

## **PBRG Sub-project Completion Report (PCR)**

### **A. Sub-project Description**

- 1. Title of the PBRG sub-Project: Integration of Postharvest Technologies and Best Practices in the Value Chains of Fruits and Vegetables**
- 2. Implementing organization (s):** Bangladesh Agriculture Research Institute & Centre for Advanced Research in Sciences, Dhaka University.
- 3. Name and full address with phone and e-mail of Coordinator, Associate Coordinator and PI/Co-P (s):**

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**4. Sub-project budget (Tk.):**

4.1 Total: (in Tk. As approved): 18477763.00 (One crore eighty-four lakh seventy-seven thousand seven hundred sixty-three BDT Only)

4.2 Latest Revised (if any): N/A

**5. Duration of the sub-project:**

5.1 Start date (based on LoA signed): 20 March 2018

5.2 End date: 15 February 2022

## **6. Background of the sub-project along with justification & literature review:**

Food security, in terms of both availability and access to food, poses a challenge to rapidly growing population in Bangladesh and all over the world. Fruits and vegetables make a significant contribution to food security, nutrition, poverty reduction and in generating economic development in Bangladesh. Despite increased production of fruits and vegetables in recent years, postharvest losses accounted more than one-third of the total production or a total of more than two million metric tons in 2015. During the process of distribution and marketing, substantial losses are incurred which range from a slight loss of quality to enormous spoilage of some fruits and vegetables. Microbial factors account for about 30% of the losses. Poor quality, questionable safety and high postharvest losses are major bottlenecks faced in traditional fruit and vegetable marketing chains. In addition, number of factors concerned: lack of basic knowledge and awareness in safe handling practices during production and post-harvest operations, inadequacy of postharvest specific infrastructure such packing houses, pre-cooling, sorting and storage facilities, lack of tools and equipment, deterioration of produce quality owing to rough handling, improper packaging, overloading and damage during transportation, unskilled handlers coupled with poor technical extension and training facilities and poor access to market information. So, taking care and management during and after harvest are undoubtedly one of the major concerns of these crops in Bangladesh. It is urgent to make necessary interventions to reduce postharvest losses and maintain quality in fruits and vegetables.

Nowadays, postharvest quality and produce safety are considered very important and prioritized by the government of Bangladesh. There is enormous potential for fruits and vegetables for domestic and foreign investments if critical requirements are maintained in the entire supply chain. In this regard, undertaking modern and need based research is a need of the time. Proper postharvest handling practices are important to reduce postharvest losses and improve overall harvest quality of fruits and vegetables. Efforts to reduce postharvest losses of high perishable produce such as fruits and vegetables in developing countries are considered crucial not only to avoid wastage but also to reduce the cost of preventing food losses (Booth and Burton, 1983). While researchers have identified many potentially useful postharvest technologies to be implemented in developing countries, there is no good alternative but dissemination of low cost integrated technologies in the value chain in maintenance of quality and reducing losses. For this purpose, existing technologies should be improved and new technologies should be intervened. Postharvest priorities across the globe have evolved considerably over the last decades from being exclusively technical in their outlook, to being more responsive to consumer demand. Growing populations across the world continue to create demand for fresh produce and processed horticultural products. Meeting these requirements as well as those of export markets necessitates assuring quality and safety in both domestic and export supply chains. Capacities must therefore be developed in order to respond to consumer and market demands.

Proper postharvest handling practices are important to reduce postharvest losses and improve overall harvest quality of fruits and vegetables. One of the main goals in developing postharvest technologies is to advance innovative packaging equipment such as active and intelligent packaging with enhanced functions in response to the difficulties in maintaining adequate postharvest storage and distribution, aimed at improving quality and safety of the produce. Cleaning and sanitization practices have become standard postharvest handling operations, which could substantially reduce the major postharvest problem. The integration of improved technologies such as use of simple postharvest tools and equipment, use of plastic crate or innovative packaging system along with the use of sanitizer and best practices would be able to reduce the postharvest losses to minimum. Mango is very much popular, nutritionally rich, commercially cultivated high value fruit. Bananas are available round the

year and have the highest per capita consumption (BBS, 2014). Brinjal, cauliflower and carrot are high value vegetables and have significant role in agribusiness sector in Bangladesh. High postharvest losses of these crops are reported in the supply chain of country (BARI Annual report, 2008-2013). The present project is designed on up-scaling and validation of potential postharvest technologies of the mentioned crops and dissemination of the technologies among the growers and other value chain actors to reduce postharvest losses. Thus, this proposed project ultimately aims in integrating improved tools for harvesting, handling, packaging and storage operations, cleaning and sanitization practices, and building capacity of stakeholders who directly involved in the value chain of selected crops and intensification of postharvest technologies and best practices through demonstration, hands on training and other associated intervention methodology.

There is an increase in fresh fruit and vegetable consumption around the world that is mainly motivated by the recommendations made by different organizations, such as the World Health Organization, the Food and Agricultural Organization, the US Department of Agriculture, and the European Food and Safety Authority, etc., because of their healthy properties (Allende *et al.*, 2006; Warriner *et al.*, 2009). Fruits and vegetables are important sources of a wide range of vital micronutrients, phytochemicals and fibers promotes good health, may reduce the risk of certain diseases, and protects against cancers and chronic illnesses (Meng and Doyle, 2002; CAC, 2010). However, despite the benefits derived from eating raw fruits and vegetables, quality and safety and losses in quantity and quality are still an issue of concern (Lynch *et al.*, 2009).

Food waste and loss is a large and increasingly urgent problem and is particularly acute in developing countries. Food losses take place at production, postharvest and processing stages in the food supply chain (Parfitt *et al.*, 2010). In developing countries, 90% of wastage occurs from food loss within the value chain. It directly impacts poor producers through foregone income and impacts poor consumers by reduced food availability, increased prices, and decreased nutritional content. Efforts to reduce postharvest losses of high perishable produce such as fruits and vegetables in developing countries are considered crucial not only to avoid wastage but also to reduce the cost of preventing food losses (Booth and Burton, 1983). Food loss occurs all along this chain but is most acute between harvest and distribution in developing countries, which accounts for 50% of the loss. Booth and Burton, (1983) considered this to be the less costly option compared to producing a similar additional amount of food of the same quality. Abd. Shukor *et al.* (2003) pointed out that it is pertinent to evaluate the postharvest handling chain of vegetables in a holistic manner in order to identify the causal factors of postharvest losses and thus provide appropriate control measures.

The total production of fruits and vegetables of Bangladesh were 4.58 and 3.35 million mtons in 2010-11 (BBS, 2016). The estimated consumption of fruits and vegetables is only 211 g day<sup>-1</sup>capita<sup>-1</sup> (fruits, vegetables and potato), which is far below the minimum average requirement of 400 g day<sup>-1</sup>capita<sup>-1</sup> (FAO/WHO 2003; HIES 2010). The present production cannot fulfill the requirements of the nation. Again, a significant portion of fruits and vegetables are damaged due to lack and ignorance of postharvest care and management. About 23 to 44% of harvested fruits and vegetables are damaged every year in Bangladesh (Hassan, 2010). On the other hand, it is only 5 to 25% in developed countries (Kader, 1992). Molla *et al.* (2010) stated that the total postharvest loss of mango in supply chain of Bangladesh were 39.38%. These were reported as 26.63%, 22.0% and 32.0 for banana, brinjal and respectively (BARI Annual Report, 2008-2013, Molla *et al.*, 2012, Islam *et al.*, 2013), denoted the necessity of improving postharvest management and quality maintenance. The total area and production of mango per year in Bangladesh were estimated 37,846.15 ha and 11, 61,685 metric tons, respectively (BBS, 2016). Losses in quantity and quality of fresh

produce occur after harvest at different points in the value chain. Various factors such as maturity stages (Medlicott *et al.*, 1990), harvesting method (Abu-Bakr and Hafiza, 2004), postharvest treatment and handling procedures and mode of transport (Tucker and Seymour, 1991) are highly correlated with the quality and marketability of fruits. With poor harvest and handling practices, various kinds of blemishes develop over the fruit skin from field onwards, thus reducing the quality and consumer acceptability (Mazhar *et al.*, 2011). Anthracnose and stem end rot are two most important postharvest diseases found in mangoes, which cause severe damage and commercial devaluation of harvested mangoes (Cruz Medina and Garcia 2002; Esguerra *et al.*, 2017; Liu, 1984). Traditional harvesting technique and postharvest handling procedures prevailing in the mango industry of Bangladesh severely diminish the quality of mango along the value chain showing 31% due mainly to decay that manifested at the retail level (Rahman and Saha, 2015). The integration of improved postharvest technology including hot water treatment at 55°C for five minute effectively reduced the incidence of decay of mangoes (Huang and Yang, 1988; Esguerra *et al.*, 2017; Couey, 1989 and McGuire, 1991).

Many organic and inorganic sanitizers were studied to wash fresh produce include, acidified NaOCl (Inatsu *et al.*, 2017; Nei *et al.*, 2009) Ca(OCl)<sub>2</sub>, acidified Ca(OCl)<sub>2</sub> (Kim *et al.* 2006; Inatsu *et al.*, 2010; Elano *et al.*, 2011), Na<sub>3</sub>PO<sub>4</sub>, Tsunami™ (Beuchat *et al.* 2004), H<sub>2</sub>O<sub>2</sub> (Ukuku *et al.*, 2012), gaseous acetic acid (Nei *et al.* 2010), organic acid ozone (Ukuku *et al.* 2012), ozonated water & ozone nano bubble (Inatsu *et al.*, 2011), acidified electrolyzed water (Bari *et al.*, 2003; Rahman *et al.*, 2010), peroxyacetic acid (Beuchat *et al.* 2004), Combination of EDTA and organic acid, and competitive inhibition (Bari *et al.*, 2005) etc.,. However, most of these sanitizers, were either expensive or non-user friendly or involves some risk. Furthermore, ozone, electrolyzed water, mild heat treatment (Yasmin *et al.*, 2008; Ingram & Millner, 2007) organic acid, and other natural sanitizers alone or in combinations have been applied to various fresh-cut vegetables and are acceptable for non-organic fresh produce. In this project, commercial scale feasibility study of two non-chlorine sanitizers [calcinated calcium (0.00.00.01% CCa), and 0.5% H<sub>2</sub>O<sub>2</sub> for 1-2 min wash] will be compared with 200ppm chlorine sanitizers, in enhancing quality, microbial safety and increased shelf life of vegetables at open and MAP kept at ambient temperature.

Vegetables cleaning machine is used to remove impurities (field soil, dust and surface microorganism, fungicide/insect, sap and black spot) in freshly harvested vegetables. The capacity of the machine was 20 kg/batch of vegetables and revolution per minute of it was 20-30. Power required was one person (<http://www.tnau.ac.in/eagri/eagri50/AENG252/pdf/lc07.pdf>). A study on development of vegetable washing machine under BARC funded Core research grant was conducted during 2014-17. Leafy & fruits vegetables and root crop washing machine were developed and tested at Ishurdi, Panba, Jessore, Savar and Manikgonj during 2016-17. Performance of the machine of carrot washing showed satisfactory results but some drawback from scientist and carrot grower and traders came to some improvement and fine tuning would be needed. Further modification and fine tuning is essential for better performance. Fruit production of mango, banana, and papaya are very high, Washing machine for fruit are very important to remove microbial load and dirt for hygienic, safe and fresh products. BARI developed vegetable washing machine will be modified to clean fruits easily and packaging. Post-harvest heat treatments of fruits and vegetables are important to reduce the post-harvest loss and to increase the shelf-life. Hot water treatment is a common, easy and low cost post-harvest treatment method. On the other hand, hot water immersion system can be easily assembled because it is durable, mobile, and inexpensive (Sharp, 1989). Hot water immersion is inherently more efficient than vapor heat as a heat transfer medium (Sharp, 1989). It destroys anthracnose and retards the process of enzyme activities of the

fruits. It also develops attractive yellow color of banana that can be sold at a higher price. The plant has no detrimental effect on human health and environment.

Long travelling distance of fresh produces with poor packing methods and transportation were the major sources of wastage. Transport of Fresh fruits and vegetables using plastic crates in cold environment minimize the loss (Arivazhagan, *et al.*, 2016). In Bangladesh, the postharvest loss of brinjal was estimated 29.4 % from harvesting to consumption (Hasan, 2010). Washing of red amaranth with 0.01% scallop powder followed by a distilled water wash could reduce 1.0 -1.5 log CFU g<sup>-1</sup> of viable bacterial load and coliform bacterial load (Mamun *et al.*, 2012). Packaging provides protection from dust and reduces microbial contamination from surroundings. The storage of fresh fruits and vegetables in plastic films restrict the transmission of respiratory gases for the accumulation of carbon dioxide and depletion of oxygen around the crop, which may increase their shelf life (Kader *et al.*, 1989). Brinjal in perforated polyethylene bag prolonged shelf life and maintained quality compared to unpacked fruit (Nasrin *et al.* 2008).

Appropriate postharvest handling practices are important to minimize postharvest losses and to maintain the quality of fruits and vegetables. Potential postharvest handling activities include packaging, pre-treatment, pre-cooling, washing with water and sorting. The function of packaging is to protect the produce from mechanical injury and contamination during marketing. It also prevents moisture loss, and facilitates in chemical treatment and ethylene absorption (Kader and Rolle, 2004). Pre-treatment of fruits are mostly carried out to protect the produce from decay causing factors such as microorganisms (Fan *et al.*, 2008, Nasrin *et al.*, 2008), chilling injury (McCollum *et al.*, 1993; Paull *et al.*, 2000) and ripening (Paull *et al.*, 2000). Usually, cleaning and washing are the major preservation treatments applied to fresh fruits and vegetables (Yildiz, 1994). In addition, sorting is carried out to discard decayed or injured produce and therefore to limit the spread of infection to other units, especially if no postharvest pesticides are used (Kitinoja and Kader, 2002).

A supply chain is simply a transfer of a commodity from one stakeholder to another in a chained manner. On the other hand, value chain entails value addition at different stages of transfer. The value chain describes the activities required to bring a product from its conception to the final consumer (Ensign, 2011). There is enormous scope of intervening of improved postharvest technologies and best practices developed and identified by scientist in different organizations. Optimal postharvest treatments for fresh produce seek to slow down the physiological processes of senescence and maturation, reduce/inhibit the development of physiological disorders and minimize the risk of microbial growth and contamination. Ultimately, FLW could be reduced mainly through capacity development, in the form of education, training and extension services, for all actors across the food value chain. Kitinoja *et al.* (2011) suggested postharvest loss interventions should be integrated and due consideration include: to test reduction innovations under local conditions, identify the most promising and cost-effective techniques and practices, provide demonstrations of innovations determined to be technically and financially feasible, and provide hands-on training and capacity building to farmers.

## **7. Sub-project general objective(s):**

General objectives:

- To improve the quality and safety of fruits and vegetables by introducing new tools, machinery and means of harvesting, handling, packaging and cool chamber facilities.
- To strengthen postharvest management capacity across the value chain of selected fruits and vegetables.
- To reduce postharvest losses of fruits and vegetables.

## **8. Sub-project specific objective(s):**

*Coordination Component: Postharvest Technology Division, BARI*

- To organize events or activities in order to ensure the involved organizations work together effectively.
- To coordinate the research, development and technology transfer activities of the implementing components.
- To present outcomes of the project through seminar and publish project completion report.

*Implementing Component-1: Postharvest Technology Section, HRC, BARI*

- To provide knowledge and supports to the contract growers and suppliers in maintaining produce quality during production and postharvest handlings of fruits and vegetables.
- To intervene and dissemination of improved postharvest technologies to the value chain actors and other stakeholders through training and demonstration.
- To improve capacity of value chain actors in maintenance of quality and reducing postharvest losses of fruits and vegetables.

*Implementing Component-2: FMPE Division, BARI*

- To develop and up-scaling of improved tools, machinery and means of harvesting, handling, and packaging of fruits and vegetables.
- To validate the postharvest tools and machineries in maintenance of quality and reducing losses in the value chain and to make an economic analysis of the machine.
- To intervene and dissemination of improved technologies to the relevant stakeholder through training and demonstration.

*Implementing Component-3: Center for Advanced Research in Sciences, Dhaka University*

- To develop safe postharvest sanitizing protocols in maintenance of quality of selected fruits and vegetables.
- To assure safety and quality of improved postharvest technologies to be intervened.
- To develop and transfer improved technologies and safety and quality guidelines to the relevant stakeholders.

## **9. Implementing location (s):**

Rajshahi and Bogura districts, and Gazipur and Dhaka City (and Pabna and Savar, Dhaka only for conducting trial on washing machine of carrot).

