Palletization and Staging for Cooling/Storage/Shipping

Palletization facilitates handling efficiency and reduces physical injury to mangos by reducing handling of individual cartons.

- Use good-quality, standard, repairable, four-way entry pallets (40 x 48 inches; 100 x 120 cm).
  
  *Note: Mango retailers’ most common complaint is the use by some in the mango industry of cheap pallets that fail during handling!*

- Pallet boards should not block carton air vents.

- The footprint of pallets should be designed to facilitate conditioned airflow through and around cartons in order for the vertical (i.e., bottom to top) air delivery of seagoing refrigerated containers and the horizontal (i.e., rear to front) airflow of over-the-road trailers to maintain optimum temperatures during transit.

- Examine cartons and do not stack those that are damaged, improperly constructed, or have fruit protruding above the top edge of the carton.

- When stacking cartons of mangos onto pallets, be sure that the first layer of cartons is placed completely within the outside edges of the pallet. If the cartons overhang the pallet, carton failure is imminent. Failure of bottom-stowed cartons on pallets can result in the unitized pallet leaning over or completely collapsing.

- Carefully stack mango cartons on pallets in register so that the corners of all cartons in a column line up precisely. Otherwise, the stacking strength of the cartons will be severely compromised and pallet leaning and collapse will result.

- Prior to stacking cartons on a pallet, a few drops of glue may be placed on the cartons to stabilize them when stacked.

- Corner braces and strapping should be used to stabilize and secure pallets and must be sufficiently strong to ensure the integrity of the pallets during the rough, extreme conditions that they are likely to encounter during shipping. The tension on strapping should be sufficient to hold the corner braces and cartons in place but not so tight as to crush the corners of the cartons, thereby causing carton failure, reduced stacking strength, and leaning pallets.

- Completed pallets should be transferred to a refrigerated area as soon as possible.
Cooling Prior to Shipping

Packed and palletized mangos should be cooled as rapidly as possible to their optimum shipping and storage temperature (12°C [54°F] for mature green mangos). Lowering the temperature slows fruit metabolism (including ripening), reduces water loss, and slows the initiation and spread of decay. Since mature green mangos are susceptible to chilling injury at temperatures below 12°C (with severity determined by exposure time and temperature), they should not be cooled below this point.

ROOM COOLING

Rapid cooling requires good contact between the refrigerated air in the postharvest environment and the product in the package. Heat transfer in room cooling is achieved by cold, refrigerated air coming into contact with exposed pallet surfaces, with the heat from the interior of the pallet slowly transferred by conduction to the surface. Thus, room cooling is a relatively slow cooling method that typically requires 24 to 48 hours for palletized mangos.

FORCED-AIR COOLING

It is recommended that mangos be forced-air cooled in order to remove heat from the fruit as rapidly as possible. Forced-air (or ‘pressure’) cooling improves heat transfer compared to room cooling by creating a pressure differential from one side of a pallet to the opposite side that pulls the cold, refrigerated air through the ventilation holes in the cartons, directly past the fruit within the pallet. Properly designed forced-air cooling systems are capable of reducing mango flesh temperatures from an initial range of 30 to 40°C (86 to 104°F) down to around 12 to 15°C (54 to 59°F) within 2 to 4 hours.

HYDROCOOLING

Hydrocooling involves immersing or drenching produce in cold water to remove heat. Although hydrocooling cools faster than forced-air cooling, it is not typically used to cool mangos prior to shipping due to logistical and sanitization management challenges.

Hydrocooling presents several logistical challenges. Water sanitation management is critical to avoid transfer of decay pathogens between fruit. Hydrocooling must either be applied before packing, in which case the fruit must
be thoroughly dried prior to packing, or the fruit to be hydrocooled must be packed in water-resistant shipping cartons.

Guidelines for room cooler and forced-air cooler design can be found in the publication *Commercial Cooling of Fruits, Vegetables and Flowers*, available from the Postharvest Technology Research & Information Center (http://postharvest.ucdavis.edu/bookstore/Commercial_Cooling/).

