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## POST HARVEST HANDLING OF MANGO – A REVIEW

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**Abstract**

The mango is an important fruit grown in many tropical and sub tropical regions of the world. India is the largest producer of mango covers about 35 per cent of area and accounts 22 per cent production of total fruits in the country and has been acclaimed as the "King of fruits". Besides delicious taste, excellent flavour and attractive aroma, it is rich in vitamin A and C. Unfortunately, 25-30 % of mango produce is lost due to improper post harvest operations; as a result there is considerable gap between the gross production and net availability. If proper care is taken from harvesting to final marketing, considerable losses can be minimized and better quality fruit can reach to consumers, ensuring higher returns to the growers. Many attempts have been made to maintain the post harvest health of fruit which includes hot water treatment, irradiations, use of growth regulators and chemicals, packaging, storage at low temperature and modified atmosphere packing and controlled atmosphere. The objective of this paper is to review the current handling, storage and treatment techniques for mangoes for reducing the post harvest losses.

**Key words:** Mango, ripening, heat treatment, MAP & CA, growth regulators, chemicals, radiations, fruit coatings, packaging, post harvest diseases.

**Regulation of fruit ripening**

Treatment of mature green fruit with ethylene shortened the period from picking until full colour development (Fuchs et al., 1978). The response of mango fruits to post harvest Ethrel treatment is not consistent throughout its life cycle, and its age at the time of harvest has obvious effect on ripening (Barmore, 1974; Pandey and Singh, 1976). Ethrel (10,000 ppm) treated fruit of early, middle and late maturing varieties ripened in 48-65, 70-92 and 72 h, respectively, as compared 118 h in control. Similarly Ethrel in hot water was found to be effective in uniform ripening in late-maturing mangoes cv. Mallika (Kalra and Tandon, 1983). The use of pre-storage treatment of nitrogen had a beneficial effect on retarding ripening, although as storage progressed, this effect was lost (Burdon et al., 1994). (Prakash and Pandey, 2000). Hot water ( $51 \pm 1^\circ\text{C}$ ) treated fruits when packed in LDPE perforated film could keep their firmness for 17 days at  $15 \pm 1^\circ\text{C}$  (Cao and Wang, 2000).

## **Heat treatment**

Post harvest heat treatment has been used to regulate the ripening of fruits and control decay losses during storage. Vapor heat treatment is accepted quarantine treatment for export of mangoes. It resulted in better marketability of fruits due to uniform peel colour development with enhanced ripening (Pal et al., 1999). It also manages the infestation of fruit flies. It involves stacking the boxes of freshly harvested fruits in room that is heated and humidified by injection of steam. The temperature and exposure time are adjusted to kill all stages of insect without damaging the fruit (Jacobi et al., 1993). Buoio mangoes held in hot water at 52 °C for 5 min or 10 min and packed in plastic bags resulted in reduction of post harvest diseases and disorders compared with untreated fruits during storage at 12 °C (Nguyen et al., 1998). In highly susceptible cultivars such as Doodath and Rose, the decay losses could be controlled effectively with hot water treatment along with fungicide Benomyl (Passam, 1982). In Tommy Atkins mangoes, Nyanjage et al. (2001) observed decreased fruit reflectance and storage time and increased storage temperature. Likewise, heat treatment (44 °C and 50 % RH for 160 min) delayed ripening in Manila fruits, as measured by colour and texture changes, compared to control (Yahia et al., 2000). Hot water treatment resulted high correlation between carotenoid content and the colour attributes, hue and chroma (Zambrano et al., 1998). In mango cv Tommy Atkins, after cold storage and ripening, the heated fruits had a lower incidence of diseases and developed less chilling injury than non heated fruits (Ketsa et al., 2000). Washing of mango fruits with 75 ppm chlorine, and then dipping in hot water at 53°C for five minutes resulted in longer storage life and higher organoleptic rating (Suhardjo et al., 2000). Hot water (52 °C for 15 min) together with carbendazim treated fruits could be stored for 26 days at 12 °C without any anthracnose infection (Prakash and Pandey, 2000). Hot water (51 ± 1 °C) treated fruits when packed in LDPE perforated film could keep their firmness for 17 days at 15 ± 1 °C (Cao and Wang, 2000).