## **10. Methodology in brief (with appropriate pictures):**

*Implementing Component-1: Postharvest Technology Section, HRC, BARI*

Survey of the selected value chains of target crops, establishment of pack house in the growing areas (at or near to assemble market) of target crops, organize value chain actors including growers in the selected areas and intervention of improved postharvest technologies were the major concerns of Postharvest Technology Section (PHTS) of HRC, BARI. Accordingly, the following activities were taken within the plan designated for component-1 of this project:

**Baseline survey of the value chains:** Survey (mentioned as Study#1 in PP) was conducted mostly to assess value chain situation and intervention opportunities of postharvest technologies of fruits and vegetables. It was conducted at different levels of the distribution chain of target crops from the growing areas (Fig. 1, 2, 3 & 4) to destined city markets. A sample size of 50 was targeted for a crop. Data were recorded on postharvest practices, value adding activities, quality, safety and losses perception, etc. Also, the existing value chain

problem or constraints associated in the value chain and scope and opportunities of intervening of improved practices were searched out and compiled from this survey.



Fig. 1. Pictorial view of conducting survey on mango: a) Group discussion b) Interview



Fig. 2. Pictorial view of local assemble market while conducting value chain survey on mango: Local transport system and market view of at Baneswar bazar, Rajshahi.



Fig. 3. Partial pictorial view of assemble markets of banana while conducting value chain survey in Bogura districts: a and b: local transport c. activities of sellers and buyers d. loading banana bunches in truck for distant market transportation.



Fig. 4. Pictorial view of local assemble market and marketing activities while conducting value chain survey on vegetables (cauliflower, carrot and brinjal) in Bogura area.

**Establishment of Model pack house:**

Packhouse is a structural unit which is made with accumulation of stepwise postharvest processes facilities including sorting, grading, washing and hot water treatment facilities. Also, coolbot cold room could be an option for short-term storage. According to PP, there was plan to establish two pack houses by modifying the existing house/structures of interested farmer/farmers’ group or fruits and vegetable supplier group in the local area and/or market in target districts. Before establishing these packhouses, extensive visit was done in the growing areas and fruit and vegetable assemble market of target crops in Rajshahi and Bogura districts. Rajshahi was targeted mostly on mango and Bogura was selected mostly on vegetables. Several discussion meetings were held with the growers and other value chain actors and DAM, DAE and other official personnel in the target areas. Thus, two sites were selected at the adjacent/nerarer area of fruit and vegetable assemble market. The first one was at Baneswar Bazar, Rajshahi (Fig. 5 & 6) which is the second biggest mango markets in Bangladesh. During the peak harvesting season, every day about 40-50 trucks

(1200-1500 kg/truck) mangoes were sold from the market and distribute to the different districts of the country. The second one was at Vatra, nearby Mirzapur Bazar, Sherpur Upazilla, Bogura (Fig. 7 & 8). It was an emerging and potential vegetable growing area near to Mirzapur and Fulbari vegetable assemble market in Bogura district. Different kinds of vegetables are producing round the year in this area.

The pack house at Banewar bazar was established in cooperation with Agricultural Marketing Department Four open spaces, each of which consisted of 10m×10m inside the ground floor of NCDP market building at Baneswar bazar, Rajshahi were selected for converting into packhouse and also construct a coolbot cold storage inside the pack house. A consent letter was collected from the DG, DAM, Khamar Bari, Farmgate, Dhaka-1215 for this purpose. Finally, a model packhouse along with a coolbot cold storage had been established with a size of 20m×20m×3m on 400 m<sup>2</sup> land. The pack house is very near to Rajshahi-dhaka highway. There is a side way to the highway, so all kind of vehicle including truck can easily reach to there and carry vegetables from the house. About 100 traders and lead farmers are connected with the Baneswar bazar assemble market. Sometimes traders directly communicate with farmers to collect fruits from the farm, not far from Baneswar bazar.

The pack house at Vatra village (Fig. 7 & 8) was made with the cooperation of Vatra Uttarpara CIG (Phasol) Somiti. The size of vatra pack house was 36m×17m×3m. It was established in the ground floor of a building in Vatra village, Sherpur, Bogura with the consent of Vatra Uttarpara CIG (Phasol) Somiti. An agreement was made for this purpose. The sanctioned open space of the mentioned building was converted into pack house along with a colbot cold storage room for short term storage of packed products. The land area of the pack house included coolbot cold room was 612 m<sup>2</sup>. There is a front yard and ahead of the front yard, there is a link road to Mirzapur bazar and Phulbari bazar. This link road is connected with Dhaka-Bogura highway near Mirzapur bazar. There are many traders and lead farmers are connected with the Mirzapur and Phulbari bazar assembling market. The members of Vatra CIG (Phasol) Somiti are involved in crop cultivation and trades. Sometimes traders directly communicate with farmers to collect vegetables and banana from the farm.

Logistics and postharvest processes facilities for fruits and vegetables provided in the established pack houses. Necessary hardware facilities including sorting/grading table, weighing scale, water supply, water tank, plastic crate, harvesting tool, knife, delatexing tray, etc. were provided to the packhouse. The pack houses have water tank(s), water pump, ceiling fans, exhaust fans and also was connected with electricity and water pump.

There were two units/areas, one for product receiving area/entry area and another for product exiting/departure area in each established packhouse (Fig. 6 & 8). Sorting and grading table, washing tank, basin/sink for hand washing etc. were set in receiving area. Drying and packaging table were set in exiting area. Weighing balance, seating chairs, table for accounting and management, accounting book and register were set within the receiving unit or any other convenient positions. Both the pack house had water and electricity supply systems. There were some ceiling fans. Stand fans were kept as an extra. Sanitizing and personal hygiene maintenance materials e.g. soap, Apron, face masks, hand gloves were facilitated in each pack house. A Hot water treatment plant developed by BARI was installed in the packhouse of Baneswar bazar, Rajshahi. It was used to treat mango and other fresh products which are fit to treat hot water. A vegetable washing machine developed by BARI was installed in the packhouse of Vatra, Bogura. It was suitable for washing of banana and carrot including other root and fruit type vegetables. These two machines had features to be installable to other pack house where it is applicable.

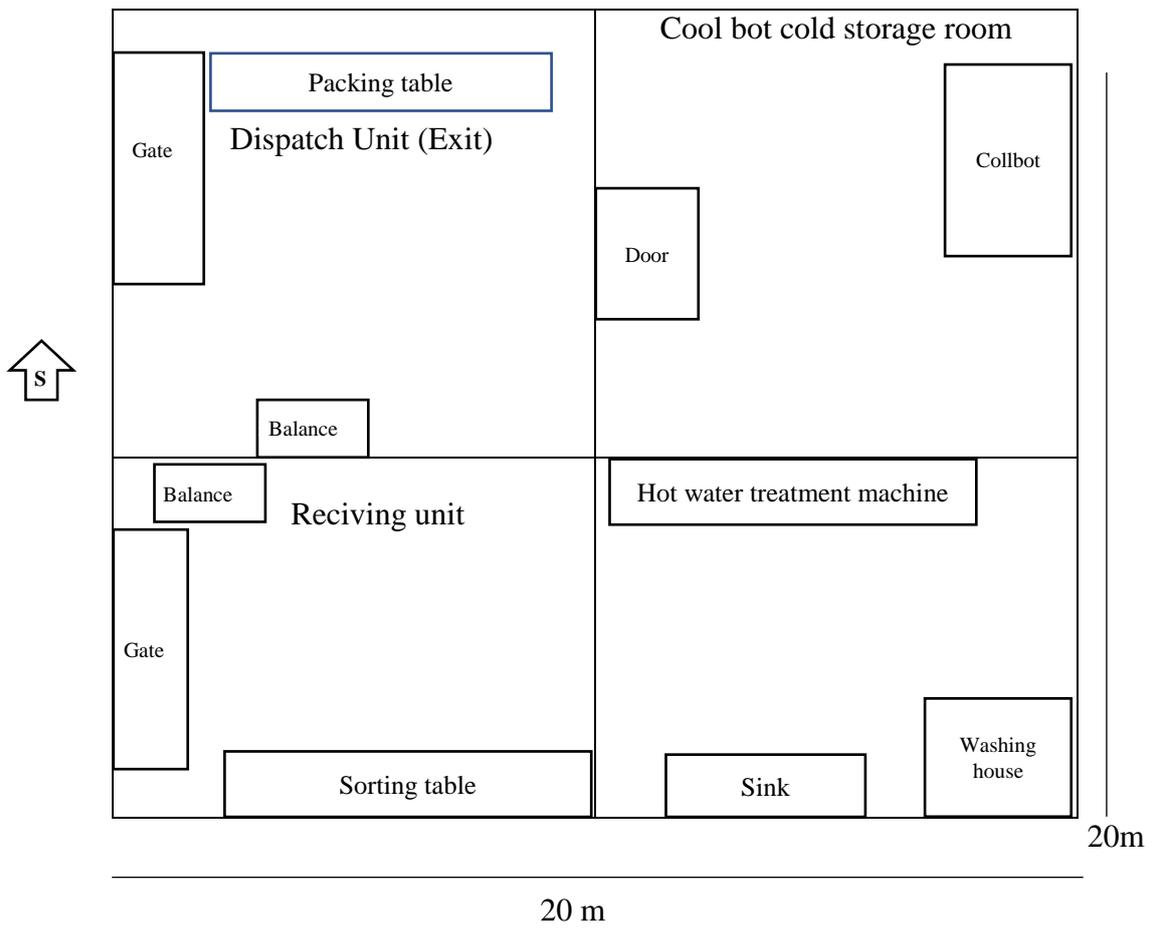


Fig. 5. Sketch diagram of Baneswar bazar pack house, Rajshahi



Fig. 6. Partial Pictorial view on establishing of pack house including coolbot cold storage in NCDP growers' market building at Baneswar bazar, Rajshahi.

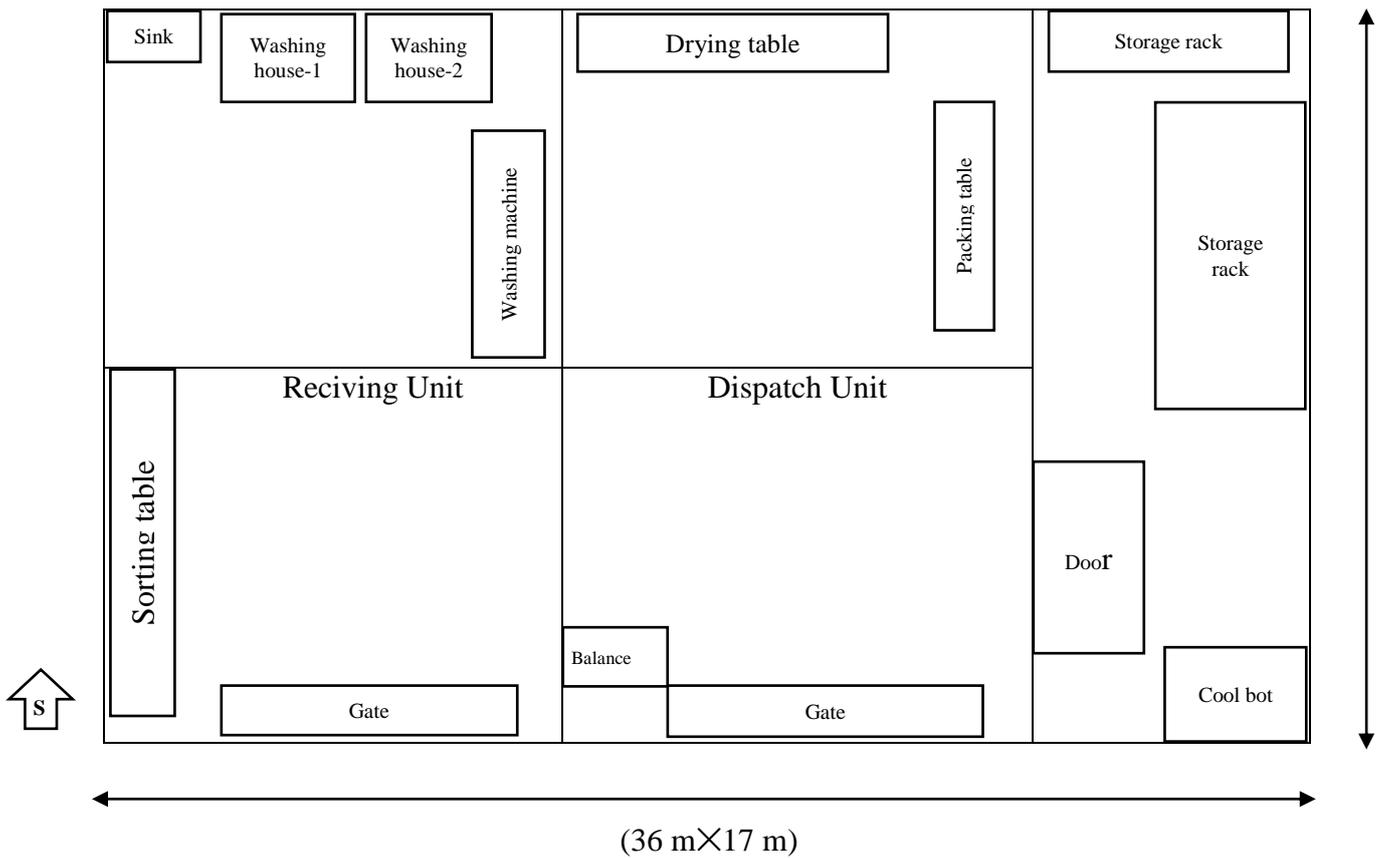


Fig. 7. Sketch diagram of Vatra bazar pack house, Mirzapur, Sherpur, Bogura



Fig. 8. Pictorial view on establishing of pack house including coolbot cold storage in Vatra CIG Sommiti sanctioned building at Vatra, Sherpur, Bogura.

Two executive committee formed with 15 members including 02 women to operationalize the two pack houses. The committee is constituted with different type of actors of fruit and vegetable value chain. The local fruit and vegetable trader, wholesaler based in Dhaka and farmers are the members of the committee. Interested members of NCDP Growers' Market association were included as general members in Banesar bazar pack house. All members of Vatra CIG (Phasol) Somiti were the general members of Vatra packhouse. A board of 09 members headed by president has been also formed for each pack house. The committee has plan to take 3% service charge to meet up the rent of the house (Tk. 500/month) and the rest of the savings money will be used for managing the house and also give soft loan to the members.

**Intervention of postharvest technologies and best practices in the value chain** (Study #2, as mentioned in PP):

In view to intervening of improved postharvest technologies in the value chain, five experiments were undertaken on five crops viz. mango, banana, brinjal, carrot and cauliflower. These studies were conducted on handling trials for comparing existing and improved postharvest management systems to find and assess technical and economic feasibility of integrated technologies in the value chain of targeted crops. Before conducting research program on postharvest management practices, target fruit plants of mango and banana were selected in the contract grower's field/orchard and nourished with good agricultural practices through recommended production practices by Pomology division and that the vegetables were produced in contract grower's field with cultural practices recommended by Olericulture Division of HRC, BARI. The improved postharvest management practices were integrated including the technologies developed in the preceding R&D activities and best practices and recent innovation, such as optimum harvest maturity, proper harvesting method, use of harvesting tools (for mango) and container e.g. plastic crate and bucket, de-handing (for banana), de-sapping (for mango and banana), proper sorting, avoiding contact with ground soil, use of plastic crates and improved CFB carton as transport container, use of container liners, proper loading and unloading during transport, etc. The packed fruits and vegetables were transported to Gazipur city wholesale markets through traditional transport vehicle (truck). Transported fruits and vegetables were evaluated individually as to the incidence of mechanical damage. Fruits or vegetables with evident compression damage and bruising/abrasion were classified as moderately damaged, and those with cracks and cuts were sorted as severely damaged and considered unmarketable. The quality and marketable life of the fresh commodities were assessed and evaluated at last point of value chain i.e. retailer's shop up to the last date of marketability acceptance. The collected data were analyzed to calculate the loss in the whole supply chain.

