Training and Capacity Building Recommendations to Improve Postharvest Handling of Agricultural Produce in Bangladesh

Dr. Elhadi M. Yahia, PhD
Emeritus Professor/Senior Scientist/Senior International Consultant on Food Production and Preservation and Postharvest Technology,

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Dr. Elhadi M. Yahia

Dr. Elhadi M. Yahia is a distinguished academic with extensive expertise in postharvest technology, food science, and human nutrition. He currently serves as a professor at the University of Querétaro, Mexico, and as courtesy professor at the University of Florida, USA. Dr. Elhadi holds a PhD in Plant Science from Cornell University, New York and an MSc in Horticulture from the University of California, Davis. He is a member of the GCCA Scientific Advisory Council and provides expert assessments and consultations to the USDA Bangladesh Trade Facilitation project as part of GCCA's implementation of activities to improve storage and handling of perishable goods. Dr. Elhadi conducted a mission to Bangladesh in March-April 2024 where he visited production sites (in Munshiganj, Lalmonirhaat, and Nilphamari Districts) and markets, and consulted with farmers, cold store operators, and food processors.

This paper is a summation of findings and presents a table of recommendations based on Dr. Elhadi's observations and consultations, including techniques for specific products and an outline of a proposed training agenda to improve handling and postharvest treatments, storage techniques, and temperature controls for selected agricultural produce in Bangladesh.

Category	Observation	Recommendation
General (Training)	The value chain of perishable commodities is very disintegrated, with little or no integration between production, transport, storage, marketing, export, and import.	Train and provide consultations to as many sectors as possible at one time to reduce the disintegration between the sectors and promote collaboration.
Precooling	Proper precooling (room cooling, fast-air cooling, hydro-cooling, use of ice, and vacuum cooling) is not used at all for any of the perishable commodities.	Promote proper precooling, especially forced-air cooling and hydro-cooling, crops such as carrots, melons, mangos, and many others very much need this type of cooling.
Design Build	The existing multi-level cold storages offer little or no options for mechanization and fast and easy handling such as loading and unloading making it difficult to establish uniform cold air circulation, cold temperature, relative humidity, and gases such as carbon dioxide and ethylene.	Encourage consideration of alternate designs (single level) for fresh fruits and vegetables and provide information as to the utility of how alternate designs provide a better product for postharvest treatment. If multiple levels of cold storage are built, minimize the number of levels and consider establishing ways to promote adequate cold air circulation, uniform temperature, relative humidity and gases.
Value-Addition	Value addition for perishable commodities, such as pre-selection, washing, disinfection, chemical treatments such as the use of authorized pesticides against insects and diseases, waxing, grading, appropriate packaging including consumer packaging, ripening methods, and quarantine treatments, is minimal for most commodities.	Provide comprehensive training including processing and export procedures as well as production, pre-cooling, storage, and transport.
Production	Some cultivars may not be ideal for fresh consumption or for processing.	Consider the cultivation of proper cultivars for the different purposes including fresh market, different types of processing products, local markets, and export market.
Production	The potato yield is decreasing.	Do not successively plant seeds obtained from the harvested crops and do not cultivate other crops (such as melons and potatoes) as this creates competition between the crops and may lead to disease transmission.
Postharvest	Curing, which promotes the proper development and hardening of the skin (periderm) in potatoes, is not practiced.	Promote the process of curing and conditioning.
Postharvest	Washing and disinfection are generally not practiced[1]. A commonly accepted belief is that carrots should be stored with mud, which is not an ideal practice because soil and mud are a source of disease and infection spores.	Wash all products, except garlic and onions, either before or after storage. Use chlorine at very low concentration (10 to 200 parts per million), especially during the washing process. Other methods such as the use of ozone and UV are also available, although more expensive.
Storage	Thermometer usage is problematic with only air temperature monitoring instead of product (crop pulp) temperature; too few thermometers in the wrong locations; and a disregard for relative humidity.	Provide training and information on the importance of crop pulp temperature (not only air temperature) as well as location and usage; provide or encourage the purchase of adequate types of thermometers.
Storage	Cold stores regularly turn refrigerated systems on and off, purportedly to save energy and reduce costs.	Encourage businesses to avoid turning off the refrigeration system. Energy and costs can be achieved by other means such as better packaging, air circulation,

[1] It is observed that washing garlic produce is often practiced, which should be discouraged. If for any reason washing of garlic is needed, then it should be done after storage, and the garlic should be completely dried after washing and before marketing, preferably by using hot air.

