphasized. Where possible, wet fruit should not be harvested, picking scissors must be regularly disinfected, and snap picking (especially if the peduncle is then missing) must be avoided to decrease the risk of stem end rot. In accordance with USA phytosanitary regulations, fruit should be transported to the packing plant within 3 hours of harvest, and no fruit should be picked up from the ground.

The arrival area at the packing plant must have an insect exclusion structure to comply with USA phytosanitary regulations. If possible, the holding area should be cooled (50oF to 59oF) and humidified.

Packing and cooling

Fruit must be moved through the packing plant and packed within 24 hours of harvest. The faster this and fruit cooling occurs, the better.

The pack line should be checked for any sections that can cause additional damage to lenticels. The dumping and washing sections are particularly important in this regard. The fruit flow rate onto the line is also important to decrease fruit to fruit rubbing and ensure packers can keep up with the volume. Water dumping will cause less damage than dry dumping, but the water bath must use a filter to keep it clean and contain a disinfectant such as calcium hypochlorite chlorine at 100 to 150 ppm checked regularly.

In the washing section, the minimum number of brushes needed should be used, as this is the point on the line of most damage to lenticels. A fruit sanitizer such as peroxyacetic acid at a concentration of 100 to 150 ppm should be added. This is important for food safety and in a Colombian context, to help reduce the chance of post harvest fungal diseases.

After washing, hot air drying at 95oF to 104oF is done. Again, brushes used to help remove water can be a source of lenticel damage and should be kept to a minimum.

Fruit grading and sizing are usually not significant areas relating to fruit quality problems. However, an allowance of approximately 2% fruit weight for water loss during cooling and shipping should be made. If fruit of numerous producers is being packed, the characteristics of the fruit such as shape needs to be taken into account, and sizer re-setting may be needed to ensure that boxes are correctly filled when using the USA box and packing patterns.

Fruit cooling is possibly the most important process in the packing plant procedures, as far as later fruit quality is concerned. All fruit must be adequately cooled to the lowest temperature that does not cause chilling damage. The cooling and shipping temperatures used depend on:

- Fruit maturity (considering dry matter and oil content)
- Destination
- storage requirement
- Harvest season
- Risk for cold damage

Fruit should be cooled as fast as possible, but the cooling process must be carefully monitored using pulp and skin temperatures if possible, so that both pulp and skin temperature reach the desired point without the possibility of chilling damage, especially if skin temperature is allowed to decrease below the target temperature. In practice, end the cooling cycle when 80% of pulp sensors have reached the target temperature and the remaining sensors are within 1oF of target temperature.

Humidification of the cooling tunnels increases the efficiency of the cooling process and also decreased the fruit water loss during cooling, which helps limit the possibility of chilling damage.

The cooling characteristics of the standard USA box are different to the European 4 kg box and 10 kg plastic crate. Colombian packing plants may be packing for Europe and the USA, and it is important to cool only one packaging type at a time in the cooling tunnels where possible.

Containerization

When loading the containers, all pallets must be checked for temperature and loaded only if at or below the target set temperature. If warm pallets are loaded, hot spots will occur in the container, resulting in fruit ripening during transit, causing soft fruit and physiological disorders on arrival. Fruit of similar maturity and risk profile should, where possible, be loaded together. If higher risk pallets have to be loaded, then these should be loaded closer to the container door, as it is slightly warmer than at the front (air delivery side) of the container.

Due to the fairly short shipping time from Colombia to the USA, it is likely that controlled atmosphere (CA) will not be used. However, it is very important in this case that the containers be set to allow ventilation. If any shipping delays are expected, such as customs and phytosanitary clearance, the use of CA should be considered. The best CA conditions for Colombian fruit are not presently known, and therefore commonly used CA conditions suggested are 4% O2 and 6% CO2 or 5% O2 and 5% CO2.

As the packing plant knows the risks linked to each consignment, specific temperature, ventilation or CA conditions and handling instructions can be included on the bill of lading.

Handling after arrival

Colombian fruit is shipped to both east and west coasts of the USA. Depending on the port of discharge, the logistics chain may differ. It is important to maintain as far as possible, the cold chain at the shipping temperature. At re-packing or distribution centers, the fruit may be mixed with fruit from other origins. The physiology and therefore temperature requirements may be different. Where possible, therefore, keep the Colombian fruit separate and at the shipping temperature if different to other fruit in the system. If fruit is to be ripened, it is also suggested that the Colombian fruit be kept separate from fruit of other origins due to the likelihood of a different physiology as well as transit times and maturity, and therefore the need for different ripening protocols.