The title of five experiments and treatments of each experiment under the study of Technical and economic feasibility of improved postharvest technologies integrated in the value chain (mentioned as study #2 in pp) were as follows:

**Expt. No. 1.** Postharvest Quality of Mango as affected by Traditional and Improved Practices integrated in the Value Chains

**Material:** Mango (*Mangifera* 'Langra')

**Treatments:** 9

i) **TP=Control/Traditional practices:** NFBG+NDS+NHW+PC+T

- Traditional cultural and plant protection measures + No fruit bagging (NFBG)+ Using local harvesting tool + *No pedicel* keeping + Using plastic crate as local transport container +Sorting only by removing insect-pest infested fruits observed at pack house operations + *No de-sapping (NDS)* + *No washing and No hot water treatment (NHW)*+ Using plastic crate as distant transport container City market

- ii) **IP-I**=Improved practices-1: NBG+DS+HWT+PC+T
- No pre-harvest fruit bagging (NFBG)+ recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container + Sorting by removing all kind of defective fruits + *Keeping 0.5 cm pedicel + De-sapping* (DS) with BARI made de-sapping tray + *Hot water treatment* (HWT)+ packed in plastic crate +transported by truck (T).
- iii) **IP-1A**=Improved practices-1A: NBG+DS+HS+PC+T
- No pre-harvest fruit bagging + recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container + Sorting by removing all kind of defective fruits at pack house operations + *Keeping 0.5 cm pedicel + De-sapping with tray + Hot sanitizer (CCa 0.1%) treatment* (HS)+ packed in plastic crate+transported by truck.
- iv) **IP-2**: Improved practices-2: BG+DS+NHW+PC+T
- Pre-harvest fruit bagging (BG) + recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container + Removing fruit bagging + *0.5cm pedicel keeping + de-sapping with tray +No hot water treatment* + packed in plastic crate+transported by truck.
- v) **IP-2A**=Improved practices-2A: BG+DS+HWT+PC+T
- Pre-harvest fruit bagging + recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container + Removing fruit bagging and sorting by removing all kind of defective fruits at pack house operations + *0.5cm pedicel keeping + de-sapping with tray + Hot water treatment* + packed in plastic crate+transported by truck.
- vi) **IP-2B**=Improved practices-2B: BG+DS+HS+PC+T
- Pre-harvest fruit bagging + recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container+Removing fruit bagging and sorting by removing all kind of defective fruits at pack house operations + *0.5cm pedicel keeping + de-sapping + Hot sanitizer (CCa 0.1%) wash* + packed in plastic crate+transported by truck.
- vii) **IP-3**=Improved practices-3: NBG+DS+ NHW+PC+RV
- No pre-harvest fruit bagging + recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container + Sorting by removing all kind of defective fruits at pack house operations + *Keeping 0.5 cm pedicel + De-sapping with tray + No Hot water and sanitixer*+ packed in plastic crate+transported by reefer van (RV) (cool chain transport)
- viii) **IP-3A**=Improved practices-3: BG+DS+HWT+PC+RV
- Pre-harvest fruit bagging + recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container + Sorting by removing all kind of defective fruits at pack house operations + *Keeping 0.5 cm pedicel + De-sapping with tray + Hot water treatment*+ packed in plastic crate+transported by reefer van (cool chain transport)
- ix) **IP-3**=Improved practices-3: BG+DS+HS+PC+RV
- Pre-harvest fruit bagging + recommended cultural and plant protection measures + Using BARI mango harvester + Using plastic crate as local transport container + Sorting by removing all kind of defective fruits at pack house operations + *Keeping 0.5 cm pedicel + De-sapping with tray + Hot sanitizer (CCa 0.1%) wash* (HS)+packed in plastic crate+transported by reefer van (RV) cool chain transport)



Fig.9. Partial pictorial view of establishing research on integrating practices on mango; showing in: a) visiting selected plants in contract grower's orchard wherein the study was initiated b) preharvest bagging



Fig. 10. Partial Pictorial view of conducting research on integrating improved practices on mango (contd.); showing in: a) Harvesting mango with BARI Mango Harvesting tool. b) Harvested non-bagged mango with pedicel c) Trimming and de-sapping of harvested mango in the orchard d) Trimmed bagged mango keeping 0.5 cm pedicel e) & f) Hot water treatment g) Drying surface water of hot treated mango in different integrated practices h) packed mangoes waiting for transportation i) Data collection during storage

**Expt. No. 2.** Postharvest Quality of Banana as affected by Traditional and Improved Practices integrated in the Value Chains

**Material:** Banana (*Musa* 'Amrit Sagor')

**Treatments:** 6

- i) **TP** = Traditional practices: TP=NDH-NW-BH-T
- Traditional cultural and plant protection measures-*Traditional* postharvest practice including: *No de-handing* (NDH) from banana bunch, keep full bunch + *No desapping and washing* (NW) + traditional transporting system: *No packaging* (NP) and loaded full bunch by *heaping* (BH) in *truck* (T) by taking the full bunch.
- ii) **IP-1** = Improved practices-1: IP-DH-WWH-WMAP-PC-T
- Improved production practices with recommended cultural and plant protection measures + *Improved* postharvest practice including: sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers (three quarter filling of fingers up to upper mid hand of bunch and color initiation on the fingers of 2<sup>nd</sup> hand) + *de-handing* (DH) with care by de-handing tools and carefully done initial *de-sapping* on bedding banana leaves in the field + carefully transport to pack house by pick-up van + washing once by dipping and lightly brushing to *wash* in clean water in washing house (Water wash in House) for 15 minutes + drying under ceiling fan on drying tray + packed in *plastic crate* (PC) lining with clean newspaper and *without* (WMAP) + transport by *truck*.
- iii) **IP-2** = Improved practices-2: IP-DH-AWH-WMAP-PC-T
- Improved production practices with recommended cultural and plant protection measures + *Improved* postharvest practice including: + sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers (as mentioned in the treatment of IP-2) + *de-handing* with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van + washing twice i) by dipping and lightly brushing handling in clean water in the washing tank for 10 minutes and then ii) dipping in alum water in second washing house for 15 minutes (AWH) + drying as mentioned in IP-1 + packed in plastic crate as mentioned in IP-1 + transport by truck.
- iv) **IP-3** = Improved practices-3: IP+DH+AWH+PC with MAP
- Improved production practices with recommended cultural and plant protection measures + *Improved* postharvest practice including: sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers (as mentioned in the treatment of IP-2) + *de-handing* with care by de-handing tools and carefully initial de-sapping on bedding banana leaves in the field + carefully transport to pack house by pick-up van + *washing twice*: i) by dipping and lightly brushing handling in *clean water* in the washing tank for 10 minutes and then ii) dipping in *alum water* in second washing house for 15 minutes + drying under ceiling fan + *packed in plastic crate* lining with clean and fresh newsprint paper newspaper and *with MAP* + transport by truck.
- v) **IP-4** = Improved practices-5: IP+DH+WWM-WM+PC without MAP
- Improved production practices with recommended cultural and plant protection measures + *Improved* postharvest practice including: sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers (as mentioned in the treatment of IP-2) + *de-handing* with care by de-handing tools and carefully initial de-sapping on bedding banana leaves in the field + carefully transport to pack house by pick-up van + washing twice i) by clean water in the *washing machine* for 10 minutes and then ii) dipping in *alum water* in *washing machine* for 15 minutes + drying under ceiling fan on drying tray + packed in *plastic crate* lining with clean and fresh newsprint paper newspaper and *without MAP* (WMAP) + transport by *truck*.
- vi) **IP-5** = Improved practices-6: IP+DH+WWM+AW+PC with MAP
- Improved production practices with recommended cultural and plant protection measures + *Improved* postharvest practice including: sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers (as

mentioned in the treatment of IP-2)+*de-handing* with care by *de-handing* tools and carefully initial *de-sapping* on bedding banana leaves in the field + carefully transport to pack house by pick-up van +washing twice i) by dipping and lightly brushing of banana hands in clean *water* in the *washing house* for 10 minutes and then ii) second washing of banana hands in *alum water* through washing machine (WWM) +drying under ceiling fan on draying tray+packed in *plastic crate* lining with clean and fresh newsprint paper newspaper and *with MAP* +transport by *truck*).

There were four lots in each treatment:

- 1) For observing and getting physical quality and quantitative loss at retailing outlet (This lot will be kept at retail outlet)
- 2) For observing storage and physicochemical changes during storage (This lot will be kept at laboratory)
- 3) For observing ripening changes and recording marketable life during storage (This lot will be kept at laboratory)
- 4) For recording quality defects, rotting incidence, damages and losses (This lot will be kept at laboratory)

Additionally, for microbial analysis, fingers/hands were taken from each of the treatment followed by aseptic handling practices. These samples were taken by DU for analyzing of microbial loads.



Fig. 11. Partial Pictorial view of conducting research on integrating improved practices on banana; in: a) visiting contract grower's orchard wherein the study was conducted b) *de-handing* and *de-sapping* of harvested mango in the orchard c) washing done in washing house d) washing done in washing machine e) drying surface water of banana hands on drying table in pack house f) packing the banana hands in pack house.

**Expt. No. 3.** Technical and economic feasibility of integrated postharvest management practices in maintenance of quality and reducing losses in carrot value chain

**Treatments:** 4

i) **TP**=Traditional practice: TP+TW+PS

- Traditional cultural and plant protection measures + Sorting by discarding only physically injured carrots + No size selecting and maturity consideration + Trimming + Traditional washing technique: *remove surface dirt with human legs and water* + Not Properly drying

after washing + Packing in synthetic plastic sack (PS)+ traditional transporting system: loaded in truck (T) with other commodities (vegetables).

**ii) IP-1=Integration of improved practices-1: IP+CI wash+PC without MAP**

- Recommended cultural and plant protection measures+ sorting by discarding all defective ones +Selecting only moderate size optimally matured carrots + Trimming + *Washing twice: Removal of dirt through traditional practice+wash in 100 ppm chlorinated water in water house (CI wash)+ drying under ceiling fan on draying tray + packed in plastic crate without MAP but lining (just a layer around inside crate) with clean newsprint paper (PC without MAP) +transport only carrots by truck (single crop loading).*

**iii) IP-2=Integration of improved practices -2: IP+CCa wash+PC without MAP**

- Recommended cultural and plant protection measures+ sorting by discarding all defective ones + Selecting only moderate size optimally matured carrots + Trimming (by keeping ½ cm green tops)+ *Washing in calcinated calcium (1g CCa in 10L water) mixed water through washing machine (CCa wash) + drying under ceiling fan on draying tray + packed in plastic crate without MAP but lining with clean newsprint paper+ transport only carrots by truck (single crop loading).*

**iv) IP-3=Integration of improved practices-3: IP+CCa wash+WM+PC with MAP (PPS)**

- Recommended cultural and plant protection measures + sorting by discarding all defective ones + Selecting only moderate size optimally matured carrots + Trimming + *Wash twice through washing machine: wash in clean water+followed by wash in calcinated calcium (10g CCa in 10L water) mixed water in washing machine (WM)+drying under ceiling fan on draying tray+packed in plastic crate with MAP (PC with MAP) transport only carrots by truck (single crop loading).*



Fig. 12. Partial Pictorial view of conducting research on integrating improved practices on carrot in: a) Experimental plots of carrots in contract growers field b) Harvesting carrot from contract grower's field c) Traditional method of surface dirt removing and washing of carrot using by human legs d) washing done in washing machine e) packing of carrots in different integrated treatments waiting for loading in truck and transport to city markets.

**Expt. No. 4. Technical and Economic Feasibility of Improved Postharvest Handling Practices in Cauliflower Value Chain**

**Treatments: 5**

The integrated treatments were as below:

i) **TP**=Traditional practices: TP+UNP+SNB

- Control/Conventional practices: Traditional cultural and plant protection measures (TP)+ Sorting by discarding only physically injured cauliflowers+No maturity and size consideration (taking all)+Trimming+Covering curd face by used newspaper (UNP)+Packing in synthetic netted bag (SNB)+traditional transporting system: loaded in truck with other commodities (vegetables). [Traditional Practices in Bogura area]

ii) **IP-1**= Improved practices-1: IP+PPB MAP+SNB

- Recommended cultural and plant protection measures+ sorting by discarding all defective ones+Selecting only fully size, compact structured cauliflowers+Trimming+Packaging individual cauliflower inside 1% perforated polyethylene bag (PPB MAP)+ Packing in synthetic netted bag (SNB)+ transport only cauliflowers by truck (single crop loading)

iii) **IP-2**=Improved practices-2: IP+NPP+PC without MAP

- Recommended cultural and plant protection measures+ sorting by discarding all defective ones+Selecting only fully size, compact structured cauliflowers+Trimming+Covering curd face by newsprint paper+Packing in plastic crate +transport as mentioned above.

iv) **IP-3**=Improved practices-3: IP+ PC with PPB MAP

- Recommended cultural and plant protection measures+ sorting by discarding all defective ones +Selecting only fully size, compact structured cauliflowers+Trimming+Packaging individual cauliflower inside 1% perforated polyethylene bag (PPB MAP) +Packing in plastic crate (PC) lining with clean newsprint paper +transport only cauliflowers by truck

v) **IP-4**=Improved practices-4: IP+PC with PPS MAP

- Recommended cultural and plant protection measures+sorting by discarding all defective ones+Selecting only fully size, compact structured cauliflowers +Trimming+packed in plastic crate by packaging of all the cauliflowers (7-8 pieces equivalent to 10-12 kg) with 1% perforated polyethylene sheet (PPS MAP) +transport only cauliflowers by truck.



Fig. 13. Partial Pictorial view of conducting research on integrating improved practices on carrot in: a) Cauliflower grown in contract grower's field b) trimming of harvested cauliflowers on sorting table in pack house c) & d) packed cauliflowers in different treatments of integrated practices e) traditional packing of cauliflowers e) transported cauliflowers at ambient condition at retail shop.

**Expt. No. 5.** Technical and Economic Feasibility of Improved Postharvest Handling Practices in Cauliflower Value Chain

**Treatments:** 4

Integrated management approaches were applied to compare improved postharvest practices with traditional operations. The integrated treatments were as below:

i) **TP**=TP+NW+PS+T

➤ Traditional practice: Using bamboo basket as harvest container+No Washing+Plastic sack packing+loaded in truck to transport.

ii) **IP-1**=Improved practices-1: IP+CW wash+ PC without MAP

➤ Using plastic crate as harvest container+Clean water wash in washing house+Plastic crate packing (lining with clean, newsprint paper) without MAP+ loaded in truck to transport.

iii) **IP-2**=Improved practices-2: IP+CCa wash+PC with MAP

➤ Using plastic crate as harvest container +Calcinated Calcium (1%) mixed water wash in washing house+ Plastic crate packing with MAP+loaded in truck to transport

iv) **IP-3**: Improved practices-3: IP+CCa wash+WM+PC with MAP

➤ Using plastic crate as harvest container +Calcinated Calcium (1%) mixed water wash through washing machine+ Plastic crate packing with MAP+loaded in truck to transport

There were four lots for each of the treatment:

1. For observing marketability and marketing life and recording quantitative loss at retailing outlet (This lot will be kept at retail outlet)
2. For observing marketability and marketing life and recording marketable life during storage at laboratory (This lot will be kept at laboratory)
3. For recording quality defects: physical damages (pressed mark, bruising, spots, breaking, etc.), rotting incidence and quality losses (This lot will be kept at laboratory).
4. For observing physicochemical changes during storage (kept at laboratory)



Fig. 14. Partial Pictorial view of conducting research on integrating improved practices on brinjal in: a. seedling raising in contract grower's nursery bed b. Harvesting of brinjal from farmer's field and c. washing in water house d. washing through machine f. packaging in MAP.

**Data recording:** Almost similar types of data were taken for abovementioned five experiments conducted on mango, banana, carrot, cauliflower and brinjal. The methods

followed for collection of data on quantitative, qualitative, biochemical and economic traits and analysis were as follows:

**Quantitative losses:** Data were collected on weight loss, mechanical damage and decay/rotting, etc. (according to the fruit or vegetable nature and requirement) were recorded in different intervals during the displaying/storage of respective crops in ambient condition at retail shop and/or PHTS laboratory of HRC, BARI.

**Qualitative evaluation:** Changes in the external appearance of the target fruit and vegetable which affects marketability was monitored and evaluated till the end of marketable life of the respective crop for each of the treatment. Quality defects such as incidence of withering, or softening, squeezing of fruits, blemish and decay or rotting were estimated as follows:

$$\%DI = \frac{N_D}{N_T} \times 100$$

Where, DI = Defect Incidence: withering, squeezing, decay, etc.

$N_D$  = Number of fruits with quality defect

$N_T$  = Number of total cauliflowers kept for evaluation

**Firmness:** Firmness is as widely used traits for quality estimation and measured with Fruit Texture Analyzer (GUSS, Model No. GS25, SA) supported by FTA Win Software and expressed in kilogram-force (kg-f). Quality defects such as incidence of withering of petiole and sepals, softening and squeezing of fruits and decay or rotting were estimated as follows:

$$\%DI = \frac{N_D}{N_T} \times 100$$

Where, DI = Defect Incidence: withering, squeezing or decay

$N_D$  = Number of fruits with quality defect

$N_T$  = Number of total carrots kept for evaluation

**Marketability and Marketable life (Day):** Marketability means the marketable potentiality of a commodity on a definite time. On the other hand, marketable life is the total length of period till the commodity retains its marketable quality. It indicates the period from harvesting to the last stage (day) of marketability retention when the commodity obtained the least acceptable score but does not cross the border line. The marketability and marketable were evaluated and recorded by observing external physical quality mostly based on fruit freshness and non-incidence or less incidence of quality defects like withering, softening and squeezing, and decay or rotting, etc. The marketability was judged by putting through a scoring rate of 5-point hedonic scale, as 5= Highly marketable, 4 = Fairly marketable, 3 = Moderately marketable, 2 = Slightly marketable, and 1= Not marketable.

