Post-harvest management of mango for quality and safety assurance

Guidance for horticultural supply chain stakeholders
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INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most important and popular fruits in Bangladesh and is referred to as the “king of fruits” because of its excellent overall eating characteristics. It is consumed as a fresh fruit, in the frozen, preserved or dried forms or is processed into juices, purees, chutneys and pickles. Ripe mangoes are best eaten as fresh fruit, usually as a dessert and are used in the production of confectionery, ice cream, and bakery products. Mango contains a variety of phytochemicals and nutrients. The fruit pulp is high in dietary fiber, Vitamin C, provitamin A, carotenoids and diverse polyphenols.

The main varieties of mangoes produced in Bangladesh are Fazli, Gopalbhog, Khisrapat, Langra and BARI Aam 2, 3 and 4 (Photo 1). These are table varieties intended to be eaten as ripe cut fruit. Unripe mangoes are usually added to a dal or curry to enhance flavor.

Photo 1. Examples of mango varieties grown in Bangladesh

The major growing regions are in Rajshahi, Chapai Nawabgonj, Nawabganj, and Dinangpur which are far from the consumption centers of Bangladesh like Dhaka. Maintaining the quality and ensuring the safety of harvested mangoes from the farm until the fruit reaches the consumer should be the prime consideration of all stakeholders in the mango supply chain. This will also reduce the levels of post-harvest loss in the supply chain.

IMPORTANCE OF POST-HARVEST HANDLING

Losses in quantity and quality (or post-harvest losses) occur after harvest at different points in the handling chain. A loss assessment study conducted under this project in 2015, showed that losses amounted to 31 percent due mainly to decay that manifested at the retail level (Photo 2). Bruising and weight loss which represent loss in marketable weight are the other nature of losses. These losses can be attributed to poor harvesting, rough handling, and poor packaging and transport conditions. The high incidence of decay mainly in the form of anthracnose and stem end rot can be attributed to the high level of pre-harvest infection due to improper disease management during production.

Anthracnose is a latent infection and symptoms of the disease become apparent only as the fruit ripens.
Post-harvest losses represent a waste of the resources – land, labour, energy, water, fertilizer, etc. that went into producing the crop. Every effort must therefore, be made to minimize these losses. Unless these losses are minimized, the gains from production will be offset and potential income cannot be realized.

Moreover, consumers are now increasingly paying attention to quality and safety. They are looking for and are willing to pay a premium price for good quality mangoes that are safe (Photo 3). Preservation of the nutritive value goes hand in hand with the prevention of quality deterioration.

With the changing tastes and lifestyles of consumers, and the need to reduce the high levels of post-harvest losses, the need for good post-harvest handling becomes a matter of concern. The continuous growth of supermarkets and hypermarkets and the demands from institutional buyers require giving more attention to post-harvest handling of mango to satisfy demand for better quality and safe produce.

Photo 3. **Good quality mangoes desired by consumers**
CHARACTERISTICS OF MANGO FRUIT THAT IMPACT ON POST-HARVEST LIFE

Mango fruits undergo programmed changes

The mango fruit, being a living tissue is subject to continuous change until it completely deteriorates. The process of ageing and eventual dying in living tissues is called senescence. There are programmed changes in the fruit like ripening that influence appearance, flavor, texture and nutritive value that cause them to age (Photo 4). While some changes are desirable (e.g., changes associated with ripening), most are deteriorative. These post-harvest changes cannot be stopped but can be slowed down within certain limits.

In general, the application of post-harvest technology can only maintain, not improve or little if any, the quality of harvested fruit.

The main objective of applying any post-harvest technology is to keep fruit quality and safety as high as possible until it reaches the final consumer.

Mangoes lose water

The pulp of the mango fruit consists mainly of water. When harvested, the fruit can no longer replace the water that is lost through respiration. Mangoes are, therefore, subject to shriveling (Photo 5) and weight loss and consequently loss in marketable weight. Exposure of the fruit to the sun results in rapid water loss.

Photo 4. Stages of ripeness of mango fruit

Photo 5. Exposure of fruit to the sun leads to shriveling and loss in marketable weight
Mangoes are prone to decay

Fruits are susceptible to attack by insects and decay-causing organisms (called pathogens) which can eventually accelerate their deterioration. Rough handling may create wounds which serve as entry points for pathogens. Field containers like bamboo baskets (Photo 6) have rough and pointed edges that could damage the fruit, hence the need to line the containers with clean plastic sacks or jute sacks to prevent injury on the fruit.

