POSTHARVEST PHYSIOLOGY OF MANGO FRUIT

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My experience with mangos is mostly through eating them, which I do whenever I can. There is one minor problem; I am allergic to the sap but can handle ripe fruit. Limited work has been done on the postharvest life of mangos in Hawaii. I am familiar with mango postharvest research in the US, the Caribbean, Australia, and Southeast Asia. Mango postharvest research in Hawaii has been limited, first, by the absence of an industry here, and second, by inability to obtain sufficient quantity of a selected variety. Varietal selection is needed because there is great varietal variation in susceptibility to postharvest disorders. The choice of one, two, or three varieties for commercial purposes is therefore crucial to industry development. In addition, insect quarantine procedures are variety specific, hence limiting the number of varieties that can be handled.

Postharvest Characteristics of Mango

The mango is a climacteric fruit that ripens from the seed outwards (Figure 1). It is chilling sensitive, being damaged by temperatures below 12°C (about 55°F). Relating to its climacteric nature, it is sensitive to ethylene, which means that we can use ethylene to ripen the fruit postharvest.

Calcium has a significant effect on fruit firmness and rate of ripening (Table 1). This response has been studied in Florida, Southeast Asia, and Australia. Fruit shelf life can be increased by dipping in 4-5 percent calcium chloride. There is, however, a varietal difference in response, and the response varies from season to season with the same variety. Calcium uptake by fruit is via the xylem and is very dependent upon environmental conditions.

Ripening changes. As mangos ripen there is an increase in total soluble solids from 8.5 to 19 percent, mostly a result of starch conversion to sucrose. Titratable acidity declines dramatically from 3.8 percent to about 0.3 percent. Citric acid is the major titratable acid, followed by tartaric and malic acid in lower quantities. Vitamins C and A increase during ripening. Phenolics, which give the tart flavor, decline, reducing astringency.

Climacteric fruits like mangos, bananas, and apples go through a marked change as they ripen. Fruits harvested mature green with a touch of color have already begun the ripening process. The climacteric fruit is characterized by a dramatic rise in respiration as skin color develops (Figure 1), while fruit firmness declines. Citrus fruits and pineapple, on the other hand, are not climacteric and do not exhibit such dramatic changes. Mangos given an ethylene treatment ripen several days ahead of nontreated fruits

Table 1. Response of 'Julie' mangos to calcium dip treatments (Mootoo, Tropical Science 31:243-248).

% Ca	Shelf life (days)
0	4.5
2	8.6
4	9.4
6	14.6
8	14.8

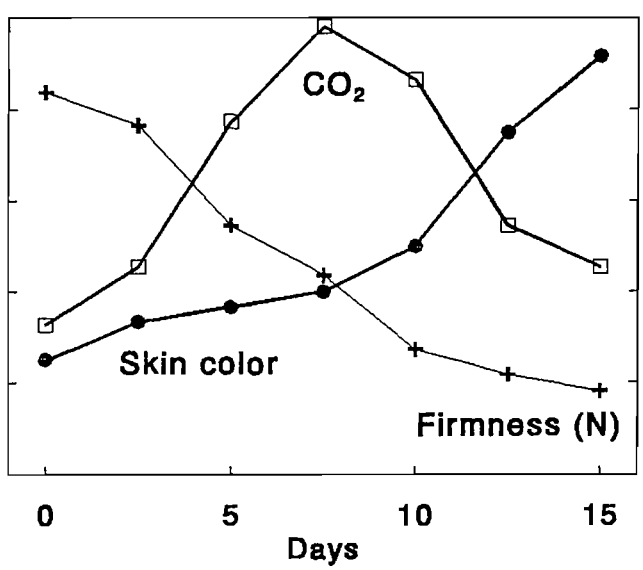

Figure 1. Changes in respiration, skin color, and mango fruit firmness after harvest.

(Figure 2). Ethylene is a major atmospheric contaminant, with cars being the main source. There is a dramatic loss of water during mango ripening (Figure 3), and we need to develop ways to reduce this shrinkage. Consumers object to buying fruit that is shriveled. In general, fruit that have lost 7 – 10 percent of initial weight show some shriveling. The example shown in Figure 3 is rather severe and represents a maximum.

Maturity indices. A number of indices have been tried to estimate when the fruit is at mature green stage and ready to harvest. Immature fruit do not ripen to full flavor and aroma. Proposed maturity indices include softness of cheeks, peel color (the most common), and shoulder development (roundness). Starch content is of use but is destructive and difficult to measure. These indices are all observed at an advanced stage, and each mango variety has its own criteria. You can also count the number of days from flowering, but variability is large. Specific gravity has been suggested as a means of dividing fruits into ripeness classes, but it does not work with all varieties.