**Biochemical Traits:** Total soluble solid, titratable acidity and total sugar were measured thrice, 1-day, 3-day and 5-day after fruit harvesting. TSS (%) was measured by hand refractometer (Model No. ATAGONI- Brix 0-32). Titratable acidity, total sugar, reducing sugar and Vitamin C content were determined by Visual Titration Method (Rangana, 1991).

**Organoleptic evaluation:** Organoleptic evaluation was done for fruits and carrots only. Colour, firmness, weight, disease severity, taste, flavour, peel colour of treated and untreated mangoes were measured during storage period at room temperature. Fruits and carrots were exposed to a panel of 10 assessors using a 1-9 scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike lightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much and 9=like extremely) for general appearance. Fruit or vegetable slices (carrots) were presented to a panel of 5 tasters and rated the eating quality using a 9-point scale (Jacobi and Giles, 1997).

**Economic analysis:** A partial budget analysis was done to analyze the changes found with intervention of most important practice(s) among the postharvest management operations for

the vegetables. Thus, added returns and cost was estimated to evaluate the profitability of using improved practices including washing materials and plastic crate packing.

**Experimental design and statistical analysis:** All the experiments were set in randomized complete (RCB) design with three replications. A two-way analysis of variances (ANOVA) was conducted for quantitative parameters by using statistical method (MSTAT C). The mean separation was done by Duncan’s Multiple Range Test (DMRT). In case of quality attributes mean scores were computed by Microsoft Excel and presented with graph.

***Implementing Component-2: Farm Machinery & Postharvest Process Engineering, BARI***

**Expt. Improvement and fine tuning of washing machine for mango, banana and brinjal**  
Leafy and fruit vegetable machine was improved and fine tuning for washing of mango, banana and brinjal. It was improved and fabricated with locally available iron materials at Farm Machinery and Postharvest Process Engineering Division (FMPE), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur in 2018. Performance test of the machine was evaluated with mango at FMPE workshop and farmers’ field in 2018-19. One final prototypes of washing machine was fabricated and distributed to vegetable growing area (Bogura) for long term performance test of the machine and for creating awareness to the farmers and traders through trainings and demonstrations in 2019-20.

**Fabrication of leafy and fruit vegetable washing machine**

Overall dimension of the machine is 3220 mm × 1230 mm× 1150 mm. Main parts of the leafy and fruit vegetables unit are such as trapezoidal type water tank; mesh type conveyer; power transmission system; water supply system; and trays. Conveyer was run by an electric motor of 1.1 kW with help of chain and sprocket. Water spray through perforated pipe is pumped by the centrifugal pump of 1.1 kW. Speed of the conveyer and brush rollers are 20 rpm and 92 rpm respectively. A photographic view is shown in Fig. 15.



Fig. 15. Photographic view of modified leafy & fruit vegetable and fruit washing machine

**Water tank**

A trapezoidal water tank was made of MS sheet and MS angle bar which was welded to a separate frame of MS angle bar. The tank had mesh conveyor, water supply pipe, brush rollers and water. Specifications of the different materials to fabricate the tank are shown in table 1.

Table 1. Specifications of the materials of the trapezoidal tank

Materials	Specifications
Overall dimension (L×W×H), mm	(2465-1830)×885×615
Thickness of MS sheet, mm	1.6
MS angle bar, mm	38
Height of leg, mm	290
Capacity of water tank, liters	900

## Water house

A rectangular water house was made of MS sheet and MS angle bar which was set to the input side of the machine. The house had water, supply and delivery pipe. Water was agitated in the house through centrifugal pump. At first, leafy vegetable was rinsed here before input on the small conveyer. Specifications of the different materials to fabricate the house are shown in table 2.

Table 2. Specifications of the materials of the rectangular

Materials	Specifications
Overall dimension (L×W×H), mm	750×520×460
Thickness of MS sheet, mm	1.6
MS angle bar, mm	38
Capacity of water house, liters	140

## Conveyer

Conveyer is an important functional part of the machine. It is made of MS pipe, MS mesh net with rubber covered, nylon brush rollers, fibre sheet, shaft, bearing, chain, sprocket, clamp etc. Conveyer was divided into two segments for turning out of vegetables in operation from small segment to larger segment. Small one was set in higher positioned than larger one. Two rollers those were made of MS pipe were set both the ends of each conveyer. Each end of the roller was blinded with metal plate, and sprocket was welded with the plate. The shaft was inserted into the pipes and welded with the plate. The other end of the shaft was inserted into the bearing that fixed with tank to rotate easily. Both the outer edges of MS conveyer were linked with the chain by means of rod those were inserted across the conveyer. Diameters of rods were 4 and 5 mm those were inserted through the conveyer net alternately apart 30 cm. Tees/lugs were placed on the conveyer apart from 30 cm to move the vegetable forward and to avoid gathering vegetables in a place. The conveyer was rotated by means of chain sprocket. Power was transmitted to shaft of the roller from motor by chain sprocket. It was used to convey the mangoes from one end of the machine to the other. The specifications of different materials of the conveyer are shown in table 3.

Table 3. Specification of the different materials of the conveyer assembly

Items	Specifications	
	Large one	Small one
Dimension of conveyer (L × W), mm	1880×635	890×635
Size of tee (L × D × T), mm	580×40×1.2	Nil
Number of Tee	11	Nil
Spacing of from Tee to Tee, mm	340	Nil
Size of sprocket, grade 28 T, 4nos, 14T	420	420
Size of the chain	420	420
Speed of conveyer, rpm	28	28
Mesh conveyer	1	1
Shaft inserted the net hole, mm	4-5 (diameter)	4-5 (diameter)
Bearing P205	4	4

Note: D= diameter, L= Length and T = Thickness, H=Height, t= teeth

## Brush type roller

Conveyer brush rollers are the functional part of the washing machine. It includes fibre shaft, MS shaft, nylon brush, FL and PL bearing, chain, sprocket, clamp etc. Conveyer brush roller was made of fibre shaft along with nylon brush. Each end face of the fibre shaft was blinded with metal plate that was attached with screw, and MS shaft was inserted through the fibre shaft. The shaft was welded with the metal plate. The sprocket was welded with the MS shaft.

The other end of the shaft was inserted into the bearing that fixed with tank to rotate easily. The conveyer brush rollers were rotated by means of chain sprocket. Power was transmitted to shaft of the roller from motor by chain sprocket. Four brush rollers were rotated clockwise. It was used to clean mud from the mango, banana and brinjal and convey the vegetables and fruits from one end of the machine to another. The specifications of materials of the brush rollers are shown in table 4.

Table 4. Specification of the different materials of the conveyer brush roller assembly

Items	Specifications
Overall dimension, mm	560×415×75
Size of fibre shaft (L × D), mm	740×25
Height of nylon brush, mm	20
Size of sprocket, grade	420 (15 T, 6nos)
Number of roller and bearing	4 and 168 (P-205)
Size of the chain, grade	420
Speed of roller, rpm	80

Note: D= diameter, L= Length

### **Brush type bar**

Two nylon brushes were incorporated with the machine for removing dirt from upper surface of the fruit and fruit vegetable. The overall dimension of the brush was 560×40×100 mm. They were set over the brush roller.

### **Power transmission system**

Power transmission system is the most important parts of the machine. It included motor, pulleys, belt, pinions, gear reducer box, UC bearings, and chain sprocket. A single-phase electric motor of 1.1 kW was used as power source. Motor rpm was stepped down from 1400 to 48 by using gear reducer by means of belt-pulley and later from 48 to 20 and 92 rpm by using chain, and pinions. Power was transmitted to the shaft of the roller of conveyer from shaft of gear reducer by chain sprocket. The power transmission system was set on the frame under input portion of the machine.

### **Water supply system**

One of the essential parts of the machine is to supply water through pipe over the vegetables at a particular period. It includes two centrifugal pumps and perforated pipes. One pump is used for supplying water into the perforated pipe of the water tank and other is used to agitate the water into the water house. The perforated pipes were placed horizontally at 100 mm from conveyer surface. They were fixed on the longitudinal sides at about 350 cm apart. The pump was connected to a single phase electric line. Panel board was kept with a stand made of M S angle bar, which was attached to the tank. Water flow was maintained by a regulator valve.

### **Performance test of the leafy & fruit vegetable and fruit washing machine**

Fresh red amaranth, Indian spinach, bean and banana, mango were collected from market and to test the machine at Farm Machinery and Postharvest Process Engineering Division, Gazipur. Quantity of vegetables, washing time, speed of conveyor and brush roller, electric energy use, water use, and injury of vegetables and fruits after washing were recorded during operation of the machine. Quality of washed and non-washed carrot was observed in FMPE postharvest laboratory. Due to COVID -19, experiment could not complete as per design of methodology.

## **Expt. Improvement and fine tuning of washing machine for carrot**

### **Modification of carrot washing machine**

Existing root crop washing machine was structural improved during July to September 2018 (Fig. 16). Larger wheels were attached instead of smaller wheels. Water pump was rearranged from backside to front side of the machine. Water tank was placed over the power transmission cover of the machine. Before it was set separately outside the machine. Input tray was made of MS sheet and angle bar was incorporated with machine. Delivery end of the machine is moved up and down by incorporating hydraulic jag and made the moving mechanism of front two wheels when necessary.



Fig. 16. Improved carrot washing machine

### **Developed of high capacity drum type carrot washing machine**

Brush type carrot washing machine was tested in laboratory and farmers' fields. Farmers opined that they need higher capacity low cost washing machine and movable to other places for serving of other carrot growers as custom hire basis. On basis of demand of farmers, a self-propelled diesel operated drum type carrot washing machine was developed.

#### **Design of the self-propelled diesel operated drum type carrot washing machine**

The carrot washing machine was designed with following consideration

- i. The capacity of the machine should be 1.0-1.5 ton per batch for root crop or carrot
- ii. It should be self-propelled
- iii. Fabrication cost should be minimum as possible
- iv. Water circulation should be controlled
- v. Root vegetables should be clean and moved by friction force each other and rotation force
- vi. Power transmission system should be easy
- vii. Available prime mover should be used

Engineering drawing was done using AutoCAD and Solid Work 17 software showing different parts with dimensions.

### **Brief description of the self-propelled diesel operated drum type carrot washing machine**

A root crops washing machine was designed and fabricated at Farm Machinery and Postharvest Process Engineering Division, BARI, Gazipur during June to September 2020. It was fabricated with MS flat bar, MS shaft, wood, FL bearing, chain-sprocket, wheel, self-starter diesel engine, motor, gear reducer etc. The main parts of it are: i) Main frame; ii) Octagonal drum; iii) Power transmission system; iv) water circulation system; v) delivery chute; vi) self-propelled system and vii) mechanical stirring system. An isometric view of the machine is shown in Fig.17. The top, front and side views of the root crop washing machine are presented in Fig.18. A photographic view of the machine is shown in Fig.19.

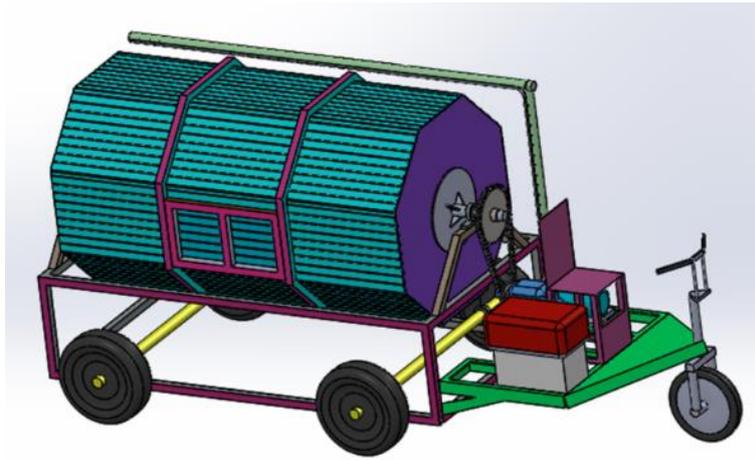


Fig. 17. Isometric view of drum type carrot washing machine

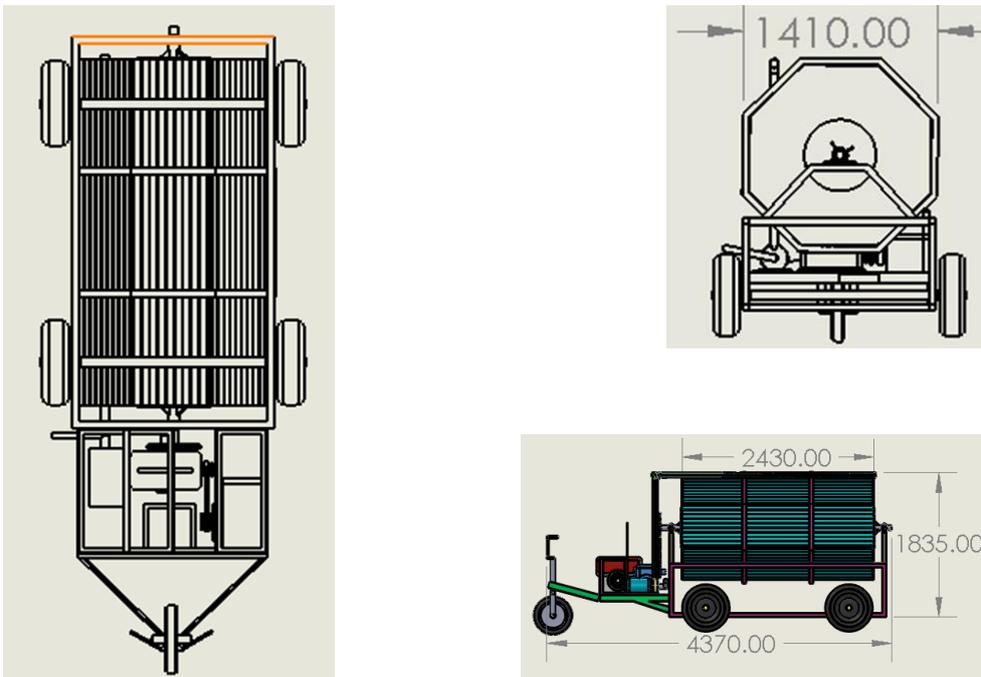


Fig. 18 Top, front and side views of drum type carrot washing machine



Fig. 19. Pictorial view of drum type carrot washing machine

## Description of main parts of the machine

### Main frame

It was fabricated with 508×508×5 mm MS square box. It was an irregular pentagonal in shape and its overall dimension was 4115× 508× 4 mm. It has three wheels, and stirring system (Fig.20).

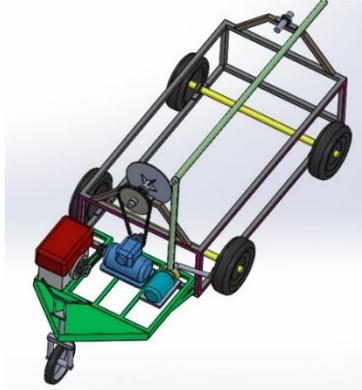


Fig. 20. Pictorial view of main frame of drum type carrot washing machine

### Octagonal drum

It was fabricated with MS plate, MS shaft, MS flat bar, MS box, MS shaft and wood etc. It is an octagonal in shape drum. Overall dimension of the drum was 2439× 1218× 457 mm. It consisted of 72 mild steel flat bar having 50 mm width and same size and number wood was incorporated with inner of the flat bar using nut bolts. Clearance between each flat bar was 2mm. An opening at one side on circumference of the drum was done for feeding carrots and deliver of carrots (Fig.21). Drum was rotated clockwise. Drum holds the carrots and rotates to clean mud.

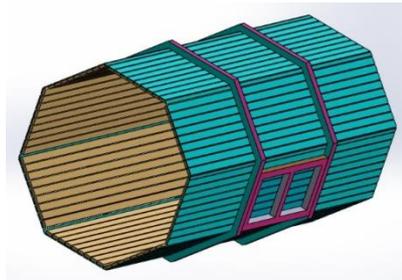


Fig. 21. Pictorial view of main frame of drum type carrot washing machine

### Power transmission system

Carrot washing machine was operated by self-propelled water cooler diesel engine. The speed was reduced from 2200 rpm to 8 rpm by means of gear reducer and belt pulley.

### Water circulation system

It was consisted of centrifugal pump, water tank, suction and delivery pipe and perforated pipe. It is one of the essential parts of the washing machine to supply water for cleaning vegetables. Electric water pump was used to supply water for washing of vegetables. A single perforated pipe was placed horizontally that was fixed on the longitudinal sides over the machine. Water flow was maintained by a regulator valve.

### Self-propelled system

The washing machine has three wheels and power transmitted from diesel engine to front wheels axle. Mechanical stirring was attached the washing machine for controlling the machine.

### **Working Principle**

First, the machine is placed on plane surface and shady place near water and electric source. The water tank is filled with fresh water. Then the diesel engine is started to run the drum and pump is started to supply water through perforated pipe. Harvested carrots are directly fed in the opening gate of the machine. About one to two minutes after operation, water supply is started for removing mud. They are rolling slowly among them by 5-7 minutes. Later on, water is sprayed for removing mud from the surface of the carrots. Then engine is stopped and the washed vegetables are collected in a plastic crate or jute sack through delivery opening gate. This process is continued. Finally, the washed vegetables are carried out to the drying place to get their surface dry.