Category	Observation	Recommendation
		better staking system, and better flow and circulation of cold air in the cold chambers.
Storage	Energy costs are high.	Promote potential energy sources to reduce costs including solar energy and alternative low energy cooling systems such as the "CoolBot" system.
Storage	There is a lack of knowledge regarding the optimum conditions and factors influencing the shelf life for practically all commodities.	Educate and train cold storage operators on the appropriate idea conditions for each commodity, and information on the optimum conditions of the different commodities should be made available in the local language.
Design Build	There is no formal, properly designed, established, equipped or functioning packing house in the country, except the central packing house that is not well designed nor functioning as an adequate packing house.	Provide support/advisory services to companies seeking to establish properly designed, equipped, and functioning packing houses in different regions in the country.
Packing	Sacs, mostly jute sacs, are the dominant packages used in the country for almost all commodities (transport, storage, and marketing). There is very little use of boxes, crates, or bins made of plastic during harvest, transport, storage, and marketing.	Demonstrate the benefits of investing in better designs and characteristics of carton boxes for export and selective national marketing to reduce the reliance on jute sacs.
Transport	National transport of perishables uses non-refrigerated transport modes.	Build awareness, educational, and training programs for the improvement of transport conditions and systems to reduce causes for excessive deterioration and losses.
Transport	Significant air transport is still being used for the export of perishables from Bangladesh, especially to Europe, and only very little is transported by sea. Sea transport for products with intermediate to long postharvest life has several advantages including lower cost and availability of cooling on many of the ships.	Use sea transport where possible, at least for products with intermediate to long postharvest life (such as mango, jackfruit, potato, onions, garlic, etc.).
Regulatory	Review quarantine systems and assess available treatments that are established and applied in Bangladesh.	Work with phytosanitary body to plan and program for the quarantine of pests, including quarantine requirements by importing countries. Establish agreements with the phytosanitary authorities of targeted importing countries on quarantine and treatments and the proper facilities needed.
Postharvest	Ripening of bananas in Bangladesh is done by using calcium carbide. This process is inefficient, does not ensure a uniform ripening process, and requires very high acetylene concentration, which could be unsafe, among other disadvantages.	Promote alternative ripening methods such as the use of ethylene. It is more efficient, promotes uniformity, and is safer if done properly.
Processing	Value addition of perishable commodities, including processing, is extremely low.	Develop awareness, educational and training programs on different types of processing (including minimal processing, drying, freezing, etc.) of the different commodities in the different regions.

Specific Commodity Recommendations

Banana

Banana, a climacteric fruit, do not ripen properly on the plant, and therefore they should be harvested at the mature stage (green and very firm, but mature, based on universally used maturity indices) and ripened on arrival to destination. The ideal method for banana ripening is with the use of ethylene, at 10 to 100 parts per million (ppm), at temperatures of 15 to 20°C for 24 to 72 hours, and high (90 to 95%) relative humidity. Lower temperatures, lower ethylene concentrations, and longer ripening durations are used when bananas are required to ripen slowly, while higher temperatures, higher ethylene concentrations, and shorter ripening durations are used when bananas are required to ripen faster. Ethylene can be used in the form of gas, although could be insecure if not done correctly and if the ethylene concentration is accumulated to very high levels (to 32,000 parts per million in air). Therefore, the safest method is to use ethylene generators, which commonly generate lower concentrations of ethylene. In addition, the unit is small and mobile and thus can be used in different locations.

Bananas, being tropical commodities, are very sensitive to low temperature injury, and therefore, they should always be maintained (during transport or storage) at no lower than 13 to 14°C (the ideal temperature) and high (90 to 95%) relative humidity.

Bananas are not commonly precooled, but if needed they can easily be precooled using the method of room cooling.

Bananas can greatly benefit by the use of modified atmospheres, which are used commercially during their packaging. The easiest and most used modified atmosphere method is “Banavac”, a very simple method that consists of using a vacuum at the last step of packaging, maintains the oxygen concentration at 2 to 5%, enough to delay fruit ripening and prolongs its postharvest life. The universally, most adequately used package for bananas are telescopic carton boxes of about 18 kg capacity, with a plastic liner to reduce water loss and to help the establishment of a modified atmosphere.

Carrots

Carrots are not sensitive to low temperature injury and therefore they can be maintained properly at the lowest possible (above freezing) temperature of 0 to 2°C and high relative humidity of 85 to 90%. Since carrots are not a very perishable crop, carrots can be maintained for several months in storage (up to 7 to 9 months), if handled correctly.

Since carrots are grown below the ground, and commonly harvested with soil or even mud, depending on the soil type and conditions of the region, they can contain different types of contaminants including microorganisms. It is important that they be washed and disinfected.