For both room cooling and forced-air cooling, it is recommended that the room air temperature be maintained at 10°C (50°F). In both cases, the intent is for the mangos to be exposed to 10°C air only temporarily. The flesh temperature of mangos should not be allowed to fall below their lowest safe temperature of 12°C.

- Once ¾ to ⅞ cooling has been achieved by forced-air cooling, the mangos should be transferred from the forced-air cooler to a 10°C storage room to complete cooling.
- Mangos that are room cooled or transferred from forced-air cooling should ideally be loaded onto transport vehicles only when the fruit flesh temperature reaches 12°C.

The concept of ⅞ or ⅞ cooling relates to the characteristic time that it takes a cooling system to remove sufficient heat to reduce the difference between the cooling medium temperature and the product temperature by 75% or 87.5%. An example would be using 10°C air to reduce the temperature of 30°C mangos (i.e., mangos that are 20°C warmer than the cooling medium) down to either 15°C (i.e., ⅝ cooling) or 12.5°C (i.e., 17.5°C cooler = ⅞ cooling).

- Problems with excessive water loss encountered with forced-air cooling are due to the bad management practice of leaving pallets on the forced-air cooler past the time when ⅞ to ⅞ cooling has been achieved.

Storage Rooms
Temporarily holding mangos in a 10 to 12°C (50 to 54°F) storage room prior to loading onto marine containers or truck trailers is an important part of good temperature management.

- Refrigeration capacity in mango storage rooms should be sufficient to maintain uniform product temperature (within 1°C [2°F]) throughout the load. This requires both sufficient cooling capacity and adequate air circulation.
  - A rule of thumb for airflow in cold-storage rooms used for room cooling is 0.052 to 0.104 cubic meters per second (cms) per 1,000 kilograms of produce capacity (100 to 200 cubic feet per minute [cfm] per ton).
  - To maintain produce temperature, a lower airflow of 0.0104 to 0.0208 cms per 1,000 kilograms of produce capacity (20 to 40 cfm per ton) is all that is required.
  - The room should be loaded in such a way that air flows uniformly past all of the pallets.

*Note: Forced-air cooling actually reduces water loss compared to room cooling by cooling the surface of the fruit extremely rapidly, which reduces the water vapor gradient across the fruit skin, thus slowing water movement out of the fruit.*
• It is necessary to humidify storage rooms if mangos are likely to be held for more than a few days, especially if the room is used for room cooling since the high airflow rate can cause excessive water loss. The ideal relative humidity range for mangos is 85 to 95%.

• The humidification system should be able to maintain uniform (within 2 to 3%) relative humidity levels and be designed to distribute the moisture uniformly throughout the storage space. This minimizes problems with condensation, which can lead to weakening of fiberboard cartons.

**Holding Sample Lots of Fruit for Quality Control**

For quality control (QC), it is recommended that a representative sample (at least 25 randomly selected fruit or one carton of each fruit size) from each lot that passes through the packinghouse be retained in the storage room while the rest of the lot is being shipped to the U.S. and until the lot is delivered to the buyer. At that time, the QC fruit sample should be transferred to an air-conditioned room, such as an office, at 24 to 25°C to complete ripening. This procedure allows the packer/shipper to compare the fruit quality under ideal storage and ripening conditions to the reported quality of the shipped fruit, and can provide evidence as to whether any discrepancies that might be noticed by receivers are due to the different conditions to which the mangos were exposed during distribution as opposed to problems with initial fruit condition.

**Shipping**

**STAGING FRUIT FOR LOADING**

The area in which mangos are staged for loading onto marine containers or truck trailers should be refrigerated at 10 to 12°C (50 to 54°F). Dock doors should remain closed until a trailer or container has been backed up against the door.

• Mangos should be stowed in precooled reefer containers or trailers from a staging area that is properly refrigerated (i.e., cooler than 12°C). Cold tunnels should be situated tightly between the climate-controlled loading dock door and the rear (door end) of the reefer container or trailer. The cold tunnels prevent outside ambient air from entering the refrigerated dock and the interior of precooled containers.

• When mangos are loaded in a hot, humid ambient environment (loading area), moist air can enter the interior of the precooled container when the trailer or container doors are opened. Consequently, some transportation companies have advised shippers to