ACTION ITEMS

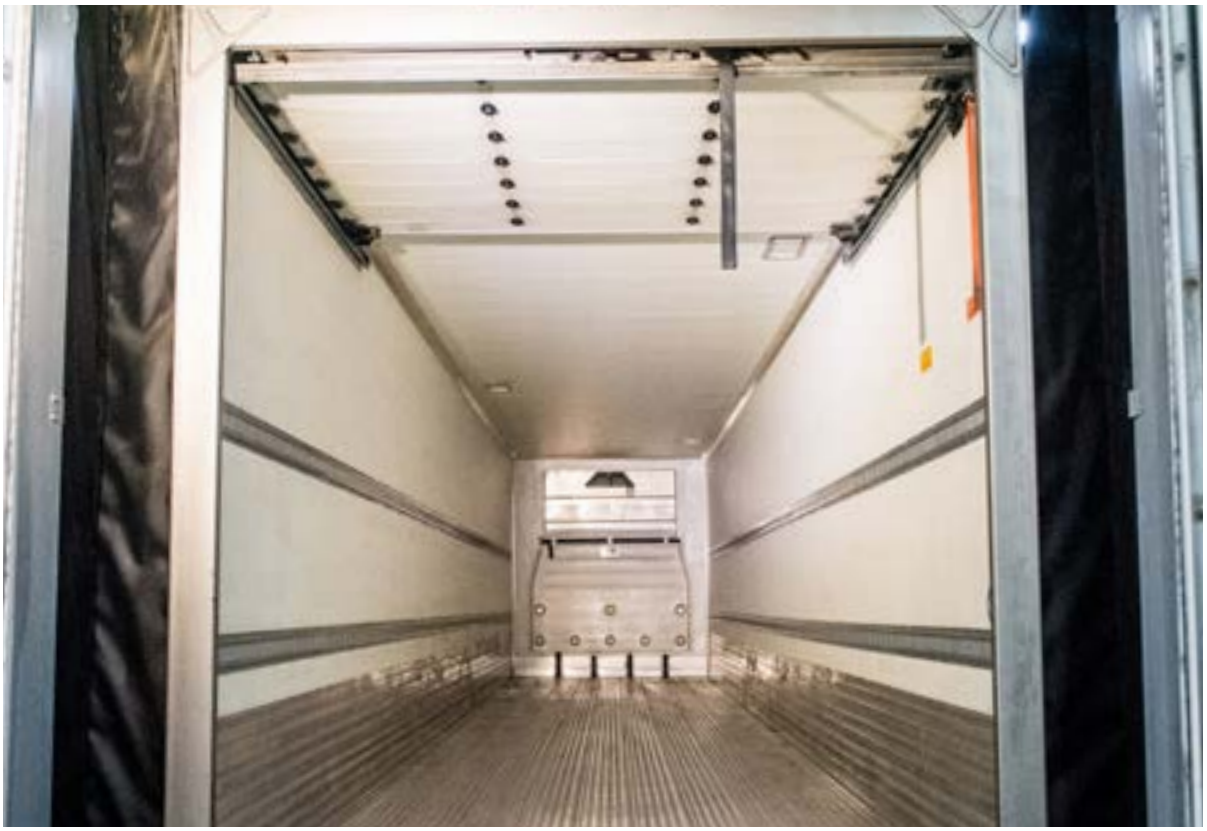
PACKING HOUSES OUTSIDE CALIFORNIA

COLOMBIA

- ☐ Ensure pre harvest fungicidal spray programs are implemented and make sure the field is in compliance with USA phytosanitary requirements
- ☐ Check tree and fruit nutrition status before harvest, especially calcium (>0.05%), nitrogen (<1%) and boron (accepted leaf analysis levels of 50 to 80 ppm) to help determine post harvest risk
- ☐ Check fruit maturity using dry matter (minimum 23.0%) as well as oil content (minimum 11.2%)
- ☐ Take care to not damage fruit during harvest as lenticels are easily damaged. Preferably do not harvest wet fruit and ensure fruit arrives at packing plant within 3 hours
- ☐ Check pack line for anything that can damage fruit especially lenticels. Brushes in the washing and drying section are particularly important
- ☐ Use a fruit sanitizer such as peroxyacetic acid at a concentration of 100 to 150 ppm
- ☐ After packing, cool fruit as fast as possible. Cooling and shipping temperature depends on risk of chilling damage. Take into account fruit maturity, season, nutritional status
- ☐ Be careful not to over-cool some pallets causing chilling damage but ensure no hot spots in pallets. Use humidifiers in cooling chambers to increase efficiency and decrease fruit water loss.
- ☐ If not using CA for shipping to USA ensure container ventilation
- ☐ On arrival at destination Colombian fruit should be treated separately to other avocado fruit due to different physiology and transit times. Take note of any instruction on the waybill and store at the shipping temperature if possible.

TRANSPORT

This section is related to road transport of fruit within the USA. It does not include container transport of imported fruit from country of origin to the port of entry, but does take into account the temperature and atmospheric conditions within such containers.



Transport of fruit is very important to eventual fruit quality. The transport operation is complex because it may entail short distances with multiple stops for loading or unloading, or long distance inter-continental travel over a number of days. The transport may be from packing house origin to distribution centers, to retail sales points or from ports of landing for imported fruit or trans-shipment of fruit at the USA Mexican border in the case of Mexican origin fruit. There are therefore multiple parameters to consider, and optimal fruit handling will need to consider different situations, but still ensure maintenance of cold chain to prevent premature ripening and loss of shelf life and quality.

The primary concern in relation to fruit quality and handling during transport, is the maintenance of temperature, and the correct choice of temperature.

Prior to loading, the truck needs to be cooled to carrying temperature. This needs to be checked and recorded by both the driver and person responsible for releasing fruit to be loaded.

- The carrying temperature should be stipulated by the packing house if fruit is being loaded at a packing house.
- If fruit is imported fruit, the original shipping temperature set by the packing house should be used.
- If fruit is loaded at a pre-packer or ripening facility, the facility should determine the transport temperature.