Storage temperature. The recommended storage temperature for mangos is about 12.5°C (about 55°F). Even at 12°C you see softening with time (Figure 4); at 17°C, softening is more rapid, but you still get some delay in softening. At room temperature (22°C), fruit would be ripe in about six days.

Chilling injury is a major problem below 12.5°C, particularly below 10°C. Not only do you see skin scald and pitting, but the fruit is more susceptible to decay (Figure 5). After 20 days of refrigerated storage, then removal to ambient temperature, fruits stored at 0°C show a sharp rise in disease incidence, with fruits stored at 10°C showing a somewhat slower increase. In this particular case, those stored at 5°C had a slight delay in disease development, for unknown reason.

Chilling injury is the major postharvest disorder of tropical products, occurring at various steps in the shipping chain. The reason for this is a lack of appreciation of the recommended mango storage conditions by people at those various steps in the handling chain. The people who store the fruit under excessively cool conditions may not see any problem, but the next person will likely see deteriorated fruit. Chilling injury is a temperature and time function (Figure 6). You can store mangos at 0°C for a few days, but if you store the fruits for a longer period, a threshold is reached where they are unable to recover from the effects of the low temperature and are damaged. At 10°C, mangos can tolerate about 12 days, but after that there is injury, skin scald being one of the first symptoms.

Disorders

Sapburn injury is a major problem occurring at harvest, when you get sap running down the side of the fruit. This needs to be removed, particularly because it can cause damage, trap fungal spores, and act as a site for disease development. Sunburn can be a problem when fruits are exposed to direct sun. It is problem associated with fruit on the

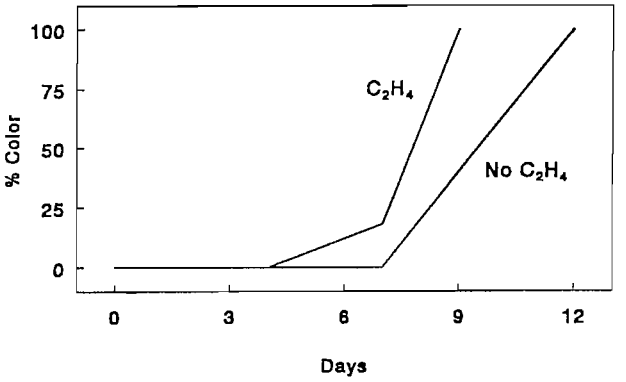

Figure 2. Mango cv. 'Haden' response to a 48-hr exposure to ethylene (100 ppm) (Fuchs et al., 1975, Tropical Science 17:211-216).

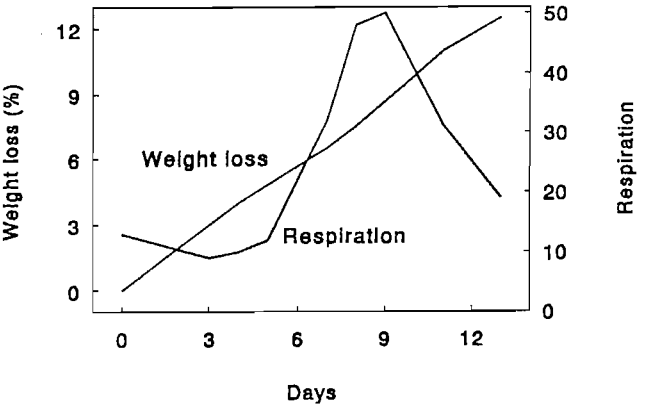

Figure 3. Weight loss from 'Pairi' mango held at 28°C shows a continuous increase, and the rate does not change during the climacteric. Weight loss, mainly water, occurs via stem scars, stomata, and lenticels (Krishnamurthy and Subramanyam, 1973, Tropical Science 15:167-193).

outer areas of the tree canopy and the poor handling of boxes of fruits left exposed to the sun. Hot-water scald is associated with disease control treatments. Bruising is a major problem wherever you go, and is associated with poor handling and improper equipment. Abnormal ripening due to various environmental conditions is not a common problem but occurs intermittently.