Mangoes are prone to injury

Mangoes are susceptible to damage. When damaged, all of the biological processes within the fruit, like respiration and ethylene (the ripening agent produced naturally by mangoes) production proceed at a rapid rate leading to rapid deterioration. Moreover, damage may not be apparent externally but can show up later in the handling chain typified by the failure of the damaged portion to change color and the presence of a starchy layer just beneath the peel of the ripe fruit (Photo 7).

Photo 7. Rough handling leads to damaged portion with white starchy areas and failure to turn yellow
HARVEST MANAGEMENT PRACTICES

A fruit is considered mature when it has reached a stage of development such that after harvesting and during post-harvest handling, both the external and internal quality attributes are acceptable to consumers. Harvesting at the proper stage of maturity, the manner in which the fruit is detached from the tree and the time of harvesting are important considerations during harvesting.

Maturity indices

Mango fruits harvested at the correct stage of maturity develop good peel and pulp color and have full flavor and aroma at the ripe stage. Mangoes harvested at an immature stage of development can be induced to ripen but the quality of the ripe fruit and particularly the flavor, is inferior.

Maturity indices are an indication of the readiness of the fruit for harvest. There are several methods of assessing the maturity of mangoes. These include:

✦ **Shape** – flat shoulder at stem end; fullness of cheeks (Photo 8a).
✦ **Peel appearance** – presence of bloom (white powdery substance on the peel, Photo 8b); change in peel color from dark to light green (for some varieties).
✦ **Pulp color** – light creamy yellow pulp.

Photo 8. **Fullness of cheeks, flat shoulder at stem end (a) and presence of bloom as indices of maturity (b)**

Photo 9. **Latex stains in mango due to improper time of harvesting**
Time of harvesting

The recommended time for harvesting mature fruits is from 9:00 a.m. to 3:00 p.m. to minimize latex flow. Latex stain (Photo 9) which leads to unsightly latex burns are major causes of rejection especially if fruits are to sold on export and premium markets like supermarkets and hotels. Harvesting immediately following rain, should be avoided.

Photo 10. Recommended mango picking tool with net at the end (a) and plastic crates as field containers (b)

Harvesting method

Mango fruits are generally harvested manually using a picking pole with net bag attached for catching the fruit once it is severed from the branch (Photo 10). The harvested mangoes are then transferred to a collecting container that is lined with clean plastic or jute sack to prevent damage on the fruit (Photo 10c). Plastic crates are the most suitable field containers. Harvesting tools and aids such as field containers must be clean to avoid contamination.

Minimizing damage and deterioration during harvesting and field handling

✦ Harvester must wash their hands before harvesting. Good personal hygiene must be practiced to avoid cross-contamination of the produce.
✦ Line collecting baskets with clean plastic sacks or newspaper to protect fruits from punctures and cuts caused by sharp or protruding edges of the baskets. Cuts and punctures provide avenues for water loss and invasion of decay-causing organisms. Wounded fruits also produce a lot of ethylene that hastens the ripening process.
✦ Gently lower filled collecting baskets to the ground. Do NOT pour harvested fruits onto the ground (Photo 11) – pour on to a clean tarpaulin. Harvested mangoes should not get in contact with the soil in order to avoid microbial contamination.
✦ Minimize damage and avoid contamination of fruits with soil, pathogens, fertilizers or other agro-chemicals.
✦ Avoid exposing harvested fruits to the heat of the sun to prevent heat build up.
✦ Leave 2-3 cm of the stem (pedicel) attached to divert latex flow away from the fruit.
POST-HARVEST OPERATIONS

Post-harvest operations refer to activities done to the fresh produce to meet the requirements of the target market. These operations can be done in the field, in collection centers or in a packinghouse (Photo 12). The packing area should provide adequate protection from sun and rain, kept clean at all times, pet animals should be kept away from the packing area, and all workers should practice good personal hygiene.

The sequence of operations should insure that cross contamination is avoided. The surroundings of the packinghouse should always be kept clean.