After inspection and acceptance of the truck in accordance with legal requirements, including food safety (consult requirements of the Food Safety and Modernization Act), to be signed off by both the driver and the person responsible for releasing fruit for loading, the truck can be loaded. Ensure that pallets are loaded in accordance with the first in last out principle, especially important if the fruit is destined for more than one destination.

At packing houses, fruit transfer centers (Mexican USA border) and distribution centers with loading docks from the cold room holding areas, trucks need to be correctly positioned such that the door to dock seal is correct in order that fruit temperature is maintained.

Maintenance of the cold chain in imported fruit is more complex, because it depends on the time taken for customs and USDA/APHIS to inspect and clear the fruit. This includes Mexican fruit, which although in theory goes through a temperature controlled holding and storage area, may be subject to delays and cold chain breaks. The objective in the case of imported fruit, is to unload containers (or trucks in the case of Mexican fruit) and transfer to storage or directly to transport as fast as possible, and with as little break in cold chain as possible. There is a possibility that the cold chain break will result in some fruit warming, especially in outside boxes on pallets. Where possible, fruit should be re- cooled, but with care to ensure that excessive cold air is not applied. Static cooling in a cold holding room or in the truck should be sufficient.

In the case of imported fruit arriving at USA ports in containers (such as from Peru and Chile), it is of the utmost importance that the cold chain is disrupted as little as possible. Containers need to retain cooling until fruit is finally removed, and where fruit needs to be removed for inspection, the cold chain must be disrupted as little as possible.

For long distance transport, pallets must be loaded such that air movement through the fruit is ensured. Pallets must therefore be tightly packed, or if the truck is not full, air movement needs to be restricted such that it can only move through the pallets of fruit.

Where possible, avocado fruit should not be transported together with any other commodity. This is especially important for long distance transport. For short distance, such as distribution center to retail store, this is less important or feasible, but should be limited wherever possible. Avocados should not be shipped with ethylene producing products (such as apples, peaches, nectarines, bananas, melons, kiwifruit), although citrus, as a non-climacteric fruit, is generally safe.

Apples | Peaches | Nectarines | Bananas | Melons | Kiwifruit

To ensure that there are no cold chain breaks, the cooling unit should never be switched off. The temperature inside trucks can increase very rapidly without cooling, especially in summer.

Unloading at destination should be done to ensure the minimum cold chain break.

ACTION ITEMS

TRANSPORT

- ☐ Check that truck conforms to requirements
- ☐ Cool to transport temperature
- ☐ Certify that temperature logs are correct
- ☐ Load to ensure maximum efficiency and least potential for cold chain breaks especially if pallets are to be off loaded at more than one site
- ☐ Do not transport avocados with any other product except for short distances and avoid co-transport with ethylene producing products

DISTRIBUTION CENTERS

Distribution centers need to take responsibility for holding the fruit until it is transported to retail outlets (in the case of retail store distribution centers) or for onward distribution to pre-packers, ripeners, food service processors, retail stores or retail store distribution centers. However, this variety of downstream customers does not materially affect the principles of avocado fruit storage for quality maintenance.

On arrival, fruit should be off-loaded as fast as possible, and with the minimum chance of cold chain breakage. Pallets should be moved into the center and into cold rooms as fast as possible.

Temperature logs of the trucks should be checked and any discrepancies with required temperature protocols noted.

In the case of arrival at the first distribution center after the packing house or arrival of imported fruit, if downloadable only (non- tracking) temperature devices are present in one or more pallets of the arriving consignment, remove them and download the information. If trackable devices are present, they can be removed at this point, or left to continue tracking. See instructions on documentation from the packing house.

Where the distribution center is not the first point of arrival a temperature logging device may or may not be present. If present, remove and download or if tracking, leave to continue tracking.

Whether a temperature tracking temperature device is present or not, fruit pulp temperature measurements need to be taken on a random selection of pallets immediately after off-loading. At least two pallets of every 20 should be checked. Preferably, a pallet at the truck door end as well as one at the front should be chosen. If either is out of protocol by more than 1°F, then every pallet unloaded should be checked.

Information concerning every consignment as described in the bill of lading (not only those deemed out of protocol) should be submitted back to the packing house or fruit origin (if imported fruit).

Storage of fruit should be at a temperature as close as possible to the stated shipment temperature. The variation from shipping temperature should not exceed 2°F higher than shipping temperature or 4°F lower in a static cooling holding store. Unless specifically requested by the original shipper, distribution centers should not be considered ripening centers or places where fruit may start ripening. Therefore, temperatures should be as stated for shipping, and not increased. In fact, if fruit are stored at temperatures which allow ripening to start, but below ambient ripening temperature, there is a high potential for the development of physiological and pathological disorders.

It is essential that temperature breaks are kept to a minimum, and therefore unloaded fruit should be placed in the appropriate cold rooms as soon as possible.

If fruit quality evaluations are done at the distribution center, results should be sent to the original packing house or shipper, where all quality co-ordination is done. Results should be communicated electronically, as soon as possible.

QUALITY EVALUATION UPON ARRIVAL TO DISTRIBUTION CENTER

Avocado fruit should preferably not be stored with any other commodity. If this is unavoidable, ensure that the fruit is not stored with or placed in proximity to any products known to produce ethylene. Of note are apples, peaches, nectarines, bananas, melons and kiwifruit.