Internal disorders include stem-end cavity, a breakdown of the fruit flesh around the stem, the cause of which is unknown. Jelly seed, where the flesh around the seed becomes mushy and off-flavored, is common and variety specific; for example, 'Tommy Atkins' is very prone to this disorder. There are a number of possible causes for jelly seed, none of which has been accepted. Impact damage leading to internal breakdown without any surface disruption is a common problem in rough handling. Premature ripening is a major problem related to variety, environment, harvesting, and management conditions.

Postharvest Treatments

Waxing and wraps vary in their effectiveness in improving postharvest qualities of mangos. Wraps control oxygen transfer and water loss, and are much better than waxes in controlling water loss. Ethylene is used by some countries in a rather crude fashion; the Thais use acetylene generated from calcium carbide, which has the same effect as ethylene. Hot water treatments are usually used for disease control but also may be used for fruit fly control. Irradiation is another treatment that has been researched in great detail. Fungicides are also used to control postharvest diseases; the range of approved fungicides is now very limited in the U.S.

Table 2. Effect of irradiation on scald and internal breakdown development on two varieties of mangos (Spalding and von Windeguth, 1988, HortScience 23:187-189).

	Scald severity		Internal breakdown	
Grays	Tommy Atkins	Keitt	Tommy Atkins	Keitt
0	1	1.5	3	42
150	1.3	2.7	3	48
250	1.8	3.3	20	41
750	6.3	6.5	22	37

Fruit disorders resulting from irradiation treatments are varietally related (Table 2). Scald severity at 150 Grays is more dramatic on 'Keitt' than on 'Tommy Atkins'. Also, internal breakdown can be made more severe by irradiation, as was observed with 'Tommy Atkins'.

Postharvest Constraints

Varietal selection is a major factor influencing postharvest handling, and postharvest characteristics need to be considered when varieties are evaluated and selected. A maturity index needs to be developed for each commercial variety. Storage limitations must also be considered. My personal view is that anyone in the handling chain who has mangos for a day has them for 20 hours longer than needed. Fruit flies and the mango seed weevil

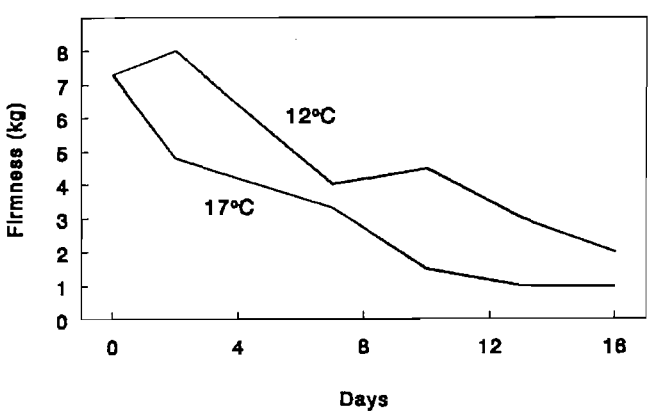

Figure 4. Effect of storage temperature on the rate of decline in mango cv. 'Tommy Atkins' softening (Medlicott et al., 1986, Jour. Sci. Food Agric. 37:469-474).

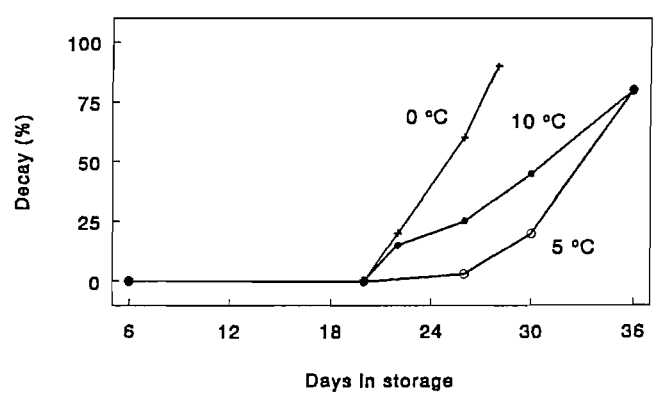

Figure 5. Effect of 20 days storage at various temperatures on 'Taimour' mango susceptibility to decay as a result of chilling injury (Abou Aziz et al., 1976, Scientia Horticulturae 5:65-72).

are two major problems, for which we need quarantine treatments. Before these treatments are developed, we need to have selected commerical varieties. Disease, particularly anthracnose, is also a major problem postharvest, though heat treatments do help to control disease.