### **Laboratory test**

Carrot was collected from cold storage from Genda, Saver on 20 March 2020 for determination of storage life of washed and unwashed carrots. Machine was tested with storage carrots at Farm Machinery and Postharvest Process Engineering Division, Joydebpur, Gazipur on August 2020 to conduct preliminary test of the machine for checking functional parts of the machine. Quantity of carrots, washing time, speed of drum, water use, and injury of vegetables after washing were recorded during operation of the machine.

### **Field test**

The machine was tested with fresh harvested carrot 10 March 2021 at Musurikhola, Saver, Dhaka (Fig.22). Quantity of carrots, washing time, speed of drum, water use, and injury of vegetables after washing were recorded during operation of the machine.



Fig. 22. Testing the carrot washing machine at Musurikhola on 10 March 2021

### **Expt. Effect of different packaging on the quality and shelf-life of banana for long distance transportation**

Information on location and initial properties of harvested banana is presented in table 5. It was observed that the variety of rangin sagar banana cultivated new sucker own land that is called Lichi (first cut) in Shibpur, Chargat, Rajshahi district. The latitude and longitude are found to be  $24^{\circ}36'06''$  and  $88^{\circ}74'79''$  respectively. They were harvested within thirteen months after planting. The maturity parameters of banana such as firmness (74.46-81.35 N), °Brix (3.4), angularity ( $45.75-52.67^{\circ}$ ), colour parameters ( $L^*, h^{\circ}, C^*$  as 47.12-52.82, 117.12-119.99, 27.88 respectively) were recorded.

Table 5. Information on location and initial properties of banana on 28 September 2019

Farmer's information			
Farmer's/trader's name	Akram	Address:	Shibpur, Chargat, Rajshahi
Location information			
Location:	Shibpur, Chargat, Rajshahi	Longitude and latitude	24°36'06" and 88°74'79"
AEZ	11	Temperature, °C	27.9-28.3
Relative humidity, %	79.2-79.5		
Crop information			
Crop: First cut, Luchi (শুচি)	Banana (Sagar)	Variety:	Rangin Sagar
Age of banana pseudostem	10 Months	Maturity of bunch, days	90
°Brix	3.4	Firmness, N	74.46-81.35
Angularity, °	45.75-52.67		
Colour (L*, h°, C*)	47.12-52.82; 117.12-119.99; 27.88	Bunch size, length × dia., cm	76×125 to 85×115
Bunch weight, kg	16 to 28.00	Hand no. per bunch	7 to 9
Hand weight, kg	1.5 to 3.5	No. of finger per hand	9 to 16

### Banana supply chain protocol

Two hundred twenty banana bunches of local Rangin sagar from orchard at Shibpur, Charga and fifty bunches of same variety from Banessar assemble market under Rajshahi district were purchased on 28 October 2019 (Fig.23). Hands were separated from one hundred fifty bunches of banana by BARI developed dehandling tool and removed the latex from the crown of hands and later packaging and loaded them in track in heap (Fig.24). Hands were cleaned, sorted (over and under size, crack, spot) and graded (chosen of 2, 3,4,5,7 hands from each bunch out of 7-9 hands). Carton of 20 kg, plastic crate of 15 kg and wooden box of 20 were used for conducting the study. They were packed in wooden box, plastic crate and CFB carton with wrapping of news print paper, cling paper and without wrapping. Rest of hands and bunches were heaped in track. Five treatments and six replications (for P<sub>1</sub>, P<sub>2</sub> and P<sub>3</sub> treatments) were followed for conducting the experiment. Weight, colour, firmness, °Brix, temperature, relative humidity, oxygen, carbondioxide in package and banana heaps, decay, fruits damage due to loading, unloading and transportation, shelf-life were recorded. Supply chain protocol of banana long transportation was developed in Fig.25.

### Treatments: Packaging materials

P<sub>1</sub> = Putting individual hand of banana in wooden box and loaded in truck

P<sub>2</sub> = Putting individual hand of banana in plastic crate and loaded in truck

P<sub>3</sub> = Putting individual hand of banana in corrugated fibre board (CFB) and loaded in truck

P<sub>4</sub> = Traditional practice (keep banana bunch in heap in the truck)

P<sub>5</sub> = Putting banana hands in heap in the same truck



Fig.23. Farmer's banana orchard at Banessar, Rajshahi



Fig.24. Dehandling, sorting, grading and packaging of banana



(1) Banana orchard



(2) Harvesting banana bunch by *Dha*



(3) Placing the banana bunches on triple and tagging



(4) Measuring dimension and Weighing of banana bunches



(5) Dehandling of banana by BARI dehandling tool



(6) Measuring of °Brix, Colour of banana hands



(7) Delatexing and wrapping, packing



(8) Loading bunches and packages in the truck



(9) Unloading banana in wholesale market chowrasta, Gazipur



(10) Stacking banana in Arath wholesale market chowrasta, Gazipur



(11) Unloading the track and laid over the floor of Arath



(12) After unloading, Compare to hands of banana purchased from market and orchard



(13) After unloading, Compare to bunched of banana purchased from market and orchard



(14) After unloading, compare between wrapping with cling paper and without wrapping in the plastic crate



(15) After unloading, compare between wrapping with cling paper and news print paper in the plastic crate



(16) After unloading, compare between wrapping with cling paper and without wrapping in the wooden box



(17) After unloading, compare between wrapping with cling paper and news print paper in the wooden box



(18) After unloading, compare between wrapping with cling paper and news print paper in the CFB carton



(19) After unloading, without wrapping packed in the CFB carton



(20) Physioco-chemical analysis in the FMPE lab

Fig. 25. Supply chain protocol of banana transportation in picture

### Expt. Adoption of a hydraulic lifter for bagging of mango

#### Performance evaluation of imported hydraulic lifter for bagging of mango

Performance of imported hydraulic lifter was evaluated at Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur during October 2019 (Fig.26). Specifications of the lifter are illustrated in table 6.



Fig. 26. Imported hydraulic lifter

Table 6. Specifications and performance test of the lifter

Sl. No.	Specification	Quantity
	Brand name and Model Number	
	Safe working load	320~ 350kg
	Extension platform safe working load	113~ 120kg
	Working height	12m or better
	Platform floor height	10m or better
	Overall length and width	2.48m and 2.0-2.5m
	Platform size (length/width)	2.27m*1.12m
	Lifting motor	24v /4.5kv
	Drive motor	24v/1.5kv, 220-230 V
	Up/down speed	54/42sec
	Gradeability	25%
	Weight	2500-2600kg

### Performance test of hydraulic lifter and modification of hydraulic lifter

Performance of imported hydraulic lifter was tested for bagging of mango at Farm Machinery and Postharvest Process Engineering Division, and horticultural mango orchard of Bangladesh Agricultural Research Institute, Gazipur during 2020. During bagging of mango fruits, the following problems were observed (Fig.27, 28, 29 and 30). The problems and remedies of the lifter are mentioned in Table 7.

Table 7. Problems faces during testing the lifter and remedies of them

Sl. No.	Problems of machine	Remarks
1	Lifter can't move in clay soil or soft soil and narrow road.	Wheel should be replaced with larger.
2	Prime mover is used a power tiller for transportation in working place. This system is not properly work for turning and less speed	Prime mover will be replaced like ricksaw van. So, it should be made a shelf-propelled machine
3	Dioad was problem	Di-oaad was replaced
4	Hydraulic oil was poured (VG-46)	Oil should be measured and poured in down position but not done in lifting position
5	Latex was dropped over operator body, clothe is damaged.	Cloth apron

Sl. No.	Problems of machine	Remarks
6	If, Electricity goes to load shading when lifter is up or working, solenoid valve should be used to down the lifter	Lifter should be operated by 12 volt battery with converter or incorporated generator of 5 kVA to control or operated in field instead of electricity.
7	Lifter is vibration when lifting more than 25ft	Supporting legs must be fitted when it is lifting



Fig. 27. Lifter was driven through due to power tiller in the HRC mango orchard



Fig.28. Wheel of hydraulic lifter was slippage soft soil of orchard for raining



Fig. 29. Tractor pulled hydraulic lifter from the muddy orchard to the road



Fig. 30. Mango were bagged with brown and black colour bag using hydraulic lifter

### Field test of the lifter

Field test of the lifter was conducted at Fruit Research Station, Binodpur, Rajshahi on 15 March 2021 (Fig. 31).



Fig. 31. Testing the lifter at at Fruit Research Station, Benodpur, Rajshahi on 15 March 2021

**Expt. Determination of combined effects of temperature and exposure time on treating mango in hot water**

**Mango sample collection and experiment setup**

Rajshahi district, located at 24°34' N latitude and 88°16' E longitude in the northwestern part of the Bangladesh, produces the highest amount of mangoes and their qualities are the best in the country. Mangoes are cultivated there on commercial basis and marketed throughout the country. Matured of BARI Aam-3 was harvested by the BARI developed mango harvester from farmer's mango orchard at Banessar, Rajshahi on 26 June 2019 (Fig. 32). °Brix, colour, firmness and specific gravity of mango (Fig. 33) were measured for maturity parameters. About five hundred kilogram harvested fresh mango was packed in plastic crate and transported by pickup from orchard to FMPE Division, BARI, Gazipur (Fig. 34). The following treatments with three replications were considered to conduct the experiment. The matured mango was treated using BARI developed hot water treatment plant (Fig.35).

Factor- A Treating

T<sub>0</sub> = Control

T<sub>1</sub> = 50 °C

T<sub>2</sub> = 55 °C

T<sub>3</sub> = 57 °C

Factor-B Treating Exposure time

t<sub>1</sub> = 3 min

t<sub>2</sub> = 5 min

t<sub>3</sub> = 7 min

t<sub>4</sub> = 9 min



Fig.33. Measuring the specific gravity of mango

Fig.32. Harvesting mango using BARI mango harvester at Rajshahi



Fig.34. Sorting, grading and packaging of mango



Fig.35 Treated mango using BARI developed hot water treatment plant at FMPE workshop

### Organoleptic evaluation

Colour, firmness, weight, disease severity, taste, flavour, peel colour of treated and untreated mangoes were measured during storage period at room temperature. When the fruits reached edible stage, general appearance (skin colour and taste) and eating quality was assessed. Fruits were exposed to a panel of 10 assessors using a 1-9 scale (1=like extremely, 2=like very much, 3=like moderately, 4=like lightly, 5=neither like nor dislike, 6=dislike slightly, 7=dislike moderately, 8=dislike very much and 9=dislike extremely) for general appearance. Fruit slices were presented to a panel of 10 tasters and rated the eating quality using a 9 point scale (Jacobi and Giles, 1997). Eating quality of ripe mango was evaluated on the basis of color, flesh, flavour and taste (Fig. 36).



Fig.36. Organoleptic evaluation of mango

### Expt. Effects of cold storage temperature and humidity for different packaging on shelf-life and quality of carrot

The study on temperature and humidity for different packaging on shelf-life and quality of carrot in cold storage was conducted during 2018-2020. The following seventeen treatments were considered in first year and nine same treatments in the both second and third year. Second and 3<sup>rd</sup> year treatments were taken on the basis of first year findings.

#### *Treatments (during March 2018)*

- T<sub>0</sub>= kept unwashed carrots into jute sack package (conventional practice)
- T<sub>1</sub>= kept washed in water carrots into jute sack package
- T<sub>2</sub>= kept washed in water + CCA carrots into jute sack package
- T<sub>3</sub>= Unwashed carrots and polyethylene bag covered with jute sack
- T<sub>4</sub>= Washed carrots in water and polyethylene bag covered with jute sack
- T<sub>5</sub>= Washed carrots in water + CCA and polyethylene bag covered with jute sack
- T<sub>6</sub>= Unwashed carrots and plastic crate covered with polyethylene

- T<sub>7</sub>= Washed in water carrots and plastic crate covered with polyethylene  
 T<sub>8</sub>= Washed in water +CCA carrots and plastic crate covered with polyethylene  
 T<sub>9</sub>= Washed carrots in water and polyethylene bag packed in CFB carton  
 T<sub>10</sub>= Washed carrots in water +CCA and polyethylene bag packed in CFB carton  
 T<sub>11</sub>= Unwashed carrots in water and only polyethylene bag  
 T<sub>12</sub>= Washed carrots in water and only polyethylene bag  
 T<sub>13</sub>= Washed carrots in water+ CCA and kept them into only polyethylene bag  
 T<sub>14</sub>= Unwashed carrots and perforated polyethylene bag (0.2%)  
 T<sub>15</sub>= Washed carrots in water and o perforated polyethylene bag (0.2%)  
 T<sub>16</sub>= Washed carrots in water +CCA and perforated polyethylene bag (0.2%)

*Treatments (during March 2019 and March 2020)*

- T<sub>0</sub>R<sub>0</sub> Unwashed carrots in Jute sack (conventional practice)  
 T<sub>1</sub>R<sub>1</sub> Unwashed carrots (conventional practice) in crate with poly  
 T<sub>2</sub>R<sub>2</sub> Unwashed carrots (conventional practice) in CFB with poly  
 T<sub>3</sub>R<sub>2</sub> CCA (1g/10 litre) washed carrots in jute sack  
 T<sub>4</sub>R<sub>2</sub> CCA (1g/10 litre) washed carrots in crate with poly  
 T<sub>5</sub>R<sub>4</sub> CCA (1g/10 litre) washed carrots in CFB with poly  
 T<sub>6</sub>R<sub>3</sub> Chlorine water (3.8 ml/2 litre) washed in jute sack  
 T<sub>7</sub>R<sub>1</sub> Chlorine water (3.8 ml/2 litre) washed in crate with poly  
 T<sub>8</sub>R<sub>2</sub> Chlorine water (3.8 ml/2 litre) washed in CFB with poly

**Sample collection & Processing:** Matured carrots harvested from farmers' fields at Masuritala, Vakurta, Saver, Dhaka (GPS position 23° 51' 30.0024" N and 90° 16' 0.0120" E), packed in jute sack and transported by track to Farm Machinery and Postharvest Process Engineering Division of Bangladesh agriculture Research Institute for washing and packaging during 20 March 2018, 11 March 2019 and 18 March 2020. About one tonne of matured harvested carrots were used in each year. Metallic sound, size, shape, colour (hue angle 57-64°) and firmness (4.7 kgf/cm<sup>2</sup>) of carrots were chosen as maturation indicator. Matured carrots were trimmed, sorted and graded manually.

**Washing & Packaging:** Sanitizer of calcinated calcium (CCA) was used in first year and NaOCl (3.8 ml/2 litre) and CCA were used in second year and third year. CCA (1g/10litre of water) was mixed in the tap water of water tank of 200 litre capacity. Carrot was washed with the sanitizer mixed water by using the root crop washing machine for 5-6 minutes (Fig.37). Washed carrots were dried in ambient air for 2-3 minutes, sorting, grading and packed into jute sack (traditional practice), plastic crate, CFB carton with lining of polyethylene of 0.05 mm thickness (Fig.38). Peel colour and firmness of washed and unwashed carrots were measured by chroma meter (model 400 and made in Japan) and fruit texture analyser (model: GS, made in South Africa) respectively.



Fig. 37. Washing carrot by BARI root crop washing machine during 18 March 2018 (A), 11 March 2019 (B) and 18 March 2020 (C)



Fig. 38. Trimming, sorting, grading and packing of carrot during 20 March 2018 (E), 11 March 2019 (F) and 18 March 2020 (G)

### Performance parameters

#### Sample stored and collection from cold storage

The packaged carrot was then transported to the commercial cold storage of ASKEO MSP Centre Limited, Ashulia, Saver, Dhaka during 2018 and 2019 and to Genda MSP Centre Limited, Genda, Saver, Dhaka during 2020 (Fig.39). All treatments were stored in cold storage at 0-4° C and 97-99% rh. The physical characteristics include decay/injury, weight loss, colour, firmness; microbiological quality of stored carrots was collected for one month interval. Samples of carrots of each treatment were collected in one month intervals during 2018 and 2019. In third year of 2020, this data did not collect timely due to occur COVID-19. Collected samples of carrots were packed inside cool box for no occurring contamination. Colour, firmness of carrots was measured at FMPE postharvest laboratory and Postharvest Technology Division laboratory, BARI, Gazipur.



Fig. 39. Observation of stored carrot in Cold storage

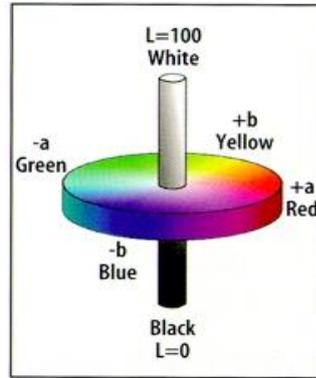
Microbial quality parameters including, Total Aerobic Bacterial Count (TABC), Total Coliform Count (TCC), Total faecal coliform (TFC) & Yeast and Mold counts and safety parameters include the presence and absence of *E.coli* and *Salmonella* of washed and unwashed carrots were determined in research laboratory of WAFFEN (Water Food Feed Environment), Banani, Dhaka. TSS, total phenolic content, total carotenoids, ascorbic acid and titratable acidity were measured. Temperature and relative humidity of stored carrot in cold storage were measured by humidity/temperature and Data logger (Model: RHT20, Extech).