Regularly check the cold rooms for gas build up, particularly ethylene. Ethylene should be non-detectable. Regular venting of fresh air should also be undertaken to prevent a buildup of gasses, especially ethylene. Venting with fresh air should be done for 15 to 20 minutes with fans running. This may be needed at intervals between 2 and 6 days. Approximately 3 to 4 air volume changes may be needed to ensure gas build-up is eliminated.

To prevent rapid build-up of gasses as described, no internal combustion engine equipment should be operated in or near cold rooms. Trucks delivering fruit or at the loading docks to be unloaded should not be running when the loading dock doors are opened, and sufficient time after truck engines are stopped should be allowed for gas emissions to disperse.

To maintain good sanitation, all cold rooms should be cleaned on a regular basis with a sanitizing agent.

To ensure appropriate handling of avocado fruit, all operational staff at distribution centers should be adequately trained through the attendance of industry approved training, to fully understand the product and the handling requirements to ensure the best possible retention of fruit quality.

ACTION ITEMS

DISTRIBUTION CENTERS

- ☐ Off load fruit from trucks as fast as possible
- ☐ Check truck temperature logs against written shipping instructions and note conformity or lack thereof
- ☐ Check pulp temperature of fruit from at least 2 pallets per 20 pallets
- ☐ Remove temperature data loggers if required and download. Leave tracking recorders in place unless requested to remove
- ☐ Place fruit in cold storage rooms without delay. Use rooms with temperatures as close to shipping temperature as possible
- ☐ Do not store with other commodities if possible, and not ethylene producing products
- ☐ Ensure the cold rooms are regularly checked for gas build up (ethylene should be non-detected), and vent rooms with fresh air regularly
- ☐ Electronically remit fruit temperature and quality information of every consignment to original packing house or shipper without delay
- ☐ Ensure that all operational staff receive appropriate industry approved training

RE-PACKERS AND FRUIT RIPENERS

Re-packing (such as in netting bags) or other retailer designated packaging may or may not be done in the same facility or to the same fruit, as ripening. They will therefore be discussed as two separate issues.

On arrival of fruit, check the truck temperature logs and any discrepancies with required temperature protocols should be noted.

If fruit arrives at the facility directly from the packing house, as imported fruit directly from the port of arrival, or in the case of Mexican fruit, from the trans-shipping stores at the border, check for presence of temperature loggers. Remove them and download the data.

UNRIPENED RE-PACKED FRUIT

Where fruit are to be packed such that they will reach the retailer in a hard and unripe state with approximately 7 to 10 days shelf life at ambient temperature, the fruit should be treated as unripe fruit and should be subject to cold chain breaks for as short a duration as possible.

On arrival all fruit should be placed in cold stores at the temperature of shipping, or as close to that as possible. The variation from shipping temperature should not exceed 2°F higher than shipping temperature or 4°F lower in a static cooling holding store. Do not store together with other produce if possible, and definitely not with any products which produce ethylene, such as apples, peaches, nectarines, bananas, melons and kiwifruit.

Fruit should be removed from the cold store for pre-packing as close in time to the pre- packing operation as possible.

It is desirable that the re-packing area be temperature controlled, at a temperature of 53°F or less.

After re-packing, fruit should be returned to the cold store and remain there until transport to the retail store or distribution center.

All cold rooms should be checked regularly for buildup of gasses, especially ethylene. This is especially important in facilities which may also ripen fruit, as ethylene build-up within the facility is more likely to occur. Ethylene should be non-detectable. Regular venting of fresh air should also be undertaken to prevent a buildup of gasses, especially ethylene. Venting with fresh air should be done for 15 to 20 minutes with fans running. This may be needed at intervals between 2 and 6 days. Approximately 3 to 4 air volume changes may be needed to ensure gas build-up is eliminated.

RIPENED FRUIT

Ripening needs to be initiated in green, hard fruit where it is intended to eventually offer ripe ready to eat fruit at final point of sale, but the fruit should not be ripened completely, as shelf life will be compromised to the extent that poor quality and diminished sales will result. The extent of ripening undertaken before further distribution depends on the intended market, and the number of days shelf life or to full ripeness is required. Unless the ripening is taking place at a food service facility or processing factory where full ripeness is required before further processing, fruit must be distributed to final sales destination before full ripeness, otherwise excessive bruising will result. Fruit bruising has been determined in a number of studies, as the most prominent cause of quality reduction at retail level. The problems will start at re-packers or ripeners if suitable precautions are not taken.

Ripening can be triggered by addition of ethylene in ripening rooms, or by allowing the fruit to ripen naturally at non storage (non cold) temperature.

For ripening, all fruit can be moved out of the cold store at the time that initiation of ripening is needed (dictated by retail or food service orders) and placed in warm ripening rooms. Because fruit from different origins, maturities, shipping temperatures and age after harvest will react differently, only uniform groups of fruit should be treated together. It is important to note that fruit that has been shipped to the USA using controlled atmosphere in the shipping containers, will react to the ripening process differently to fruit that has not been subjected to controlled atmospheres. The purpose of controlled atmosphere storage is to slow down the ripening process, and this effect will remain to some extent for a time after removal from the containers. It is particularly important to ripen the fruit slowly, and this means ensuring that ripening temperatures are not too high. Attempting to ripen the fruit too fast may result in physiological

disorders and poor ripening. The temperature of the rooms should be 65 to 68°F. Higher temperatures increase the ripening rate, but at the same time increase the risk of pathogen development, such as stem end rots, which also increases risk of vascular browning, body rots due to anthracnose and especially in the case of low maturity fruit, uneven ripening. Lower temperatures than the above decrease these risks, but tend to result in poor color development. This has the disadvantage that consumers are often unable to adequately judge ripeness, and tend to leave fruit until over-ripe with the potential that quality deterioration will have resulted. Adequate ventilation to prevent excess buildup of gases, especially CO2, is needed. High levels of CO2 will inhibit ripening and increase the potential for internal disorders such as grey pulp, as well as development of pathological disorders such as anthracnose rots. The speed of ripening and therefore the number of days at which the fruit should be left to ripen, is very dependent on the maturity of the fruit, notably indicated by the dry matter content.