Carrots that are intended to be maintained for a long period of time should be precooled immediately before storage using hydro-cooling (cold water at about 2°C) to eliminate field heat, which can be accomplished in less than one hour, or room cooling (with proper modifications to increase cold air circulation), which can take 2 to 3 days, or with the use of ice, which would take a longer period of time.

Different packages are used for carrots, whether for storage, transport or marketing, including plastic sacs.

Chili Peppers

All green chili peppers, including all types of hot and bell peppers, are sensitive to low temperatures, and therefore they should not be maintained at temperatures below 5 to 8°C and relative humidity below 85 to 90%. At these optimum conditions chili peppers can be maintained for 2 to 3 weeks. Chili peppers can be precooled using room cooling.

For dried chili pepper, drying can be carried out without any treatment (for example without blanching of the chili) or after blanching, by using sun, solar or hot-air drying. Sun (natural) drying is the easiest and least expensive, but not the most suitable, especially for large-scale production. Pre-treating pepper by blanching increases its rate of drying, and thus drying of blanched peppers is faster than that of drying un-blanched peppers. Hot air drying is about 5 times faster and preserves the hygienic quality of the dried product compared to sun (natural) drying. After harvest at full maturity, chili peppers are dried and placed in covered piles to distribute the moisture content equally. Some water may be added after drying in order to make the peppers less brittle, and are then packed tightly into sacks, and stored at 0 to 10°C and 60 to 70% relative humidity. The use of polyethylene film liners within boxes or sacks allows better storage and reduces the dust problem. They maintain a constant moisture content in the chili peppers. The low relative humidity is very important to help keep chili peppers at the optimum moisture content of 10 to 15%. When the moisture content of the chili drops to 6 to 9%, they become dry, brittle, and may shatter and lose color more rapidly. It is important to use low temperature for storage, but low relative humidity is even more important, as it discourages the increase in moisture content, and deterioration and reduces storage life. Low temperature during storage also reduces insect infestations. Dry chili peppers can be stored for up to 6 to 9 months in good quality when dried and packed properly, at the mentioned ideal temperature and relative humidity.

Dates

Fully ripe dates at the “Rutab” or “Tamr” stages commonly contain very high sugar and very low water content, and therefore are not very perishable and not sensitive to low or to freezing temperatures, and so can be maintained for long period of time, 6 to 12 months, at 0 to 1°C and low (70 to 75%) relative humidity or longer at -18°C. Cultivars of semi-soft dates, such as "Deglet Noor" and Halawy", can have longer storage-life than cultivars of soft dates, such as "Medjool" and "Barhi". Dates do not need to be pre-cooled. Insect disinfestation is needed in storage. Low temperatures are adequate for insect control, but chemicals such as methyl bromide are used in some countries, although they are not adequate, and natural gases such as nitrogen and carbon dioxide are much better alternatives, especially with regard to human health safety, and especially if the dates are organic.

Garlic

Garlic is not very perishable and is not sensitive to low temperature injury, and therefore can be maintained at the lowest possible temperature above freezing (-1 to 0°C) and at low (60 to 70%) relative humidity, for up to 9 months, if cured and handled correctly. Garlic can be kept in good condition for 1 to 2 months at ambient temperatures (20°C to 30°C) under low relative humidity (<75%), but under these conditions, bulbs will eventually become soft, spongy, and shriveled due to water loss. Good airflow is also necessary to prevent any moisture accumulation.

Garlic will eventually lose dormancy and start sprouting, and this will occur rapidly at intermediate storage temperatures of 5°C to 18°C, and higher temperatures and humidity in the storage will favor more sprouting and decay and mold growth. Sprouting can be inhibited, and storage life can be prolonged by

treating garlic with a sprout inhibitor such as maleic hydrazide before harvest (such as the case for table potatoes and onions) or irradiation after harvest.

Garlic odor is easily transferred to other products and therefore it should be stored separately.

Garlic, intended to be stored or not, should be cured immediately after harvest, by maintaining the crop at relatively high temperature (about 30 to 45°C), low (60 to 75%) relative humidity, and good airflow for 1 to 4 days, depending on the temperature and relative humidity conditions. Curing garlic is the process by which the outer leaf sheaths and neck tissues of the bulb are dried. Adequate curing process is very important to reduce water content and results in partial drying to avoid the deterioration of the crop after harvest especially due to fungal diseases.

Garlic does not need to pre-cooled.