## **Fruit coatings**

Fruit waxing is a treatment, which coats the fruit surface with a thin layer of wax. It improves the fruit appearance and extends the shelf-life by reducing moisture and weight loss and modifying internal atmosphere (Brown, 1986; Castrilla and Bermudez, 1992). In South Africa, mangoes to be exported are waxed prior to packaging. In Australia, some commercial products could be used on Kensington mangoes to reduce sap burn, without unacceptable effects on fruits quality (Shorter and Joyce, 1994). Mango cv. Haden fruits coated in 2 % fatty acids+ 1 % carbendazim + 0.1 % calcium caseinate retained fresh appearance for the longest time (Sanudo et al., 1998). Wax emulsion treatments increased the shelf life of mango fruit to 9-10 days compared with 6 days for controls (Roy et al., 1980). Treatments of polysaccharides coating consisted of modified starch, cellulose and chitosan resulted in retarded colour development, lower acidity greater firmness and reduced loss in weight (Kittur et al., 2001). Fruit fly proliferation was avoided and anthracnose incidence was reduced in Manila mangoes coated with a mixture of Malodextrin, CMC, propylene glycol and sorbitan esters (Diaz-Sobac et al., 2000). The use of wax (Prima fresh 50 E wax) reduced fruit dehydration and allowed fruit be stored for at least 21 days at ambient temperature and humidity, maintaining quality and acceptability, whereas unwaxed fruits suffered quality deterioration (Alache and Munoz, 1998).

## **Radiations**

Irradiation involves the use of ionizing energy such as gamma rays, x-rays and microwaves to disinfest mangoes to ensure quarantine security (Burditt, 1994). Irradiation is a potentially important technique to reduce post harvest spoilage. Disease control may be more effective in cultivars with greater tolerance to irradiation (Johnson et al., 1990). In Kensington Pride mangoes,  $\gamma$ -radiation caused delay in ripening of less mature fruit, characterized by inhibition of skin, degreening, and slow reduction of titratable acidity, while the fruits at the climacteric stage were unaffected (Boag et al., 1990). Better response was obtained by using lower doses of irradiation (25 krad) in combination with other treatments such as antitranspirant

vaporgard (Hassaballa et al., 1984). Activity of NADP malic enzyme, which usually increases during ripening, was significantly diminished but not delayed by  $\gamma$  irradiation with 0.75 kGY. Hot water treatment (55 °C for 5 min.) and irradiation dose of +0.75 kGY was excellent for the control of anthracnose and soft brown rot during storage and transport (Dubery et al., 1984). Irradiation treatment destroyed seed weevil in Haden and Pairi mangoes (Upadhyay and Brawbacker, 1966).

### **Growth regulators**

Growth regulators generally regulate the fruit ripening process and maintain the fruit health during storage. Post harvest dip of mangoes in N<sup>6</sup>-benzyladenine (BA) at  $2 \times 10^4$  M for 6 h delayed ripening by 2 days and enhanced sucrose, citric, malic and succinic acid contents and changed the levels of free amino acids, especially alanine (Passera and Spetooli, 1980). Pre-harvest spray of GA<sub>3</sub> (50 or 75 ppm) or etrel (500 ppm) advanced the fruit maturity and ripening by 2 weeks, significantly improved fruit quality, reduced spoilage losses during storage and there was no fruit fly damage with PGR treatments (Kumar and Singh, 1993). Mango fruit treated with 0.5 % ethylene solution at 50°C for 5 minutes, kept in air conditioned room with ethylene for 16 h and thereafter stored in ambient temperature exhibited enhanced ripening process and improved eating quality (Shangguan et al., 2001). Hot air brushing with prochloraz followed by application of 2, 4-D (75 to 175  $\mu\text{g ml}^{-1}$ ) reduced post harvest diseases (*Alternaria*, *Phomopsis* spp. and *Lasiodiplodia*) by 50-70 % and improved fruit quality during prolonged storage (Kobiler et al., 2001). Treatment of 'Kensington Pride' mango fruits with Salicylic acid (2000 mg/l) caused reduction in anthracnose severity. The fruit skin colour and firmness changes were also slowed down significantly due to inhibition of mango fruit ripening by salicylic acid (Zainuri et al., 2001). Treatment of mango fruits with Methyl jasmonate vapour ( $10^{-5}$  M MJ for 20 h at 20 °C) reduced chilling injury symptoms and enhanced skin colour development (Gonzalez et al., 2001). Fruits treated with GA<sub>3</sub> and packed in perforated polythene bags had a storage life of 11 days (Ahmad and Singh, 1999). The 250 ppm GA<sub>3</sub> treatment was most effective in delaying fruit rot and increased TSS. However highest marketable value was observed in fruit treated with 250 ppm GA<sub>3</sub> and 500 ppm Bavistin alone and in combination (Kumar, 1998).