Ripening can also be achieved using ethylene application. Automatic ethylene control systems are best for controlling the concentration in the ripening rooms. Apply ethylene as a trickle system to maintain 10ppm ethylene. If intermittent application of ethylene is done, apply a shot to obtain a concentration of approximately 100ppm. The concentration is then allowed to slowly decrease over 6 to 8 hours. During the ripening of the fruit, high concentrations of CO2 will be evolved. It is essential that the CO2 is not permitted to rise above 2%, and preferably not above 1% otherwise ripening will be retarded and internal defects such as grey pulp will occur. Ripening rooms must be vented every 8 hours for at least 20 minutes, with fans running to ensure air change.

The relative humidity of the ripening room should be maintained at 90-95%. The treatment time varies dependent on maturity of the fruit, with approximate times of:

- Dry matter <23% use 2 to 3 days
- Dry matter 23-26% use 1 to 2 days
- Dry matter >26% use 1 day

The treatment is designed to initiate fruit ripening, and the process should therefore be stopped before ripeness is actually reached. The fruit should be checked regularly for indications of ripening by a change in softness. Fruit will not be left until soft, but to the point of breaking (sprung stage, where fruit neck is slightly soft). Thereafter, fruit can be re-packed into consumer packs or left in their boxes. Fruit must be transferred to a cold room set at 41°F to 44°F for holding before shipment to final destination and to control ripening progression to fully ripe and ensure sufficient shelf life for sale.

Fruit can be packed for final retail sale in different ways, but needs to be protected against bruising during storage, shipment and at the point of sale. The most robust packaging is in clam shells. Fruit can be packed in singles or multiples, and can be sorted, using the variability in ripening speed likely to be encountered, into groups with different numbers of potential days to ripe, which is useful for retailers and consumers. Fruit sorting can be done using in-line softness touch testing or acoustic equipment. In addition, a color changing ethylene determining sticker can be included in the pack to indicate to the consumer the stage of ripeness without physical squeezing.

Once packed, all packaging must be labeled appropriately to indicate to the retail trade that the fruit has been ethylene conditioned. Ready to eat dates should if possible be applied.

Where fruit has been shipped long distances, such as from Peru and Chile, some physiological ripening processes may have already started by the time fruit arrives at the fruit ripener. It may therefore be important to adjust the above protocols to take this into account. Ethylene treatment time may require slight reduction. Exporter specific requirements should be noted.

5 STAGES OF RIPENESS

Chart courtesy of Mission Produce, Inc.

ACTION ITEMS

RE-PACKERS AND FRUIT RIPENERS

- ☐ Check truck and fruit temperature on arrival
- ☐ Remove any data loggers present and download data
- ☐ Place fruit in holding store at shipping temperature with variation not exceeding 2°F higher than shipping temperature or 4°F lower
- ☐ Do not store with any products producing ethylene
- ☐ Re-pack and cool again as fast as possible if to be sold as hard fruit
- ☐ If fruit is to be ripened use either warm temperatures (68 to 72°F) or place in ethylene ripening rooms
- ☐ Add ethylene at rate of 10 ppm for trickle application or 100ppm shot application, renewing after 8 hours.
- ☐ Vent rooms for 30 minutes with fans running to remove CO2 every 8 hours. Do not let CO2 exceed 25 and preferably not more than 1%
- ☐ Apply ethylene for 1 day (fruit dry matter >26%), 1 to 2 days for fruit dry matter 23-26% and 2 to 3 days for fruit dry matter <23%
- ☐ At sprung stage re-pack fruit if required and store at 41°F to 44°F until dispatch. Label as ethylene treated

RETAIL SALES (GREEN AND RIPENED FRUIT)

Fruit may arrive at retail sales points directly from packing houses, or via distribution centers, which may or may not be operated by the retail sales point. The fruit may be pre-ripened or in a hard state. All of these factors need to be taken into account in the management of the fruit at the retail point.

The retail sales point is where considerable damage to fruit and therefore quality loss can be caused if not managed correctly.

ORDERING AND INVENTORY CONTROL

Management needs to accept that avocado fruit is a perishable product that will soften rapidly once it starts to ripen, and will have an approximately 4 to 7 day shelf life at ambient store temperature. Ripening of hard fruit will be accelerated when placed in display bins of ripening fruits due to ethylene presence. Stock control of fruit in display bins and in the store overall, therefore needs to be tightly managed to ensure that fruit is sold before becoming over-ripe.

STORAGE OF FRUIT AFTER ARRIVAL

Inventory control should ensure that a minimum amount of fruit will need to be stored before display and sale.