As indicated in a previous section, it seems that garlic is commonly washed in Bangladesh after harvest and before marketing. This process is not ideal, but if it needs to be done for a specific reason, garlic should never be washed before but after storage and immediately before marketing, and it should be completely dried immediately after washing, preferably with the use of dry forced hot air.

Ginger

Mature and young ginger are chilling-sensitive if held below 12°C. Chilling symptoms include loss of skin color and pitting of the skin, and internal breakdown occurs in severe cases of chilling damage. Forced-air or room-cooling to 12 to 14°C are used for precooling.

Mature ginger rhizomes can be stored at 12 to 14°C with 85 to 90% relative humidity for 2 to 3 months. Storage at 13°C with 65% relative humidity leads to extensive dehydration and a wilted appearance. Superficial mold growth can occur if condensation collects on the rhizomes, especially on the broken ends. Young ginger rapidly loses water and will wilt in a few days at 25°C.

Dry Onions

Dry onions are not very perishable and not sensitive to chilling injury, and thus can be maintained at very low (0°C) temperature and relatively low (65 to 70%) relative humidity for several (up to 9) months for pungent onions, if handling conditions are adequate.

Onions should not be pre-cooled but should be cured. The curing process consists of maintaining the onions at ambient temperature (24 to 45°C) and 75 to 80% relative humidity for 1 to 4 days depending on the temperature and relative humidity conditions. The objective of the curing process is to promote some water loss and partial drying of the bulbs, especially from the neck, thus allowing the onions to resist the postharvest handling damage, reduce the potential for fungal infection, and therefore prolong the postharvest life, preserve quality and reduce losses and waste.

Pungent onions odors can easily be transferred to other crops such as apples, celery, and pears, during storage or transport, and therefore they should not be stored or transported with these crops.

Potatoes

Potatoes are not very perishable and only very slightly sensitive to low temperature, and therefore they can be maintained for several months if the handling conditions are adequate. Table and seed potatoes can be stored at 3 to 4°C and high (85 to 90%) relative humidity for up to 10 months, if the handling conditions are adequate, and especially when cured and when sprout inhibitors are used for table potatoes.

Potato for processing (such as for potato chips) must be maintained at temperatures higher than those used for table potato (about 10 to 13°C, depending on the duration of storage), as the lower temperature commonly used for table potatoes favors the conversion of potato starch into simple sugars, which can produce low quality chips when these simple sugars are caramelized resulting in dark color of the processed chips.

Potatoes are not commonly precooled but need to be cured immediately after harvest. The curing process consists of maintaining the crop at ambient temperature of 15 to 20°C and 85 to 90% relative humidity for 5 to 10 days, depending on the temperature and relative humidity conditions, to allow for the healing of the potato skin (periderm). This facilitates the postharvest handling of the tuber, reducing the deterioration, and thus prolonging the postharvest, including the storage life.

Sprout inhibitors can be used before or after harvest for table potatoes intended to be stored for prolonged periods. Maleic hydrazide can be applied to the plant about 2 to 3 weeks before harvest, and aerosol applications of chlorpropham (CIPC: 3-chloro-isopropyl-N-phenol carbamate) can be applied after harvest, during storage. Gamma irradiation at very low doses (0.03 to 0.15 kGy or 3-15 krad) is also very effective.

Potatoes may impart an "earthy" odor to crops such as apples and pears if stored, especially with low air exchange and circulation. Potatoes may also acquire an off-flavor from odor volatiles released by other produce items stored with potatoes.

Exposure to bright light in the field or during postharvest handling, or longer periods (1 to 2 weeks) of low light intensity, can result in the greening of the tubers. This is the development of chlorophyll in the potato tuber. With the greening is the formation of the bitter and toxic glycoalkaloids, such as solanine, which can also be formed due to bruising, wounding, and during sprouting. Glycoalkaloids are heat stable and minimally impacted by cooking, and therefore they should be controlled by avoiding the exposure of potatoes to bright lights before or after harvest.

Mangoes

Mangoes are of tropical origin and therefore they are sensitive to cold temperature injury and should not be maintained at lower than 8 to 12°C, but at high (85 to 90%) relative humidity, where they can be kept for up to 6 weeks. Partially ripe mangoes or mangoes intended to be maintained for a short period of time should be maintained at the higher range of temperature while fully ripe mango and mangoes intended to be maintained for the longest period of time can be maintained at the lower range of temperature.

Ideal maturity and harvesting indices for mango include shoulder formation and internal (pulp) color.

The ideal precooling method for mango is forced-air cooling, which would take 2 to 4 hours to eliminate field heal, depending on the original field initial temperature and temperature of the cold air used.