Trimming

Trimming refers to the cutting of stem that is left on the fruit (Photo 13). Packing fruits with stems attached may result in latex stains when stems break off during handling. Fresh latex oozes out of the stem end, thus staining other fruits in a pack. Dried latex is difficult to remove.
Delatexing/desapping

Delatexing, also known as desapping, is the removal of fresh latex from the fruit. The steps involved are outlined below:

✦ Remove bagging material from the fruit. One advantage of bagging is that bags can provide immediate protection from latex staining during harvesting.
✦ Trim stem neatly close to the base of the fruit using sharp and clean pruning shears.
✦ Delatexing can be done by either of the following:
  ● Inverting freshly de-stemmed fruits on plastic or steel mesh racks, allowing the latex to drip for 30 minutes (Photo 14a). Do NOT invert fruits on burlap sacks as this may lead to coagulation of latex at the base of the fruit.
  ● Dipping freshly de-stemmed fruits in 1 percent alum solution (one-half kg powdered alum per 50 liters of water) for one minute (Photo 14b). Alum enhances coagulation of the latex when fruit are dipped. Plastic crates can be used to hold the fruits during dipping. Allow fruits to dry before packing.

Sorting/grading

Sorting is the grouping of mangoes based on the criteria of the one classifying and there is no definite set of standards followed. This is the most common practice in selling mangoes. After harvest, mangoes are arbitrarily classified as “Class A” (good quality; for export or for institutional buyers like supermarkets and hotels) or “Class B” (local grade or for domestic market. Grading on the other hand, refers to the classification of mangoes based on the standard criteria accepted by the industry.

Mangoes that are of good quality and safe for consumption are mature, clean, well-formed, free from insect and disease damage, free from mechanical damage (Photo 15a) such as cuts, abrasion and punctures, free from microbial, chemical and physical contamination. Defects, if any, are only minimal as in the case of windscar and latex stain.
Mango fruits with the following defects, on the other hand, are most likely to be rejected (Photo 15b):

✦ insect damaged due to cecid fly, fruitfly and thrips;
✦ with pre-harvest damage such as scab and sooty mold, harvesting and handling damage such as latex stains and burns, bruising, abrasion, compression, cuts and punctures, and prematurely ripened.

Classifiers or sorters should practice good personal hygiene such as washing their hands with soap or detergent before handling the produce. There should also be provision for workers’ comfort during sorting/grading since uncomfortable sitting positions during sorting (Photo 16) may lead to fatigue hence inappropriate sorting procedures.

**Post-harvest disease control**

Anthracnose and stem end rot are the two most important post-harvest diseases of mango fruits (Photo 17). These two diseases cannot be detected at the green stage and symptoms of infection appear only as the fruits ripen. An integrated pre- and post-harvest disease management protocol will ensure adequate control of these diseases.

Photo 16. **Inappropriate sorting and packing conditions**
Hot water treatment (HWT) is by far the most effective post-harvest treatment against the two diseases mentioned earlier (Photo 18). HWT is a non-chemical method of controlling decay. Additional benefit gained from HWT is the removal of fresh latex and dirt adhering on the surface of mangoes.

During HWT, green mature fruits are dipped for 5 to 10 minutes in water heated to 52–55°C (Photo 19). At this temperature range, the disease-causing organisms are killed without injuring the fruit. The effectiveness of HWT is reduced if the temperature drops below 52°C and while temperature above 55°C will cause scalding of the peel of the dipped fruits.

**Procedure for HWT**

- Fill the tank with enough water to completely immerse the crate with fruits in heated water (about 3/4 of the total depth of the tank). Use only clean water for HWT.
- Heat the water to 55°C. Use the thermometer to check the water temperature.
  - Temperature should be checked at different points of the tank.
  - If temperature is uneven, check if the water pump is functioning properly and water outlets are not blocked.
Postharvest management of mango for quality and safety assurance

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Put the mangoes to be treated in plastic crates with holes on all sides and at the bottom. Do NOT overfill the crate. The crate protects the fruits from heat injury resulting from contact with the hot sides and bottom of the tank.

Dip the crates in hot water for 5 or 10 minutes.
- Stir the water occasionally (if there is no pump to circulate the water) to have uniform temperature within the tank.
- The treatment can be shortened to 5 minutes if the mangoes are produced during the dry hot period when conditions are not favorable for infection in the field.

Remove the crates from the tank.
- Cool treated mangoes for 10 minutes in clean tap water if fruits are to be brought to distant markets. Cooling is needed since HWT hastens ripening of the fruit.
- If fast ripening is desired, then fast cooling is not necessary.

Allow fruits to cool and dry before packing. Faster drying can be achieved by placing crates of mangoes in front of blowers.

**Important reminders during HWT**

- Fruits should be treated within 36 hours after harvest to get the maximum benefit of disease control.
- Hot water treatment is most effective against stem end rot when applied while fruit is still fully green.
- Do not allow latex to dry on the fruit before applying HWT since this will aggravate latex burns that develop later.
- Change the water if it becomes contaminated with latex and dirt. Dipping fruit in dirty and latex-contaminated water can increase the incidence of fruit and lenticel damage that develop during ripening.