On arrival, fruit needs to be checked for quality compliance. Fruit origin should be known, in compliance with traceability requirements. Therefore, should there be any defects, the original packer can be informed if there is any non-compliance. This, together with observations from the store display and any customer feedback, will complete the quality management tracking system.

On arrival, fruit should be stored at low temperature. The temperature should be as close as possible to arrival temperature, or as stated on the delivery manifest. Where fruit from multiple origins is received, it is probable that the storage temperature requirements are different. This is especially important where very mature late season (high dry matter fruit) is received at the same time as less mature early season (low dry matter fruit) from a different origin. Multiple temperature storage rooms should therefore be used where required.

Do not store fruit in close proximity to high ethylene producing products such as apples, and bananas.

Take care to select the correct fruit for moving out of cold rooms to retail display, taking into account fruit age and whether fruit has been primed to ripen with ethylene.

Storage cold rooms should be vented with fresh air on a regular basis to prevent excessive build-up of CO_2 and ethylene. High levels of either of these gasses will adversely affect the ripening and quality of avocados and other fruit products stored in the facilities.

FRUIT DISPLAY

The fruit display is another area of considerable concern in quality management.

Soft or softening fruit will bruise easily, become damaged and post-harvest disorders such as pathogenic rots (anthracnose and stem end rots) will be accelerated by the damage. Over-ripe fruit in the display will also be of concern for the same reason. Consumer aversion to purchase certain fruit such as those showing some blemish or lenticel and minor cold damage can affect both price and sales rate, which in turn may affect returns on other sound fruit. There are three primary reasons for problems related to fruit quality occurring at the point of sale:

- Fruit stacked too high, with lower fruit becoming damaged, especially once soft
- Large stacks of fruit with a mix of ripe and unripe fruit. The ripe fruit can become over-ripe within the stack if not carefully sorted by store staff
- Consumers testing fruit for ripeness resulting in extensive bruising

The solution to these problems has been found to be simple.

- When placing fruit into the display, either leave in the boxes it was shipped in, or place fruit carefully into the display. Do not tip fruit from the box into the display, as this will damage fruit
- Ensure that the display does not have more than 2 layers of fruit
- Do not place too much fruit into a display. Consider the display size in relation to the amount of fruit that can reasonably be sold before it becomes too ripe (a few days)
- Store staff sort the fruit daily to ensure the ripest (normally darkest colored) fruit is moved to a position the consumer will see first, and can easily reach. This means placing these fruit on top and towards the front of the display
- Manage the display by removing any over ripe or clearly damaged or decaying fruit
- Separation of riper fruit into a ripe and ready section can be useful
- Ripe and ready fruit, especially if pre-packed in consumer packs, can be displayed in chilled sections to prolong shelf life
- Consumer information and education displays to enable and encourage consumers to select fruit without checking for ripeness and thus bruising it

At check-out, train staff to try and ensure fruit is not packed under other heavy or bulky items which will result in damage which the consumer will later experience.

STAFF AND CUSTOMER EDUCATION

The final point of distribution, that being the retail store, and in-home handling after sale are the least controlled portions of the entire distribution chain, but nevertheless can have very significant effects on fruit quality and therefore consumer experience, which ultimately affects both future sales and price.

The solution to many of the problems experienced, apart from those outlined above, is training and information. In store personnel need to be adequately trained to handle fruit from the time of arrival at store and through the entire storage, display and sales processes, with the aim of supplying fruit of good eating quality to the consumer. Staff need to understand the ripening process of the fruit, and thereafter how to handle it correctly.

Clear, fast and easy to read or see, instructions to consumers need to be instituted to ensure that not only do they not damage fruit in the displays, but that they have greater appreciation for slightly externally damaged fruit and know how to treat fruit once purchasing it.

ACTION ITEMS

RETAIL SALES (GREEN AND RIPENED FRUIT)

- ☐ Ensure careful inventory control
- ☐ Check quality on arrival and report defects to original packer
- ☐ Store at appropriate low temperature in cold rooms which are vented on a regular basis. Store away from fruits known to produce ethylene
- ☐ Select fruit for display carefully taking into account fruit age and previous treatment
- ☐ Place fruit into displays carefully to avoid bruising, and use no more than 2 layers of fruit or original packaging
- ☐ Manage displays to ensure easy selection of ripe fruit by customers and removal of over-ripe or decaying fruit
- ☐ Assist consumers to be aware of how to select and handle fruit without damaging it through customer education
- ☐ Train store staff in correct handling and management of avocado fruit

COMMON FRUIT DEFECTS

In order to assist operators throughout the distribution chain to identify defects and be able to report these correctly and in a consistent manner the following can be considered:

FRUIT SOFTNESS

When checking fruit for softness, hand pressure is often used. However, this is subjective, and therefore an alternative is a penetrometer, which is designed to penetrate the fruit after a certain pressure is applied. A typical instrument sold for use on avocados has a tip of 1/4 inch (6mm). To measure a fruit, select an area on the equator of the fruit (ensure there is no bruising or damage to the fruit) and using a blade or knife remove the exocarp (skin). Apply the penetrometer tip to the fruit and gently press the instrument so that the tip penetrates the fruit. At the point where the line on the tip is level with the fruit flesh, take the pressure reading. There will be variation within any consignment of avocado fruit, both within a box and within a pallet. Therefore, a number of readings must be taken, and an average calculated. This can be used as a guide as to the overall softness of the fruit, but due to known variation, is not definitive. The softness category is described as follows:

CATEGORY	PENETROMETER AVERAGE (PSI)
Hard	>25
Firm	15-25
Breaking	10-15
Firm-ripe	5-10
Eating ripe	<5

VISUAL EVALUATION OF EXTERNAL FRUIT QUALITY

A sample of 10 fruit is used. The degree of defect is rated on a 0-10 scale as a % of the surface affected, where 1= 10% of surface affected and 10 =100% of surface affected. The score of the 10 fruits are then added, and the total is the % defect of the composite sample.

