Corner bracing and strapping being applied to a pallet

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.

Room cooling

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.

Forced-air cooling tunnels

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

Mangos being lowered into a hydrocooler

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/Pubs/pub_list.shtml#cooling).

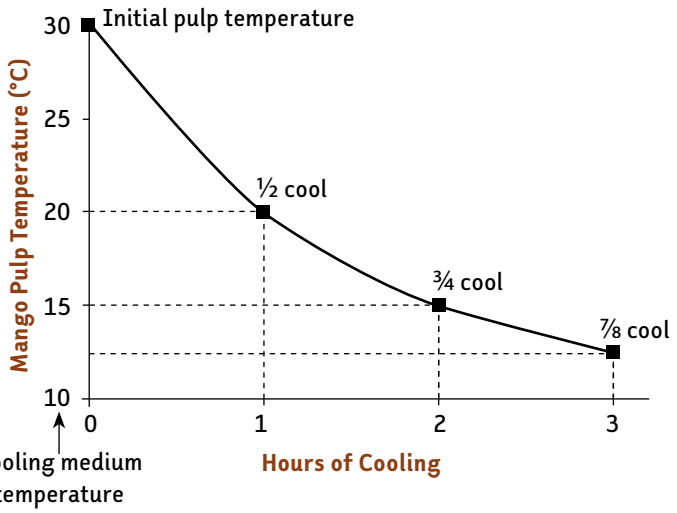
For both room cooling and forced-air cooling, it is recommended that the room air temperature be maintained at 10°C (50°F). In both cases, *the intent is for the mangos to be exposed to 10°C air only temporarily*. The flesh temperature of mangos should not be allowed to fall below their lowest safe temperature 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 ¾ 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., 15°C cooler = ¾ cooling) or 12.5°C (i.e., 17.5°C cooler = ⅞ cooling).

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.

- 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 ¾ to ⅞ cooling has been achieved.



Cooling curve for a precooling system with a 1/2-cooling time of 1 hour. The fruit are cooled from an initial fruit flesh temperature of 30°C to 12.5°C (7/8 cool) in 3 hours using 10°C air as the cooling medium. (Based on a 20°C difference between the 30°C initial fruit temperature and the 10°C cooling medium temperature.)

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.