#### Physical parameters

##### Peel colour of carrot

The peel colour of carrots was measured using a chroma meter. An 8 mm diameter measuring head mounted on the meter was calibrated each time with a standard white plate. Colour measurements were recorded using Hunter L\*, a\* and b\* scale (Hunter, 1975; Francis, 1980). The "L\*" coordinate is a measure of lightness (white-black and ranges from no reflection L=0 to perfect diffuse reflection L\*=100), the "a\*" scale ranges from negative values for green to positive values for red and the "b\*" scale ranges from negative values for blue to positive values for yellow. The L\*, a\* and b\* values were converted to hue value and chroma

(McGuire, 1992). The  $C^*$  represented the vividness of colours with values ranging from 0=least intense to 60 =most intense. The  $h^\circ$  is actual or perceived colour that used to classify the kind of colour, which vary continuously from  $0^\circ$  to  $360^\circ$ . A  $h^\circ$  of  $0^\circ$  corresponded to  $h^\circ$  of 270. The colour was measured using CIELAB scale at D65 (Daylight–Neutral) illuminant as shown in Fig. 40 and 41. Three readings were taken at three points on the surface of each carrot and the mean values of  $L^*$ ,  $a^*$  and  $b^*$  were calculated.



*Lab model*

Fig. 40. CIE (Lab) chromaticity diagram

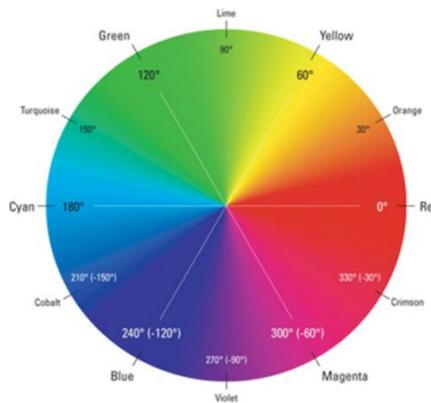


Fig. 41. Colour expression with hue angle according to Hunter Colour Lab

Hue value ( $h^\circ$ ) and chroma ( $C^*$ ) were calculated using the following equations (Lopez Camelo and Gomez, 2004).

$$\text{Hue angle} = \tan^{-1} \left( \frac{b^*}{a^*} \right) \quad (\text{when } a^* > 0) \quad (1)$$

$$\text{Hue angle} = 180^\circ + \tan^{-1} \left( \frac{b^*}{a^*} \right) \quad (\text{when } a^* < 0) \quad (2)$$

$$\text{Chroma} = (a^{*2} + b^{*2})^{0.5} \quad (3)$$

### **Firmness of carrot fruits**

Carrot firmness was measured using digital firmness tester equipped with 8 mm diameter cylindrical stainless probes. Tester was checked each day before use. The plunger was made to work in and out (about ten times) to ensure that it was running smoothly. Carrot firmness was expressed in kilogram force ( $\text{kgfcm}^{-2}$ ) or Newton. Three readings were taken at three places on the surface of each carrot and the mean value was calculated.

### **Measurement of dry matter content**

Empty container (aluminum dish) was weighed on electronic micro balance and recorded it (A). Chopped fresh pulp samples were put into the container and weighed it (B). The samples

were placed in an air ventilated electric oven at 100 °C for 24 hours (Kushman *et al.*, 1966). The samples were transferred with the container from oven into desiccators and cooled at room temperature and weighed to obtain the dry samples (C).

Percentage of dry matter content of the samples were calculated by using the following formula.

$$\text{Wet weight of sample} \quad (D) = B - A \quad (4)$$

$$\text{Dry weight sample} \quad (E) = C - A \quad (5)$$

$$\text{Drymatter content, (\% (wb))} \quad = \frac{C - A}{B - A} \times 100 \quad (6)$$

### Chemical attributes

**Preparation of carrot extract:** Grounded freeze dried carrot (1.0 g) was weighed into centrifuge tube, 10 mL of solvent (80% aqueous acetone) was added, and the sample was homogenized for 1min. Tubes were centrifuged (15 min), and the clear supernatant was collected. Supernatants were taken to dryness. The solid residue was dissolved in methanol (25ml).

**Determination of total phenolic content:** The amount of total phenolics in extracts was determined according to the Folin-Ciocalteu procedure. Samples (2mL, triplicates) were introduced into test tubes; 1.0 mL of Folin-Ciocalteu's reagent and 0.8 mL of sodium carbonate (7.5%) were added. The tubes were mixed and allowed to stand for 30 min. Absorption at 765 nm was measured (Systronics UV-vis spectrophotometer). The total phenolic content was expressed as gallic acid equivalents (GAE) in milligrams per gram dry material.

**Total carotenoids:** The total carotenoids were measured using a spectrophotometric method as described by Opiyo and Ying (2005). Samples (1.0 g) of chopped and then blended (Assistant all in one blender, AEG Electrolux, China) carrots were extracted by grinding in 14 mL solution of n-hexane: acetone (3:2 v/v). The homogenate was then centrifuged at 10,000 g for 10 min at 4 °C in an Eppendorf centrifuge (Hitachi, Japan). The supernatant was topped up to a volume of 25 mL with the extraction solution. The absorbance was determined using a spectrophotometer (Helios Omega UV-Vis Thermo Scientific, USA). Pigment contents were calculated from the following equations:

$$\text{Total Carotenoids } (\mu\text{g.g}^{-1}) = \frac{\text{OD}_{502} \times 4 \times 1000}{\text{Mass of Sample (g)}} \quad (7)$$

Pigments were obtained as  $\mu\text{g.g}^{-1}$  and later presented as mg/100 g of Fresh weight.

**Ascorbic acid:** Total ascorbic acid was content determined using the 2, 6 dichloroindophenol (DCP) titration method under subdued light as according to AOAC (2006) method 967.21.

**Total soluble solids (°Brix):** The total soluble solids (TSS) content was determined using a digital refractometer (Atago, Japan) calibrated at 23°C.

**Titrateable acidity:** Expressed as percentage citric acid, was determined by titrating with 0.1N NaOH up to pH 8.1 using a TA- Metrohm 862 compact titrosampler (Metrohm, Switzerland).

**Microbiological Quality & safety:** Microbial quality parameters including, Total Aerobic Bacterial Count (TABC), Total Coliform Count (TCC), Total faecal coliform (TFC) & Yeast and Mold counts were determined using standard microbiological methods. Safety parameters include the presence and absence of *E.coli* and *Salmonella* were determined as per standard microbiological methods.

### Performance parameters

The performance of the developed vegetable washing machine was evaluated regarding on the washing efficiency and cleaning efficiency as per equation mentioned below 8:

$$\text{Washing efficiency} = \frac{\text{Weight of the carrot after washing}}{\text{Weight of the carrot before washing}} \times 100 \quad (8)$$

Cleaning efficiency is the removal of fibrous roots from the rootstalk. In sample, the number of cleaned tubers free of the fibre refers to the extent of cleaning as given in equation (9).

$$\text{Cleaning efficiency} = \frac{\text{No of cleaned roots free of fibers}}{\text{Total number of roots}} \times 100 \quad (9)$$

### **Fabrication of mango harvester and delatexing rack**

Twenty mango harvesters and five mango delatexing rack were fabricated as per design of BARI model (Fig. 42 & 43). Mango harvester was made of iron wire, hex blade, MS sheet and nut bolts. Specification of mango harvester is presented in table 8. Mango delatexing rack was fabricated with the SS sheet, SS box, SS flat bar and plastic cup. Specification of the rack is illustrated in table 9.



Fig. 42. Pictorial view of mango harvester



Fig. 43. Pictorial view of mango delatexing rack

Table 8. Specification of mango harvester

Parts	Specification
Length with bamboo, m	2-3
Angle between blades	50
Oval ring dimension, mm	295 and 200
Size of clamp, mm	Diameter=27, Length=32
Weight, g	325
Capacity, kg/h	50-75
Price (without bamboo), Tk.	600

Table 9. Specification of mango delatexing rack

Parts	Specification
Dimension of cup, mm	85×48
Number of cup, no	81
Dimension of rack, mm	1000×1000×500
Frame size of cup, mm	25×13
Flat bar size for stand, mm	38×4
SS sheet, mm	1
Price, Tk.	10000
Weight, kg	22

## Economic analysis

### Price estimation for fabrication of leafy & fruit vegetable and fruits washing machine

The fabrication cost of the machines was calculated including cost of materials, labour, overhead, incidental expenses (Appendix-III).

### Price estimation for fabrication of drum type carrot washing machine

The fabrication cost of the machines was calculated including cost of materials, labour, overhead, incidental expenses (Appendix-IV).

### Washing cost estimation washing machine

Economic analysis of the vegetable washing machine was done as per standard procedure. Operating cost of the machine included the fixed cost and variable cost. Fixed of the machine included capital consumption and shelter. Variable costs included labour, electricity, oil fuel, water, materials, repair & maintenance.

The prices of the leafy & fruit vegetable washing machine and drum type carrot washing machine are 1,42,000.00BDT and BDT 3,00,000.00 respectively. Machine lives of both the machines are 7 years. Working duration is 175 days per year. Four labours are required for operating the machine. Labour wage is BDT 500 per day and water charge is 100 BDT/h and materials cost is 1.00 BDT/h. Interest rate of investment is 12%.

### Fixed cost

Fixed cost of the machine included annual depreciation, interest on investment, and shelter. Capital consumption included depreciation and interest.

#### i) Capital consumption (CC)

$$CC = (P - S)CRF + S \times i \quad (2) \quad (10)$$

Where, P=Purchase price, BDT

S=Salvage value, BDT

CRF= Capital recovery factor

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \quad (11)$$

Where, i= Rate of interest

L=Life of machine, yr

ii) Shelter, T=3.0% of purchase price of the machine, BDT

#### Total fixed cost per year

$$FC = CC + T \quad (12)$$

### Variable Cost

In calculation of variable cost, the following relations were assumed

- i) Labour cost per hour,  $L_b = \text{BDT man-h}^{-1}$
- ii) Electricity cost per hour,  $E = \text{Lit h}^{-1}$
- iii) Repair and maintenance (R&M) cost per year = 3.5% of purchase price of the machine
- iv) Water charge, BDT/h ( $0.03 \text{ BDT/L} \times 3000 \text{ l/h}$ )
- v) Materials cost (plastic crate, bowl, triple, pipe, pedestal fan etc)

#### Total variable cost

$$VC = L_b + E + R \& M \quad (13)$$

#### Annual cost/operating cost

$$AC = FC + VC \quad (14)$$

### Field Demonstration

Field demonstration was conducted on 11 June 2020 at Baneshar Bazer, Puthia, Rajshahi on hot water treatment plant (Fig. 44). Forty participants were attended in the program. Mr. Komala Rangan Das, additional secretary, Ministry of Agriculture presented in here as chief guest and Dr. Md. Nazirul Islam, Director General, BARI presented as special guest and Dr Md. Miaruddin, Director (Research) as special guest in the program.



Fig. 44. Conducted field demonstration on 11 March 2020 at Rajshahi

Field demonstration was conducted on 12 June 2020 at Vatra, Mirzapur, Bogura on vegetable washing machine (Fig.45). Forty participants were attended in program. Dr. Md. Nazrul Islam, Chief Scientific Officer, Horticultural Research Centre, Gazipur and Principle Investigator of the project (component-1), Dr. Md. Shihidul Alam, Principle Scientific Officer and in charge of OFRD, Bogura.



Fig. 45. Conducted field demonstration of vegetable washing machine on 12 March 2020 at Bogura

### *Implementing component-3: Center for Center for Advanced Research in Sciences, DU*

**Study# 1: Survey in the value chains (from growing areas to city retail outlet) of selected crops in relation to food safety and quality issues.**

**Materials/Crops:** Mango, Banana, Brinjal, Carrot and Cauliflower

**Study area:** Rajshahi, Bogra, Pabna (only for carrot) and Dhaka/Gazipur City

**Methods:** Survey was conducted at different levels of the distribution chain. It was conducted in collaboration with Postharvest Technology Section of HRC BARI, acted as the implementing component-1 of this project. Pre-designed questionnaires were used to gather general and specific information by value chain actors (grower, supplier, wholesalers, processor, retailer and consumers). A sample size of 50 was targeted for a crop. Data on the sanitizing practiced, potential postharvest handling activities and the factors that contribute to

quality deterioration was analyzed descriptively through statistical software. Findings of the survey would be described in the part of implementing component-1.

**Study # 2.** Study on the efficacy of non-chlorine sanitizer, natural salt and/or in combination of both against the microbes on mango, banana, Brinjal, carrot and Cauliflower

An experiment was conducted on carrot under the study on the efficacy of using sanitizer (in light of stated in PP). It was conducted in collaboration with the implementing component 2 of this project, Farm Machinery and Postharvest Process Engineering Division of BARI. The finding of this study related to sanitizers would be a basis of safe washing and might be useable in targeted other crops viz. mango, banana and Brinjal excluding cauliflower. The sample collection method, treatments and recorded data of the experiment on carrot were as below:

**Expt. 1.** Study on the efficacy of using sanitizer in preservation of carrots in cold storage

**Materials and methods:**

**Sample collection & Processing:** Matured carrots harvested from farmers' fields at Masuritala, Vakurta, Saver, Dhaka (GPS position 23° 51' 30.0024" N and 90° 16' 0.0120" E) and transported to Farm Machinery and Postharvest Process Engineering Division of Bangladesh Agriculture Research Institute for washing and packaging during 20 March 2019. Two tonnes of matured harvested carrots were used in this study. Metallic sound, size, shape, color (hue angle 57-64°) and firmness (4.7 kgf/cm<sup>2</sup>) of carrots were chosen as maturation indicator. Matured carrots were trimmed, sorted and graded manually and clean with water using BARI developed mechanical root crop washing machine (Fig. 45).



Fig 46: A) Trimming, sorting, grading and B) washing with sanitizer by BARI developed mechanical root crop washing machine; and C) sun drying for 2-3 hours and packaging manually.

**Treatment & Packaging:** Sanitization of carrots were done by dipping the carrots in water and 0.01% WSP solution (1g/10 litre of water) for 5-6 min followed by rinsed with filtered tap-water. Both the washed and unwashed carrots were sun dried and packed into jute sack (traditional practice), plastic crate, and CFB cartoon with lining of polyethylene of 0.05 mm thickness separately. The following treatment and packages were done:

- T<sub>0</sub>= Kept unwashed carrots into jute sack package (Traditional practice)
- T<sub>1</sub>= Wash carrots with chlorine water and kept them into jute sack package
- T<sub>2</sub>= Wash carrots with WSP and kept them into jute sack package
- T<sub>3</sub>= Kept unwashed carrots into plastic crate package
- T<sub>4</sub>= Wash carrots with chlorine water and kept them into plastic crate package
- T<sub>5</sub>= Wash carrots with WSP and kept them into plastic crate package
- T<sub>6</sub>= Kept unwashed carrots into CFB Cartoon with polyethylene lining
- T<sub>7</sub>= Wash carrots with chlorine water and kept them into CFB cartoon with lining
- T<sub>8</sub>= Wash carrots with WSP and kept them into CFB carton with lining



Fig 47: Sanitized carrots were packed into A) plastic crate package B) CFB carton with polyethylene lining (0.05 mm thickness) C) plastic /jute sack package.

### Sample storage and collection for analysis

The packaged carrot was then transported to the commercial cold storage of ASKEO MSP Centre Limited, Ashulia, Saver, and Dhaka (Fig. 160). All treated & packaged carrots were stored in cold storage at 0-1° C and 97-99% RH on 21 March 2019. The temperature and relative humidity of stored carrot in cold storage were measured by humidity/temperature Data logger (Model: RHT20, Extech), and O<sub>2</sub> and CO<sub>2</sub> contents were measured by O<sub>2</sub> and CO<sub>2</sub> analyzer (O<sub>2</sub>/CO<sub>2</sub> Analyzer, Q<sub>2</sub>, Quantek). The physico-chemical characteristics include decay/ injury, weight loss, color, firmness dry matter content, TSS, titratable acidity, ascorbic acid, total phenolic content and total carotenoids; and microbial quality parameters including, total aerobic bacterial count (TABC), total coliform count (TCC), total fecal coliform (TFC) & yeast and mold counts and microbial safety parameters include the presence or absence of *E. coli* and *Salmonella* spp of stored carrots was done periodically for every month. The first year carrot samples were collected on 22 March 2018 (0 month); 22 April, 2018 (1 month); 22 May 2018 (2 month); 24 June, 2018 (3 month), & 24 July 2018 (4 month). However, due to the development of fungus at the 5<sup>th</sup> month of storage on all the carrot samples, we did not proceed further. This might be due to the temperature abuse of the ASKEO MSP cold storage, but details were not provided to us. In the 2<sup>nd</sup> year, samples of carrots of each treatment were collected on 21 March 2019 (0 month), 22 April 2019 (1 month), 23 May 2019 (2 month), 24 June 2019 (3 month) and 24 July 2019 (4 month), 24 August, 2019 (5 month), 25 September 2019 (6 month). The stored carrot samples were collected in sterilized Ziploc pack and placed in cool boxes for maintaining cool temperature and transported to the laboratory for analysis. All the physico-chemical parameters were analysed in the laboratory of Postharvest Technology Division, BARI, Gazipur; and all the microbial parameters were analysed in WAFFEN Research Laboratory Limited-an accredited laboratory for microbial parameters, at Tejgoan, Dhaka.