EXTERNAL DEFECTS

Fruit color has been used for many years as a marketing tool for Hass avocado fruit, indicating to the final consumer when fruit is ripe and ready to eat. However, the degree of black coloration and intensity of color does differ within season and fruit origin, depending on maturity and climatic conditions. Therefore, color is not a good determinant of fruit quality, and should not be used.

Defect: Ridging

Ridging is usually due to some form of damage very early in fruit development, possibly even during flower development. While it may be weather or insect related, an extensive raised portion of the fruit may be genetically linked. Ridges may be seen as a clearly raised portion normally longitudinally down the fruit, of varying width, and the fruit may also be misshapen. Ridges are prone to general abrasion while fruit is on the tree, by for example leaves rubbing the area when fruit is very small. Additional damage could occur during picking, transporting and packing. Internal quality is not likely to be affected, but visually the fruit may be unattractive to buyers.

Defect: Sunburn

Sunburn is most notable as an area of hard, corky or cracked skin that may be of light yellow to reddish brown or even black in color, usually only on one side of the fruit and often towards the stem end. The flesh below the damaged area is usually also damaged and will not ripen normally. Sunburn is most prominent on exposed fruit especially at the top of trees and notably where leaf coverage is sparse.

Defect: Lenticel Damage

Lenticels are the pores of outer plant tissue that provide a direct exchange of gases between internal plant tissues and the atmosphere. Lenticel damage is characterized by black and collapsed lenticels. After extended periods of storage, particularly at low temperature, the initially small areas of damage often enlarge as the cells around the lenticels dehydrate, become more susceptible to low temperature damage and therefore also collapse and die. Unless extensive, much of the lenticel damage becomes hidden by the dark background color of ripe Hass fruit. Lenticel damage usually has little effect on internal quality.

Lenticel damage is primarily caused by abrasion during handling, usually during picking and transport to the packing house, as well as on the pack line. Fruit dumping onto the line, especially if dry dumped, and the action of brushes during washing or cleaning are major causes of the physical damage.

The rougher the fruit, the more likely the lenticels will be damaged. In addition, if the fruit is very turgid, lenticels will be more subject to damage. Trees should therefore not be irrigated the day before picking, and preferably, fruit should not be picked or transported if it is cold and wet.

Defect: Chilling Injury

Chilling injury is indicated by well defined areas of black, sunken lesions. These may vary from small to large extensive areas of the fruit surface. Often, one side of the fruit is more extensively damaged, and the distal (bottom) end of the fruit is often worse. The lesions do not penetrate into the fruit flesh, although in severe cases internal chilling damage may also occur. In the absence of internal damage, internal quality will not be affected, but the external damage may encourage development of post harvest fungal diseases.

The primary cause of chilling damage is the use of initial cooling as well as storage and shipping temperatures that are too low. Less mature early season fruit is more susceptible, as is fruit from trees high in nitrogen and low in calcium. In addition, the longer the shipping period, especially if temperature is too low, the more extensive the damage. If initial cooling is too fast, excessive air flow over fruit surfaces can result in enhanced damage, especially if this also results in fruit water loss and if lenticel damage is also present. The solution is careful use of the most appropriate cooling and shipping protocols taking fruit maturity and origin into account.

Defect: Thrip Damage

Thrip damage usually occurs early in fruit development, and is the result of the insect removing the top layer of the fruit skin. Scar tissue forms in these areas, resulting in areas of rough, corky brown scar tissue on the fruit surface which will not color with ripening. Because the damage usually occurs early in fruit development when fruit are small, the eventual result may be extensive fruit surface damage. A good pest monitoring and control program is essential. Internally, fruit are usually not affected, making the defect mainly cosmetic.

Defect: Limb Rubs (Scarring)

Lines of brown corky, scarred skin which will not color on ripening, are the result of physical damage, most notably when the fruit is small. The fruit skin can be damaged by leaves or branches rubbing against the fruit. The use of windbreaks can substantially reduce the incidence. Generally, this is confined to external blemish, with little to no effect on the internal quality of the fruit.

Defect: Copper Sulfate Residue

Copper sulfate is extensively used in many production areas to decrease orchard fungi which cause post harvest diseases such as stem end rot and anthracnose. This may leave visible blue-green spray residue, which does not in any way adversely affect internal quality or food safety, but may be unacceptable to consumers. Fruit washing and brushing on the pack line will help to remove this, but may not always be successful. Certain formulations of copper sulfate which are easier to remove are available.

Defect: Checkerboard Ripening

Checkerboard ripening refers to boxes of fruit where the fruit colors and ripens at different rates, such that the fruit within a box varies from green to varying shades and intensity of black as well as variable softness. Some fruit may never color entirely, resulting in a green to brown color even when fully ripe. While the internal quality will not be seriously affected, it is a considerable problem for fruit ripeners as it is difficult to predict ripening rate and shelf life within a consignment. The most likely cause is the packing of variable maturity fruit, most likely where there are multiple fruit set periods in a season and older, more mature fruit is mixed with younger less mature fruit.