### **Other chemicals**

Besides growth regulators many other chemicals are also used which affects the post-harvest physiology of fruits and increased the shelf-life of fruits. Calcium has been used to delay ripening and senescence. Treatment of Haden mango with calcium significantly delayed the fruit ripening, increased fruit firmness, reduced rot and improved quality. Two pre-harvest spray of CaCl<sub>2</sub> (0.6%) on Dashehari mangoes were effective in reducing cumulative weight loss, maintaining glossy appearance, flesh texture, decreased the rate of respiration, and increasing the shelf life by 2-3 days (Singh et al., 1993). Tirmazi and Wills (1981) were able to delay ripening in Kensington Pride mangoes by one week, through vacuum infiltration of 4 % CaCl<sub>2</sub>. There was reduction in percent loss in weight, controlled the disintegration of green color, and arrested carotenoid development. The middle lamella structure was best preserved with CaCl<sub>2</sub> (5%) and treated fruit showed lower activity of polygalacturonase and beta- galactosidase (Evangelista et al., 2000). Perforated polythene wrapping, CaCl<sub>2</sub> (1.5%) and Ca(NO<sub>3</sub>)<sub>2</sub> (1.5 %) were the most effective treatments for improving the storage life of fruits (Singh et al., 1998). Hot water treatment using 1 % CaCl<sub>2</sub> retarded fruit ripening by 5-8 days and reduced spoilage (Sanudo et al., 1998). Fruit quality was best when stored at 10°C with vermiculite- KMNO<sub>4</sub> treatment (Briceno et al., 1999).

### **Packaging**

It includes the packing of fruits in polythene packs, crates, wooden boxes, baskets and CFB boxes. Packing provides the convenient sized carriage units for product, protects individual fruit from contact rub and compression damage and excludes dirt, pests and contaminants. Sealing of mature-green mangoes in semi-permeable polythene bags is not recommended as it deteriorates the fruit quality in terms of taste and appearance (Straten and Oosthuysen, 1994).

Polyethylene packaging gave the best storage to the product retaining moisture content and sensorial attributes (Arnaud-Vinas, 1995). Packaging is also a marketing tool. Country of origin, cultivar, grower, packing shed, market agent, count and class should be required for labelling. Cartons that proposed to be used for export of produce must be strong, clean, unbroken and fresh. The water absorption capacity of material should be assessed, as excess absorption will lead to collapse on the pallet (Litz, 1997). Immature fruits stored in LDPE bags at 10 °C maintained good quality characteristics with acceptable flavour of minimal changes in chemical composition up to 21 days. These bags are effective in reducing the rate of fruit softening during the storage (Singh et al., 2001). Fruits packed in perforated polyethylene film could keep their freshness for 17 days at 15 °C (Pina et al., 2000).

### **CA and MAP storage**

Mango fruit could be stored under MAP conditions in cold storage to retard ripening process and achieve the longest possible storage period with the most proper fruit quality (Zambrano et al., 2000). CA at 6 % CO<sub>2</sub> and 2 % O<sub>2</sub> was promising for extending the shelf-life of mangoes cv. Kensington Pride (Lalel et al., 2001). Alves et al. (1998) reported that a film with higher rate of permeability to gases should be used to counterbalance respiration with keeping O<sub>2</sub> and CO<sub>2</sub> levels within tolerance limits of mango. Ripening of mango fruit was markedly delayed and fruit storage life extended when the pressure in the storage chamber was below 100 mm Hg (Apelbaum et al., 1978). Controlled atmosphere storage slowed the yellowing of both peel and flesh. The best conditions for CA storage were 4 % CO<sub>2</sub> and 6% O<sub>2</sub> followed by ripening at 13°C for cv. Rad (Noomhorm and Tiasuman, 1995). Respiratory metabolism and chemical composition of ripe fruits were not affected as a result of storage in 2 % and 5 % O<sub>2</sub> atmosphere for up to 4 weeks at 15 °C (Shukor et al., 2000). Manila mangoes were exposed to CA (0 KPa O<sub>2</sub> + 50 KPa CO<sub>2</sub>) at temperature ranged from 40-49 °C for 160 min, cooled in water at ambient temperature and than stored at 10 °C and 80 % RH for up to 20 days. CA is tolerated by Manila mangoes at below 44 degree C (Zaleta and Yahia, 2000). Mango fruits stored in MAP showed considerable reduction in lenticel rotting after 3 weeks at 12 °C (Rosa et al., 2001). Ethylene removal in MAP showed minimal effect on browning or yellowing of the fruit skin and softening, while fruit decay was inhibited up to 12 days of storage (Xiao and Kiyota., 2002). Ethephon induced fruit ripening combined with modified atmosphere packaging improved fruit quality and prolonged shelf-life of mango (Singh et al., 2001). Treatment with 35% CO<sub>2</sub> for 24 hrs at 20 °C enhanced the level of antifungal compounds and delayed decay development. (Prusky et al., 1993).