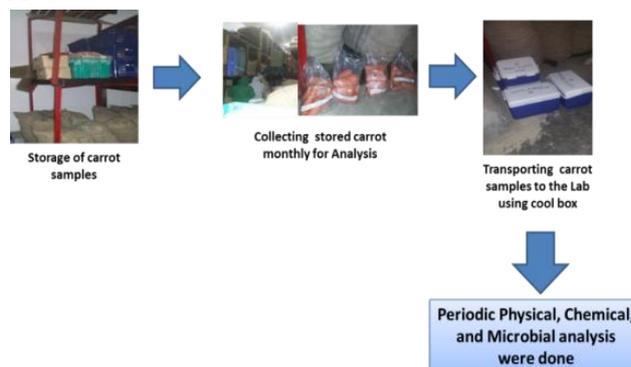


Fig 48: Carrot stored at commercial cold storage and transported to the laboratory for analysis.

**Study # 3.** Evaluation of microbial load and pesticide residues of banana, mango, cauliflower and brinjal using in intervened postharvest technologies in the value chain

According the plan designated in project proposal, four trials were taken under study#3, as outlined in PP. These investigations were done by collecting the crop sample from the conducted experiment of PHTS for assessing of ‘Technical and economic feasibility of improved postharvest technologies integrated in the value chains.’ The treatments were same or almost same as mentioned in the methodology part of implementing component-1 (PHTS). CARS of DU collected sample from each of the treatments from every experiment and data were collected for microbial loads and safety concerns. The materials and methods including treatments are stated experimentwise in below.

**Expt. No. 1.** Evaluation of microbial load in mango as affected by traditional and improved practices integrated in the value chain

Material: Mango (*Mangifera* ‘Langra’)

Treatments: 9

1) TP= Traditional management practices; IP= Improved management practices;

2) IP-1: NBG+NDS+NHW+PC+T

3) IP-2: BG+DS+HS+PC+T

4) IP-2A: BG+DS+HWT+PC+T

5) IP-2B: BG+DS+HS+PC+T

6) IP-3: NBG+DS+NHW+PC+RV

7) IP-3A: BG+DS+HWT+PC+RV

8) IP-3B: BG+DS+HS+PC+RV

NBG=Non-bagging, BG=Bagging (pre-harvest), ND=No de-latexing or de-sapping, NW= No washing, NHW=No hot water treatment, HW=Hot water treatment, HS=Hot sanitizing i.e. hot water treatment with 0.01% calcinated calcium (supplied by DU), PC=Plastic crate, T=Truck, RV=Reefer van (transport vehicle).

#### **Mango sample collection procedure for microbial Analysis**

1	Hands were washed before starting the sample collection.
2	All samples were collected aseptically so as to not be contaminated the sample (Wear clean gloves, clean lab coat, hair net).
3	Three mango samples were collected as a unit per lot unless otherwise specified. While collection a systematic random sample selection was done from the lot.
4	Each sample unit should be at least 250 g of intact, whole mango sample in the form in which it sold or distributed
5	Each mango sample unit was placed into a separate sterile sealable bag or clean plastic bag.
6	It was made sure that the top of the bag is adequately closed
7	Outside of the bag was labeled with detailed info that will identify the sample: Collection date and time Name of the growers/shops Lot size and number Sample unit weight Production date and CODE Name of the person that collected the sample
8	New sample bag was used for each sample unit.
9	The sample sheet/ lab requisition form was included in a separate plastic bag with

	the sample. It was made sure that all the fields on the lab requisition/sample sheet are filled-out and the adequate information is provided.
10	The mango samples and sample sheets were placed into a clean and sanitized cooler with ice packs.
11	The samples were kept at refrigeration temperatures (i.e. 0 to 4°C) and bring them or ship the cooler to the laboratory as soon as possible. The temperature of refrigerated samples must not exceed 7°C upon its arrival at the laboratory. Samples must be analyzed within 24 h of sampling.
12	The samples did not be frozen unless laboratory has been consulted



A) Non-Cooling Traditional Transport System



B) Non-Cooling Traditional Transport System

Fig 49. Partial Pictorial view of mango sample collection

**Expt. No. 2.** Evaluation of microbial load in banana as affected by traditional and improved practices integrated in the value chain

Material: Banana (*Musa Amrit Sagor*)

**Treatments: 8**

1) Control/Conventional practices (Traditional cultural and plant protection measures + No fruit bagging + No de-handing + No detaxing and washing + traditional transporting system: loaded in truck by taking the full bunch through heaping method). {Traditional Practices followed in Bogura area]

Designated as: TRD= TNWNDHT =Traditional- No Washing-No De-Handing-No Packaging-Transported by Truck

**2) Improved practices-1** (Recommended cultural and plant protection measures+ sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers + de-handing with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van + washing once by dipping and lightly brushing handling in clean water in the washing house for 15 minutes + drying under ceiling fan on draying tray + packed in plastic crate lining with clean newspaper and without MAP +transport by truck).

Designated as: IP-1= DHWWTPCT =De-handing-Water Wash in Tank-Plastic Crate Packaging-Transported by Truck

**3) Improved practices-2** (Recommended cultural and plant protection measures+ sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers + de-handing with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van + washing twice i) by dipping and lightly brushing handling in clean water in the washing tank for 10 minutes and then ii) dipping in alum water in second washing house for 15 minutes + drying under ceiling fan on draying tray + packed in plastic crate lining with clean and fresh newsprint paper newspaper and without MAP + transport by truck).

Designated as: IP-2= DHAWTWMPT =De-handing-Alum Water Wash in Tank-Without MAP-Packed in Plastic Crate -Transported by Truck

**4) Improved practices-3** (Recommended cultural and plant protection measures+ sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers+de-handing with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van + washing twice i) by dipping and lightly brushing handling in clean water in the washing tank for 10 minutes and then ii) dipping in alum water in second washing house for 15 minutes+drying under ceiling fan on draying tray+packed in plastic crate lining with clean and fresh newsprint paper newspaper and with MAP +transport by truck).

Designated as: IP-3= DHAWTMPT =De-handing-Alum Water Wash in Tank-With MAP-Plastic Crate Packaging-Transported by Truck

**5) Improved practices-4** (Recommended cultural and plant protection measures + Pre-harvest bagging+ sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers + de-handing with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van +washing once by dipping in alum water in washing house/tank for 15 minutes+ drying under ceiling fan on draying tray+ packed in plastic crate lining with clean and fresh newsprint paper newspaper and with MAP+ transport by truck).

Designated as: IP-4=BDHAWTMPT=Pre-harvest Bagging-De-handing-Alum Water Wash in Tank-With MAP-Plastic Crate Packaging-Transported by Truck

**6) Improved practices-5** (Recommended cultural and plant protection measures+ sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers+de-handing with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van +washing twice i) by clean water in the washing machine for 10 minutes and then ii) dipping in alum water in washing machine for 15 minutes+drying under ceiling fan on draying tray+packed in plastic crate lining with clean and fresh newsprint paper newspaper and without MAP +transport by truck).

Designated as: IP-5=DHAWMWMPT=De-handing-Alum Water Wash in Washing Machine-Without MAP-Packed in Plastic Crate Packaging-Transported by Truck

**7) Improved practices-6** (Recommended cultural and plant protection measures+ sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature

fingers + de-handing with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van +washing twice i) by dipping and lightly brushing handling in clean water in the washing machine for 10 minutes and then ii) dipping in alum water in second washing house for 15 minutes + drying under ceiling fan on draying tray + packed in plastic crate lining with clean and fresh newsprint paper newspaper and with MAP +transport by truck).

Designated as: IP-6=DHAWMMPT=De-handing-Alum Water Wash in Washing Machine-Without MAP-Packed in Plastic Crate Packaging-Transported by Truck

**8) Improved practices-7** (Recommended cultural and plant protection measures+ sorting and selecting fingers by taking hands No. 2-5/6 represents similar size/physiologically mature fingers + de-handing with care by de-handing tools and carefully initial de-latexing on bedding banana leaves in the field + carefully transport to pack house by pick-up van + washing twice i) by dipping and lightly brushing handling in clean water in the washing machine for 10 minutes and then ii) dipping in CCa water in second washing house for 15 minutes + drying under ceiling fan on draying tray + packed in plastic crate lining with clean and fresh newsprint paper newspaper and with MAP +transport by truck).

Designated as: IP-7=DHCWMMPT=De-handing-CCa Water Wash in Washing Machine-Without MAP-Packed in Plastic Crate Packaging-Transported by Truck

#### **Sample collection procedure for microbial Analysis and data recording:**

Almost similar to the experiments of mango, as mentioned in above. In addition, whether the sanitizing agents used over the banana is entering into inside the banana or not, to evaluate this, both outer and inner banana peel was observed under scan electron microscopy for its pore size.

**Expt. No. 3.** Evaluation of microbial load in cauliflower as affected by traditional and improved practices integrated in the value chain

Treatments: 5 (same as mentioned in the methodology part of implementing component-1)

- 1) TP+NPP+SNB
- 2) IP-1: IP+PPB+SNB
- 3) IP-2: IP+NPP+PC without MAP
- 4) IP-3: IP+PPB (MAP)+PC
- 5) IP-4: IP+PC with PPS (MAP)

TP=Traditional practices, IP=Improved practices, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

**Sample collection procedure for microbial Analysis and data recording:** Almost similar to the experiments of mango, as mentioned in above.

**Expt. No. 4.** Evaluation of microbial load in brinjal as affected by traditional and improved practices integrated in the value chain

Treatments: 4 (same as mentioned in methodology part of implementing component-1)

- i) **TP**=TP+NW+PS+T
  - Traditional practice: Using bamboo basket as harvest container+No Washing+Plastic sack packing+loaded in truck to transport.
- ii) **IP-1**=Improved practices-1: IP+CW wash+ PC without MAP

- Using plastic crate as harvest container+Clean water wash in washing house+Plastic crate packing (lining with clean, newsprint paper) without MAP+ loaded in truck to transport.
- iii) **IP-2=Improved practices-2: IP+CCa wash+PC with MAP**
  - Using plastic crate as harvest container +Calcinated Calcium (1%) mixed water wash in washing house+ Plastic crate packing with MAP+loaded in truck to transport
- iv) **IP-3: Improved practices-3: IP+CCa wash+WM+PC with MAP**
  - Using plastic crate as harvest container +Calcinated Calcium (1%) mixed water wash through washing machine+ Plastic crate packing with MAP+loaded in truck to transport

**Sample collection procedure for microbial Analysis and data recording:** Almost similar to the experiments of mango, as mentioned above.



Figure 50. Brinjal samples collected and transported from the field to the Laboratory for microbial analysis

**Study#4.** Evaluation of microbial quality and safety to validate integrated postharvest technologies in the value chain.

An experiment was conducted on brinjal under Study#4, as mentioned in PP. It could be used to validate the integrated postharvest technologies including application of sanitizer. To achieve the goal, marketed brinjal samples were collected and wash with various sanitizers to evaluate the microbiological quality and safety of the marketed brinjal samples. Collected brinjals were washed with distilled water, 0.01%WP (Calcinated calcium), 1% H<sub>2</sub>O<sub>2</sub> 0.5% H<sub>2</sub>O<sub>2</sub> and 150 ppm Cl<sub>2</sub> and kept at ambient room temperature. A set of brinjals for each of the treatment was preserved in refrigerator. Data were recorded on microbial loads after 4 and 7 days of storage.

## 11. Results and discussion (with appropriated pictures):

### Implementing component-1: PHTS, HRC, BARI

#### Baseline survey on postharvest practices in the value chain:

Survey was conducted in the growing areas and assembles markets of mangoes and banana in Rajshahi and those of bananas and vegetables in Rajshahi districts and wholesale and retail markets in Dhaka and Gazipur city. Value chain actors like growers, collectors (Faria/Pikar etc.), wholesalers and retailers of selected fruits (mango, and banana) and vegetables (carrot, cauliflower and brinjal) were asked to mention post-harvest practices along with specific pre-harvest practices that may contribute to postharvest quality. Percentages of respondents

against the specific practices of selected crops at different levels are presented in tabular form in the table below;

**a) Mango:**

**Preharvest practices contributed on postharvest quality:** Fruit bagging and pheromone trap were reported as two useful practices in controlling of fruit fly; thus, had contribution in getting quality fruits. However, only 11.7% of the respondents used fruit bagging and that was only 3.3% for pheromone trap (Table 10). About 88.3% of the mango orchard holders told that they did not apply preharvest bagging and that was 96.7% for pheromone trap; either they were not interested of adding value and using of extra labour or they ignored the beneficial side of the mentioned technologies because of lacking suitable markets where could get good returns.

Table 10. Pre-harvest practices that contribute on postharvest quality of mango at growers' level

Pre-harvest practices contribute on postharvest quality	% responses
Bagging:	
Follow	11.7
Does not follow	88.3
Pheromone trap for fruit fly control:	
Follow	3.3
Does not follow	96.7

**Harvesting and Postharvest practices:** Maturity determination, harvesting technique and postharvest practices followed by mango value chain actors in the study area are shown in table 11 and are discussed below:

**Maturity determination and harvesting technique:** About 28.2% of the respondents took decision to harvest mango by observing fruit size and growth (Table 11). Also they identify the maturity stage by observing the dots and waxy appearance on fruit surface in some mango cultivars/varieties (5.1%), cut the sample fruits to observe the changes in flesh colour from creamy-white to yellowish (5.2) and natural dropping of few fruits (6.3%). Among the respondents, 55.2% determine maturity by consideration of two or more maturity expressing criteria as mentioned in table 11.

In the study area, 70% of the respondent harvested mango with locally made mango harvester (Table 11). It was made of bamboo stick along with a piece of net placed at the top of the stick. Some of the growers and orchard renters harvested mango through tree jerking (11.1%). Also hand picking was followed by some respondents (18.9%), mostly for preharvest bagged fruits. About 94.4% respondent told that the mangoes harvested through locally made harvester or jerking method had no pedicel; thus, not needed of trimming.

**Postharvest Handling and transportation:** About 97.8% of the respondents did not follow the practice of de-latexing that was required to remove sap secretion from the breaking point of pedicel (Table 11). Physically injured, insect infested, diseased, damaged, and defective fruits were sorted out by 92.2% growers. It was done by 100% beparies and 51.3% retailers in their assemble points/shed and shop, respectively. Hot water treatment was used only by 1% bepari/collector). Nobody reported ripening practices by ethylene or any other ripening agent. About 41.1% growers and orchard renters used plastic crates as harvest container and 36.7% of them used still the bamboo baskets. More than 66% beparies used plastic crates as transport container. More than 65% Growers and contract collectors transported mango through locally made vehicle (Van/Nosimon/Tomtom). Some of them used bicycle (19.5%). For direct selling, they used truck (7.1%) and courier service (8.2%). All the beparies (100%)

told that they transported mango from assemble point (mango bazar) to city market through truck. Among them, above 90% respondent sent only mango in a single trip in truck (Table 11).