Mango is easily infected with fungal diseases such as stem end rot and anthracnosis, which are latent infections that occur before harvest and are expressed after harvest, and therefore proper treatments are

needed to control such diseases, including authorized fungicides before and after harvest, and postharvest heat treatments. Hot water treatment (48 to 55°C for 3 to 20 minutes; shorter duration at higher temperatures and vice versa) are very effective. Proper cooling after heat treatments, using water at ambient temperature followed by forced-air cooling is necessary.

Mangos are also very sensitive to pest infestations and some of these are quarantined in some countries, where quarantine systems may be required. Some of the quarantine treatments commercially used include heat treatments (hot water or hot dry or vapor air), and irradiation. The quarantine treatment to be used should be established in agreement between the two phytosanitary authorities of the import and the export countries. A commonly used hot water treatment, initiated in Mexico and currently used in several countries, consists of temperature of 46.1°C for 65 to 110 minutes depending on fruit weight. In addition to several legal conditions such as the proper isolation of the treatment space, the proper registry and control of temperatures, etc., cooling of the fruit after the heat treatment is needed with the use of water at ambient temperature followed by forced-air cooling.

Pumpkins

Pumpkins and winter squash are very chilling sensitive when stored below 10°C. Ideal storage conditions are 12.5 to 15°C and 50 to 70% relative humidity for 2 to 3 months depending on the cultivar. High storage temperature (>15°C) will result in excessive weight loss, color loss, poor eating quality, drying of damage areas, and more rapid breakdown of pulp tissue.

It was observed that the industry does not expect to be trained together on best practices.

To overcome this, general training systems, by grouping all or at least as many sectors together, are recommended first, which then can be followed by specific training programs for the different sectors. Grouping individual stakeholders, individual companies, individual sectors, during awareness, training, capacity building programs, is the most effective manner to support the chain as a whole, in an integrated manner, and promote the sectors to be integrated, to learn from each other, especially to learn from each other´s mistakes, and more importantly to promote them to collaborate and work together for the benefit of the whole chain. Working individually with the stakeholders only maintains the very unfortunate disintegration of the chain and maintains the many mistakes and errors been committed, without solving them effectively as a group.

Proposed Training Agenda

A. *The effects of pre-harvest conditions on the postharvest quality and postharvest life*

All the sectors, especially the production sector, but others too, should be very aware of the important effects that the many different pre-harvest factors can have on the postharvest quality and postharvest life. Therefore, adequate awareness, educational, and training programs are needed to indicate these factors, how they affect the postharvest quality and postharvest life, and how the pre-harvest handling practices can be optimized accordingly.

B. *Curing and conditioning*

- Reasons, objectives, and advantages of these processes
- Optimum conditions and applications for the different crops, such as potatoes, onions, garlic, oranges.

C. *Cold Chain*

- The importance of the cold chain, "as a CHAIN", concept and its important components.
- Proper handling of the cold storage and refrigerated transport components, including thermometers (types, adequate locations, proper handling including properly calculating relative humidity, etc.).
- Precooling methods: importance/objectives, types of methods for the different crops, establishment and adequate applications of the different methods for the different crops.
- Optimum temperatures and relative humidity for the different commodities during storage and transport.
- Air temperature vs pulp temperature.
- Cold air circulation: Importance/objectives, different systems of air circulation, importance of the types and designs of packages and staking systems for adequate cold air circulation, etc.
- Proper cold stores designs.
- Different cooling/refrigeration systems and components, and adequate practices for operations and maintenance.
- Proper handling/management in refrigerated stores: control and maintenance of temperature, relative humidity, air circulation, gases, hygiene, cleaning, washing, disinfection, etc.

D. *Transport*

- Land transport: non-refrigerated and refrigerated
- Air transport
- Water transport
- Sea transport
- Characteristics of these different systems, advantages/disadvantages, potential use for the different commodities and different markets, technical issues of proper use, etc.

E. *Export*

- Quality logistics
- Quality standards and requirements for the different commodities and different markets
- Phytosanitary and quarantine systems required for some markets
- Different transport modes (especially marine transport)

F. *Phytosanitary and quarantine systems*

- Quarantined pests
- Pre-harvest quarantine systems and strategies, methods and treatments
- Postharvest strategies and methods and treatments

- Quarantine requirements
- Important legal and logistical issues

G. Hygiene, safety, treatments, traceability

- Safety considerations and health importance
- Disinfection and other treatments, types and applications
- Traceability

H. Pesticide and analysis

- Classes and characteristics
- Health and legal issues and requirements
- Precautions of types and applications before and after harvest
- Analysis, techniques, and requirements