### **Low temperature storage**

The extension of storage life under cool temperature reduces the respiration rate and possibly lowers the production of ethylene. However, mango, being a subtropical crop, is susceptible to chilling injury at lower temperatures. Delay in placing mango fruit in cool storage after harvest can result in fruit being soft on arrival at ports and distributors overseas (Oosthuysen et al., 2000). The storage period for ripe and mature green Carabao, Pico and Tommy Atkins mangoes, was found to 18-21, 23-26 and 35 days, respectively at 10°C (Valmayor, 1972). During cold storage at 12 °C, the ripening was retarded more effectively in immature than mature fruits of Amolie and Kent cultivars, whereas Sensation mangoes ripened rapidly during cold storage, regardless of fruit maturity and can be stored at 4°C for 3 weeks without deterioration in quality (Seymour et al., 1990; Straten and Oosthuysen, 1994). The immature fruits had superior storage capacity at 12 °C than the fruits harvested at advanced stage of maturity. However, during ripening at 25 °C, immature fruits failed to develop full ripeness characteristics while mature and half mature ripened well (Medicott, 1990).

### **Chilling Injury**

Sometimes storage of fruits at a temperature below than certain critical temperature causes the injury to fruits. Storage of mango fruits below a temperature of 10 °C usually causes chilling injury, such as pitting on the surface and darkening and softening of the tissues (Hulme, 1971). Dipping of mango fruits cvs. Langra and Dashehari in hot water controlled the chilling

injury during low temperature storage. The enhanced resistance to chilling being associated with higher fruit TSS content (Mukherjee and Srivastava, 1979). Chilling injury can also be reduced by creating modified atmosphere (5 % CO<sub>2</sub> and 10 % O<sub>2</sub>) with use of microperforated polyethylene or Xtend film (Pesis et al., 2000). Zi Hua mangoes developed chilling injury during storage at 2 °C but fruit stored at 8 °C developed no chilling injury symptoms (Ji et al., 1994). Treatment with exogenous putrescine (PUT) increased endogenous polyamine level, inhibited ethylene production and maintained superoxide dismutase (SOD) activity in the pericarp at a higher level, thus retarding the increase of malondialdehyde (MDA) content and membrane permeability and postponing the occurrence of chilling injury (Zhang et al., 2000). Chilling injury causes the leakage of metabolites such as amino acids, sugars, and mineral salts from the cell structure (Wills et al., 1981). Kane and Marcellin (1978) observed chilling injury symptoms after 10 days storage at 4 and 8 °C, and succinate oxidation capacity of mitochondria decrease, the molar ratio of palmitoleic acid/palmitic acid, the predominant fatty acid mitochondrial lipids, was observed to be accompanied by succinate oxidation decrease and the induction of chilling injury.

#### **Post-harvest diseases and control**

A number of field and storage room acquired diseases appears generally on the fruit surface which leads to heavy post harvest losses. The major ones are stem-end rot, anthracnose, *aspergillus* and *Rhizopus rots*. Mangoes harvested in wet weather require careful handling to ensure adequate diseases control and to avoid brush damage. It was observed that rain on fruit at harvest increased disease severity resulting in reduced efficacy of Benomyl treatment against anthracnose (Madan and Ullasa, 1991; Johnson et al., 1994). The decay of mango fruits was reduced by 94.7, 92.0 and 84.3 percent in cvs Dashehari, Langra and Alphonso, respectively treated with Carbendazim (Sharma and Badiyala, 1994). Treatment of fruits with 0.1 % Carbendazim resulted in reduction of decay incidences for stem end rot and anthracnose (Gajbhiye et al., 2000). Dipping of mature hard green mangoes in heated solution of Mancozeb (3g a.i./l) gave excellent control of stem end rot infections and also the residue levels of treated fruits was within recommended minimum residue limits (Meah, 2000). The best control of stem-end rot was obtained with Thiabendazole 0.1 % + ethrel at either 2500, 5000 or 7500 ppm (Kalyanasundaram and Parthasarathy, 1977). Application of CaCl<sub>2</sub> reduced anthracnose symptoms but did not increased fruit shelf-life of Tommy Atkins fruits (Junior and Chitarra, 1999). Anthracnose could be controlled by dipping the fruits in Benlate in cold water (Krishnamurthy and Krishna Rao, 1983) or Benomyl in hot water at 53 to 55 °C for 5 min. or 1000 ppm solution of methyl thiophenate (DeCastro et al., 1985; Oosthuysse, 2000). Sampio et al. (1980) reported that dipping of mangoes in hot water at 50-55 °C for 5-30 min containing Benomyl (0.1%), TBZ (0.08%), or captan (0.135%) resulted in controlling the anthracnose disease during storage. Ectaconazole treatment was found to be most effective for control of post harvest decay in Tommy Atkins and Keitt mangoes (Spalding, 1982). Germination of spores of *Penicillium cyclopium* isolated from spoiled ripe Alphonso mangoes were inhibited with Bavistin treatment (Palejwala and Modi, 1985).

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