INTERNAL DEFECTS

Where fruit are evaluated for internal defects, the number of fruit within a 10-fruit sample with the defect is reported. This can also be expressed as a %.

Defect: Diffuse Flesh Discoloration

Diffuse flesh discoloration presents as a diffuse grey to black or sometimes brown coloration of the fruit flesh, which may be visible in hard fruit which has been stored or shipped but intensifies as fruit ripens. The discoloration also intensifies with time after fruit is cut. Internal fruit quality is poor, becoming increasingly so as the discoloration intensifies. The discoloration is due to the presence of dead fruit flesh tissue, which affects taste in addition to appearance.

There are multiple potential causes for the disorder, which include internal chilling injury, especially if the fruit is less mature, incorrect gas concentrations during controlled atmosphere shipping (particularly low oxygen or high carbon dioxide) or fruit that has been stored or shipped for very long periods, especially late season fruit. Fruit that starts ripening during shipping is especially prone to the disorder. Fruit from trees high in nitrogen and low in calcium are also more sensitive to the factors that cause the disorder.

Defect: Flesh Bruising

Flesh bruising is shown by an area of grey to black flesh usually on one side of the fruit extending from the seed towards the skin, and often around the middle section of the fruit. The defect is most notable when the fruit is ripe. There may be no other noticeable internal defect. Bruising is an indication of rough handling, which may occur at any time from harvesting onwards. Although hard, unripe fruit is susceptible, and only shows symptoms later after ripening, the most sensitive stage for bruising occurs once ripening begins, and is therefore particularly important in the retail sector. Rough handling, stacking of fruit too high in displays and repeated customer handling to test ripeness are important factors.

Defect: Grey Pulp

Grey pulp is a more intense form of diffuse flesh discoloration. The grey to black coloration of the flesh is particularly intense in the distal (bottom) area of the fruit, but may also extend towards the stem end. Vascular discoloration may sometimes accompany the symptom.

There are a number of potential causes, but the disorder is particularly noted in more mature fruit towards the end of the harvest season. Length of storage plays a notable role, with longer storage or shipping times significantly increasing the potential for the disorder. The temperature of storage or shipping is also important. Especially notable, is the effect of temperatures that are slightly too warm, allowing the fruit to start ripening during the shipping or storage. The presence of ethylene during a slow, low temperature fruit ripening, which would occur under these conditions, is known to enhance the problem.

Fruit from trees high in nitrogen and low in calcium are more prone to the disorder.

Defect: Flesh Adhered to Seed

When fruit is cut in half and pulled apart, sometimes a portion of the flesh adheres to the seed. The cause is uneven ripening, where some of the fruit, especially at the top of the seed, does not ripen properly, and remains hard and rubbery, while other portions of the fruit ripen normally and therefore separate from the seed easily. The disorder is more prevalent in early season less mature fruit. Incorrect ripening temperature (temperature too high) may enhance the problem. Fruit quality is affected, in that some of the fruit ripens normally while other portions remain unripened.

Defect: Stem End Rot

Stem end rot appears as translucent to brown discoloured area in the fruit flesh, starting from the stem end and progressing downwards through the fruit. Where severe, white fluffy or pinkish fungal mycelium may also be present. Externally, a black clearly decaying zone around the stem end may be present, although in early stages of development no external symptoms may be seen. At early stages of development, there may or may not be vascular discolouration accompanying the disorder. The cause is a group of fungi present in the avocado trees in the field. Dead branches within the trees are a particular source of the fungal spores which infect the fruit. Warm, wet conditions also increase the presence of the pathogens. Fruit become infected mainly at the time of harvest, the fungi entering through the cut fruit pedicels. Picking wet fruit increases the chance of infection, and less mature fruit are also more susceptible. Growth of the fungi tends to be suppressed by low temperatures, but increases rapidly once fruit start ripening.

The most common control measures involve preharvest fungicidal sprays (mostly using copper formulations) to decrease fungal presence, and removal of dead wood from trees. Postharvest fungicides are only partially effective.

Defect: Vascular Browning

Vascular browning is indicated by distinctly visible dark brown to black vascular tissue in cut fruit. The dark colored vascular tissue follows the vascular tissue from the stem end through the fruit to the distal (bottom end) of the fruit where it enters the seed. The disorder is often associated with an internal chilling damage due to long storage periods at temperatures too low for the maturity of the fruit (symptoms more noticeable around the distal end of the fruit), or with stem end rot (symptoms extend more clearly from the stem end).

Defect: Stem End Rot & Vascular Browning

In many cases, fruit shows symptoms of both vascular discolouration and stem end rot. This is particularly the case with advanced decay (with the exception of stem end rot caused by one fungal group).

The cause is a group of fungi present in the avocado trees in the field. Dead branches within the trees are a particular source of the fungal spores which infect the fruit. Warm, wet conditions also increase the presence of the pathogens. Fruit become infected mainly at the time of harvest, the fungi entering through the cut fruit pedicels. Picking wet fruit increases the chance of infection, and less mature fruit are also more susceptible. Growth of the fungi tends to be suppressed by low temperatures, but increases rapidly once fruit start ripening.

Internal defect photos courtesy of Salvador Ochoa Ascencio