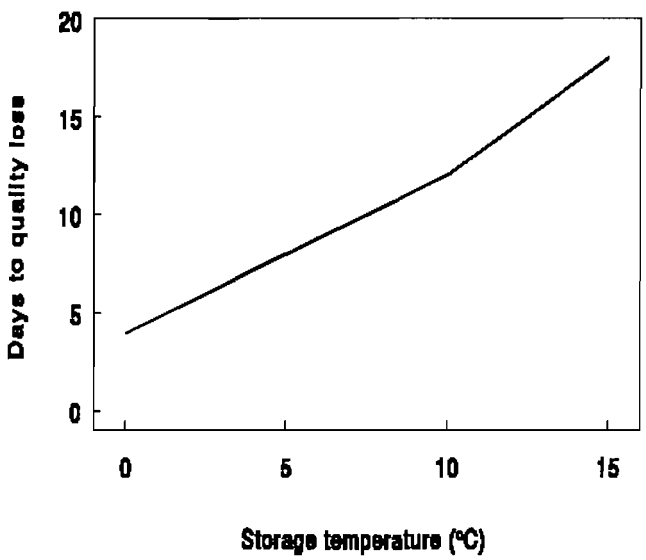

Figure 6. Relationship of storage temperature and days in storage to the development of the first symptoms of chilling injury: no symptoms below the line, increasing symptoms above the line (Abou Aziz et al., 1976, Scientia Horticulturae 5:65-72).

Q: Can calcium be applied preharvest?

A: You can apply calcium, but you may not get much into the fruit. When dipping fruits postharvest, you can get good control of calcium intake. Calcium uptake into fruits is not fully understood. Movement into the fruit depends very much on water movement into the fruit. Under certain conditions, such as high humidity, you don't get much water moving into the fruit. In papaya, when the fruits are sprayed weekly, higher levels occur on the skin but not in the flesh, which is where we want it. In mangos we are able to get it into the flesh with postharvest dips. There are a number of possible pathways for calcium to enter the fruit during postharvest dipping. The lenticels may allow some uptake, along with movement through the cuticle and stomata; there may be some stem uptake.

Q: Does calcium treatment leave any residues?

A: You may get a white coloration, but it can be washed off.

Dr. Davenport: Calcium uptake, and water uptake, occurs readily through the lactifers in mango. These are latex channels all through the fruit that converge at the stem and go up into it. When you snap the stem, the latex squirts out of the fruit. If you have a fruit that is somewhat water deficient, the latex will exchange with water quite readily.

Q: Is there any way we can predict when to pick the fruit in relationship to the amount of sap that comes out?

A: I'll let Tom Davenport answer that. During ripening, the lactifers start to break down, and you start to get some weeping of latex from these openings.

Dr. Davenport: The viscosity of the latex is dependant upon the fruit maturity. Immature fruits squirt sap many feet when you snap the stem, but mature fruits will just weep slightly. Fruits maturing on the tree may leak sap when the fruits are moved about by winds. The sap that drips down the skin may serve as a sticker for *Colletotrichum* spores and result in anthracnose damage later on after harvest.

Q: So calcium dips are the answer for improving postharvest life?

A: Not with all varieties. We can't get much calcium into papaya, for example, but we seem to be able to get it into mangos. It varies with the variety, however. There are two ways: simple dipping, or applying a vacuum to the bath. It is easier to just put the fruits in a deep bath than to apply a vacuum, and you get the same effect. They have facilities to treat apples by the pallet load. Certain fruits or varieties of fruits can get too much calcium from dips, developing a browning flesh disorder.

Q: What form of calcium do you use?

A: Calcium chloride. A 3-5 percent solution is generally adequate. It is very soluble. It is also very deliquescent and difficult to keep dry in storage.

Q: Can there be a problem with bacterial contamination during calcium dipping?

A: Yes, this has been considered with apples, although calcium dips are usually associated with decreases in postharvest disease.

Dr. Davenport: I have had problems during experiments with avocado, where *Erwinia* was sucked in with the calcium, while the fruits dipped into just water were not contaminated. The calcium-treated fruits were delayed in ripening, but they were destroyed by the bacteria in the process.

A: You don't see the same problem in apples. I should point out that the calcium is not evenly distributed within the fruit, even if you dip under vacuum. Apples are in storage for as much as six months, and there is time for redistribution of calcium within the fruit, although we do not know how that occurs.

Q: Is there any sacrifice of flavor for longer postharvest ripening with calcium dips?

A: It hasn't been reported. You do get a firmer fruit which takes longer to ripen, which makes it difficult when you have undipped and dipped fruit in the postharvest chain, with different schedules for ripening. The dipped mangos tend to be firmer than undipped ones at a given stage of ripeness.