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**PACKAGING AND TRANSPORT**

**Packaging**

Proper packaging is essential in maintaining produce quality during transport and subsequent handling. The basic functions of packaging are summarized in Photo 20.
Packaging materials should provide adequate protection to its contents, should facilitate convenience in handling the produce, attract consumers and sell the contents, and inform the consumers about the produce inside the pack.

**Packaging materials for mangoes**

Rigid containers such as plastic crates are highly recommended for fresh mangoes since they provide adequate protection against compression damage (Photo 21). They have smooth inside finish and can be easily cleaned. They are also stackable and reusable/returnable. Although more expensive than traditional packaging containers, plastic crates with long-term use (5-6 years), the packaging cost per kg of produce is relatively cheaper.
Semi-rigid containers such as bamboo baskets are also used but these should NOT be over-packed. Overpacking results in compression damage. Baskets should be lined with clean paper, jute sack or any suitable cushioning material to prevent abrasion (Photo 22) and punctures on the fruit since these containers usually have a rough inside finish.

Cartons or fiberboard boxes should be equipped with a vertical divider in the middle and with ventilation holes at the sides (Photo 23) to prevent heat buildup inside the carton. The physical strength of fiberboards decreases as they absorb moisture with time. Recycled cartons should NOT be over packed and over stacked as this results in compression damage and the incidence of premature ripening.

**Photo 22. Poor packaging (a) results in ripe fruits exhibiting damages and defects (b)**

While awaiting transport, filled cartons should not be used as a “resting” area (Photo 24) as this will lead to damage particularly compression and bruising which may not be apparent at the green stage but will show up later in the handling chain especially when fruits are already ripe.
Considerations in the use of plastic crates

✦ Hygiene – plastic crates should be thoroughly cleaned with soap/detergent after use (Photo 25).
✦ Handling – handle with care during loading, stacking and unloading; do not drop. Don’t use as seats when sorting (Photo 26).
✦ Storage – store in a clean area that will prevent harborage of insects and rodents. Store separately from chemicals and farm machinery to prevent contamination. Crates should not be left exposed to the external environment since they will readily wear out (Photo 27).
✦ Do not use as storage containers for chemicals (fertilizers and pesticides) if used for fresh produce.

Photo 25. Plastic crates should be cleaned after use
Transport

The main objective of transportation is to ensure that mangoes will arrive in good condition at the final market. Mangoes must be transported between several points in the supply chain:

✦ Field to collection center.
✦ Collection center to wholesale market.
✦ Wholesale market to retail market.

At all of these stages, good transport practices summarized below, must be followed:

✦ Handle containers gently; they should not be dropped or thrown on to each other.
✦ Containers at the bottom of the stack, should not be used as steps to allow stacking to a greater height especially if semi-rigid containers like cartons are used (Photo 28).
✦ Allow air to circulate in the stacks or piles of packaged produce by providing space in between stacks. If canvass is used as cover, provide space for air to pass through at the bottom and top of stack (Photo 29); Use light colored material as cover as this will reflect heat.
Minimize delays or facilitate the transfer of packages from one part of the market to another; four-wheeled hand trolleys will minimize damage during unloading and transfer of produce packed in plastic crates (Photo 30).

Observe cleanliness of the transport vehicle; produce safety is compromised when:
- there are decaying remains of produce from the previous shipment
- insects and rodents nesting in the vehicles
- vehicle used as storage area of farm implements when not in use (Photo 31).
HANDLING AT WHOLESALE AND RETAIL MARKETS

The wholesale and retail markets serve as the outlets of mango farmers, collectors and other traders. The basic rules that should be observed are as follows:

✦ Unload containers from the transport vehicle under cover/shade with careful handling to minimize mechanical damage.
✦ Re-sort mangoes using sorting table.
✦ Discard culls properly.
✦ Re-grade mangoes according to size, appearance and stage of ripeness as the case maybe, depending on the requirement of the target market.
✦ Display mangoes on clean retail shelves or in clean containers (Photo 32a).
✦ When mangoes cannot be sold in one day, keep unsold mangoes in storage with proper ventilation (Photo 32b).

Photo 31. Transport vehicle used as storage area of farm implements and tools

Photo 32. Mango fruits in retail display (a) and during temporary holding in the wholesale market
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