Table 11. Post-harvest practices in mango value chain

<b>Grower/Contract collector:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Harvesting/Maturity identification:	
Observing fruit size and growth	28.2
Observing dots and waxy appearance on fruit skin	5.1
Sampling fruits to cut and observe flesh colour	5.2
Observing natural dropping of few fruits from the tree	6.3
Follow two and more methods mentioned above	55.2
Harvesting method:	
Jerking	11.1
Hand picking	18.9
Locally made harvesting tools (stick with net)	70.0
Harvesting fruit with pedicel	
Follow	5.6
Not follow	94.4
Assembling place:	
Under tree	65.1
Under shed/under-graded pack house	34.9
Sorting out	
Insect, pest, bird attacked and cracked mango	92.4
Not Sorted	07.6
Pedicel trimming	
Follow	5.6
Does not follow	94.4
De-latexing after pedicel trimming	
Follow	97.8
Not follow	2.2
Grading:	
According to size and quality	51.7
Not graded	48.3
Packing for transport	
Bamboo basket	36.7
Corrugated fiber board	8.0
Plastic crate	41.1
All of the above	24.2
Marketing place:	
Local Market	23.8
Direct selling from the garden	15.1
Both of the above	61.1
Transporting:	
Van/Tomtom/Nosimon	65.2
Bicycle	19.5
Truck (for direct selling)	7.1
Courier service (for direct selling)	8.2
Mode of Transport:	
Single loading (only mango)	90.9

Mixed loading	9.1
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<b>Collector/Bepari:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing place:	
Direct from Growers' garden	40.7
From local Market	59.3
Storing place:	
Under tree	25.3
Under shed/locally made Pack house	74.7
Sorting out	
Sorted out insect, pest, bird attacked, cracked and damaged mango	100
Grading:	
Graded according to size and quality	83.3
Not Graded	16.7
Hot water treatment	
Follow	1.0
Does not follow	99
Packaging	
Bamboo basket	5.7
Corrugated fiber board	12.0
Plastic crate	66.3
All of the above	16.0
Transporting by truck	100
Mode of Transport:	
Single loading (only mango)	90.3
Mixed loading	9.7

<b>Wholesaler:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing:	
From Collectors	12.3
Not purchased but taken commission only	87.7
Storing place under shed/wholesale store	100
Sorting	
Sorted	12.3
Not Sorted	87.7
Grading:	
Graded	13.3
Not Graded	86.7

<b>Retailer:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing from wholesalers	95.6
Purchasing direct from grower's orchard	4.4
Storing/Retailing place	
Under shed/retail shop	86.7
Open selling on Van	13.3

Sorting	
Sorted	51.3
Not Sorted	48.7
Grading:	
Graded	16.3
Not Graded	83.7

From the above facts noted in this study, it is noticeable that there was scope of intervening improved technologies and best practices including fruit bagging, improved harvesting tool, trimming and delatexing technique, hot water treatment and plastic crate packing in mango value chain in target area and channel.

## b) Banana

**Preharvest practices contributed on postharvest quality:** Bunch covering (Bana Bag) was reported as effective technique in controlling of banana beetle; thus, had contribution in getting quality fingers of banana. However, only 2.5% of the respondents used Bana bag (Table 12). They rest of the growers in the study area did not use Banabag. They reported that Bana bag was less available in their area and needed support in getting information of suitable market as it required some value adding activities and extra labour cost.

Table 12. Pre-harvest practices contributed on postharvest quality of banana

Pre-harvest practices contribute on postharvest quality	% responses
Bagging/Bunch covering (Bana bag):	
Follow	2.5
Does not follow	97.5

**Harvesting and Postharvest practices:** Maturity perception and harvesting technique and postharvest practices followed by banana value chain actors in the study area in Bogura and Rajshahi districts are shown in Table 12 and the important practices are discussed below:

**Maturity determination and harvesting technique:** About 51.2% of the respondents observed shape, size and growth of the fingers in 2-5 upper hands in a bunch (Table 13) in determining of banana maturity. Some of them (7.3%) took decision to cut banana bunch by observing the fingers' angularity i.e. in most hands when 2/3 part of a finger became round. Among the respondents, 25.8% determine maturity by consideration of two or more maturity expressing criteria as mentioned in Table 12. In the study area, 100% of the respondent harvested banana by cutting and collection of whole bunch manually. Usually 2 persons were involved in harvesting activity; one cut the bunch and another collect the bunch from opposite side of cutting edge.

**Postharvest Handling and transportation:** About 77.3% of the respondents collected and transported banana as intact bunch. They did not separate banana hands from the bunch. Thus, they didn't follow desapping practice in which sap secretion was allowed to remove from the cut portion of the crown of banana hand. Above 20% growers who separated the hands from a bunch allowed to desapping of banana hands by bedding of banana leaves in the field (Table 13). Damaged and defective fingers were sorted out by 64.4% growers. It was done by only 15.3% beparies and 60% retailers required sorting out the damaged fingers in their retail shop. Above 90% growers/collectors did not practice washing of banana fingers and also 80% beparies did not wash banana in their assemble place. Nobody reported ripening practices by ethylene or any other ripening agent. About 62.5% growers and collectors transported the full bunch with locally made vehicle (Van/Nosimon/Tomtom). Some of them (16.5%) used bicycle. Shoulder carring was done by 15.2% respondents. They

sold banana in the nearest assemble market. 100% beparies tranported banana from assemble point (mango bazar) to city market through truck. Among these beparies, 52.2% respondent sent banana as a single fresh product through heaping of whole bunches in truck (Table 13). They used banana leaves as lining materials in the layers of banana bunch; the rest of respondents sent banana with other agricultural products (mixed loading).

It was evident that there was scope of intervening improved technologies and best practices including bunch covering, harvesting technique trough de-handing, introducing of de-handing tools, delatexing technique, washing, particularly with alum and plastic crate packing in banana value chain in target area and channel.

Table 13. Post-harvest practices in banana value chain

<b>Growers and collectors:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Maturity indices/Harvesting stage:	
By observing shape, size and growth	51.5
By observing angularity of banana fingers	7.3
Appearance of yellow colour on the finger(s)	15.4
Altogether of the mentioned methods	25.8
Harvesting method: Cutting and collecting the bunch manually	100
Storing place and method:	
In the orchard on banana leaves for shot time	84.4
Under tree/shade for very short time	15.6
De-handing and de-sapping	
Done in the field	20.2
Done in shed/pack house	2.5
Not done	77.3
Sorting out	
Insect, pest attacked and damaged/defective fingers/hands	64.4
Not Sorted	35.6
Grading:	
According to size and quality	26.7
Not graded	73.3
Washing:	
Washing with water	7.5
Washing with alum water	0.0
Without wash	92.5
Use of lining material in packing of de-handed banana	
Lining with straw/grass /leaf/ cloth	16.7
Without lining	83.3
Packaging	
Plastic sacks	6.5
Gunny bag	2.3
Plastic crate (for de-handed banana detached from bunch)	5.2
Heaping full bunch on transport vehicle	85.5
Marketing place:	
Local Market	65.8
Direct selling from the field	14.1
Both of the above	21.1
Transporting to local market:	

Van/Tomtom/Nochimon	62.5
Bicycle	16.5
Hand/shoulder carrying	15.2
Truck (for direct selling)	5.8
Mode of Transport:	
Single loading (only banana )	45.2
Mixed loading	54.8

<b>Collector/Bepari:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing place:	
Direct from Growers' field	16.7
From local/assemble Market	83.3
Storing place:	
Under tree	76.7
Under shed/pack house	23.3
Sorting	
Sorted out insect, pest attacked and damaged fingers/hands	15.3
Not Sorted	84.7
Lining	
With straw/leaf/ paper	46.7
Without lining	53.3
Washing	
With water	20.0
With alum mixed water	0.0
Without wash	80.0
Packaging	
Gunny bag	6.4
Nylon /plastic Bag	8.1
Plastic crate	6.2
All of the above	18.6
None, just heaping in vehicle	69.5
Transporting by truck	100
Mode of Transport:	
Single loading (only banana)	57.3
Mixed loading	42.7

<b>Wholesaler:</b>	
<b>Post-harvest Practices:</b>	<b>% responses</b>
Purchasing:	
From Collectors	36.7
Not purchased but taken commission only	63.3
Storing place under shed	100
Sorting	
Sorted	16.7
Not Sorted	83.3
Grading	
Graded	16.7
Not graded	83.3

<b>Retailer:</b>	
<b>Post-harvest Practices</b>	<b>% respondents</b>
Purchasing from wholesalers	100
Storing place	
Under shed	51.3
Open selling	48.7
Sorting	
Sorted	60.0
Not Sorted	42.0
Grading:	
Graded	46.7
Not Graded	53.3

### c) Carrot:

**Harvesting and Postharvest practices:** Maturity perception and harvesting technique and postharvest practices followed by carrot value chain actors in the study area in Bogura districts are shown in table 14 and the important practices are discussed below:

**Maturity determination and harvesting technique:** Hundred percent growers observed plant growth to take decision to harvest carrot and more than 90% respondents harvested through hand picking.

**Postharvest Handling and transportation:** Washing was done by removing of surface dirt through a locally adapted practice using human legs and pouring of water on carrot roots. About 93% growers and traders follow this practice. No washing materials or machine and tools were used to wash carrot roots. Damaged and defective roots were sorted out by 70.4% respondents. About 25.2% growers follow grading, mostly done on size. Washing was not done by the beparies (100%) and usually they did not do sorting (76.7%) and grading (84.4%). About 56.2% growers used plastic made bag as transport container and that was 35.3% for gunny bag user. In most time, the growers of this area (68.2%) used locally made rented vehicle viz. Nossimon, Tomtom, Tempu etc. to bring carrot into local market. About 98.2% bepari/collector transported carrot through truck. Among them, 53.3% bepari sent carrot as single loading product in a truck. Mixed loading was followed by 46.6% respondent. In most time, they used plastic and nylon made bag or gunny bag as a packing material comprising of 60-70 kg carrot in plastic bag and that of 100-120 kg in gunny bag.

It is evident that there was scope of intervention of improved washing technologies viz. washing machine and suitable washing materials and plastic crate packing of carrots in the study area.

Table 14. Post-harvest practices of carrot in the value chain

<b>Growers:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Harvesting Time:	
Morning	71.3
Afternoon	27.7
Maturity determination/Harvesting stage:	
Observing plant growth and estimated edible stage by own experience	100
Harvesting method:	
Hand picking	90.4
Hand picking with assistance of tools	9.6
Storing place and method:	

Under tree for very short time	34.4
Under shed for very short time	25.6
Under open spaces	41.0
Sorting out	
Damaged and defective roots	70.4
Not Sorted	30.6
Grading:	
According to size of carrot root	25.2
Not graded	74.8
Washing	
Removing surface dirt by locally adapted practice with human legs and washing by pouring water on heaped carrots)	92.6
Washing with sanitizing agent in washing house	0.0
Using washing machine	0.0
Without wash	7.4
<b>Post-harvest Practices</b>	<b>% responses</b>
Use of Lining materials in packing	
Lining with straw/grass /leaf/ cloth	6.7
Without lining	93.3
Packaging	
Gunny bag	35.3
Plastic bag/sacks	56.2
Plastic crate	3.1
Without packaging (openly carried)	5.4
Marketing place:	
Local Market	67.8
Direct selling from the field	11.1
Both of the above	21.1
Transporting:	
Van/Tomtom/Nosimon/Tempu	68.2
Riksha/Bicycle	26.2
Carved van	4.1
Truck (for direct selling)	1.5
Mode of Transport:	
Single loading (only carrot )	52.2
Mixed loading	47.8
<b>Collector/Bepari:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing place:	
Direct from Growers' field	16.7
From local Market	83.3
Storing place:	
Under tree	36.7
Under shed/pack house/own arranged place	63.3
Sorting	
Sorted out damaged, compressed and defective carrots	23.3
Not Sorted	76.7
Grading:	
Graded according to size	15.7

Not Graded	84.3
Use of Lining material in packing	
With paper (newspaper)/banana leaves/others	6.6
Without lining	93.4
Washing	
Required to do	0.0
Not required	100.0
Packaging	
Bamboo basket	10.3
Gunny bag	23.2
Nylon /plastic Bag	42.0
All of the above	22.1
Plastic crate	2.2
<b>Post-harvest Practices</b>	<b>% responses</b>
Transporting to distant market	
By Truck	98.2
Loading on top roof of buses	2.8
Mode of Transport:	
Single loading (only carrot)	53.3
Mixed loading	46.7

<b>Wholesaler:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing:	
From Collectors	31.7
Not purchased but taken commission only	68.3
Storing place	
Under shed/house	90.2
Open spaces	9.8
Sorting	14.7
Sorted	85.3
Not Sorted	
Grading	15.7
Graded	84.3
Not graded	

<b>Retailer:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing from wholesalers	100
Storing place	
Under shed/shop	64.3
Open selling	35.7
Sorting	
Sorted	60.0
Not Sorted	40.0
Grading:	
Graded	44.7
Not Graded	55.3

**d) Cauliflower:**

**Harvesting and Postharvest practices:** Harvesting technique and postharvest practices followed in cauliflower value chain in the study area in Bogura districts are shown in table 15 and the important practices are discussed below:

**Maturity determination and harvesting technique:** Hundred percent growers observed curd growth and size to take decision to harvest cauliflower. Curds were collected by pulling out the whole plants or by cut the stem portion under the curd.

**Postharvest Handling and transportation:** Collected curds were brought to shed through locally available vehicle. About 62.1% growers transported their cauliflower to assemble market through Nosimon, Tomtom or babytaxi. They used nylon netted bag (30.6%), plastic bag (25.2%), gunny bag (22.3%) and bamboo baskets (10.7%) for carrying their cauliflowers to assemble market. Nobody washed cauliflowers in water or any other kind of washing materials. Trimming was done 100% growers or contract collectors. Damaged, insect infested and defective curds were sorted out by 84.4% growers. It was done by 53.3% bepari. A good practice of covering curd face with a piece of newspaper was found to be done by some beparies/collectors' man (15.8%) in their shed. About 52% beparies/traders used plastic made bag as transport container and that was 21.1% for plastic/nylon netted bag user. Gunny bag was used by 16.7% traders. The plastic bag contained 60 kg and gunny bag consisted of 100 - 120 kg cauliflower. 100% bepari/collector transported cauliflower to city/distant town market through truck. About 37.4% retailers followed subsequent sorting practices.

Table 15. Postharvest practices of cauliflower in the value chain

<b>Growers:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Harvesting Time:	
Morning	75.2
Afternoon	24.8
Harvesting stage:	
Observing curd growth and size by own experience	100
Storing/accumulation place and method:	
Under tree/shade for very short time	64.2
Under shed/ for very short time	15.6
In the field without considering sun	20.2
Sorting out	
Insect, pest attacked, damaged and defective curd	84.4
Not Sorted	15.6
Grading:	
According to size and quality	22.5
Not graded	77.5
Washing	
Done	0.0
Not done	100
Using lining material in harvest/transfer container	
Lining with newspaper	18.3
Lining with soft cloths	21.3
Lining with banana leaves or other plant parts	18.2
Without lining	43.2

Transport container/Packaging	
Bamboo basket	10.7
Gunny bag	22.3
Plastic bag/sack	25.2
Plastic/nylon netted bag	30.6
Plastic crate	2.8
Without packaging/heaping in the local transport	8.4
Marketing place:	
Local Market	61.8
Direct selling from the field	16.1
Both of the above	22.1
<b>Post-harvest Practices</b>	<b>% responses</b>
Transporting:	
Van/Tomtom/Nosimon/baby taxi	62.1
Bicycle	12.5
Curved van	10.2
Truck (for direct selling)	15.2
Mode of Transport:	
Single loading (only cauliflower)	42.4
Mixed loading	57.6

<b>Collector/Bepari:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing place:	
Direct from Growers' field	19.6
From local Market	80.4
Storing place:	
Under tree/shade	62.7
Under shed/pack house	37.3
Sorting	
Sorted out insect, pest attacked, damaged and defective curd	53.3
Not Sorted	47.7
Grading:	
Graded according to size and quality	36.6
Not done	63.4
Washing	
With water	20.0
Without wash	80.0
Curd covering/wrapping	
Covering the curd face with newspaper piece	15.8
Not done	84.2
Packing	
Gunny bag	16.7
Nylon /plastic Bag	52.0
Plastic/nylon nettted bag	21.1
All of the above	10.2
Plastic crate	0.0
Using lining material in packing	
With straw/leaf/ paper	0.0

Without lining	100.0
Transporting by truck	100
Mode of Transport:	
Single loading (only brinjal)	43.3
Mixed loading	56.7

<b>Wholesaler:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing:	
From Collectors	36.7
Not purchased but taken commission only	63.3
Storing place under shed	100
Sorting	
Sorted	38.7
Not Sorted	61.3
Grading	
Graded	16.7
Not graded	83.3

<b>Retailer:</b>	
<b>Post-harvest Practices</b>	<b>% responses</b>
Purchasing from wholesalers	100
Storing place	
Under shed/retail shop	67.3
Open selling	32.7
Sorting	
Sorted	37.4
Not Sorted	62.6
Grading:	
Graded	46.7
Not Graded	53.3

#### **e) Brinjal:**

**Harvesting and Postharvest practices:** Harvesting and postharvest practices followed by brinjal value chain actors in the study area in Bogura districts are shown in table 16 and the important practices are discussed below:

**Maturity determination and harvesting technique:** Hundred percent growers assessed commercial maturity by observing growth and size of brinjal fruits. Then they harvested brinjals by pulling out them from brinjal plants.

**Postharvest Handling and transportation:** Collected brinjals were kept in shade for a short time by 78.4% growers. These were sorted out by removing of insect infested, damaged and diseased fruits in a shade place/packing shed. It was stated by 75.4% growers that they did sorting (Table 16). Usually grading was not done by the growers. Only 2.7% growers did it. Washing was done only by 5.2% growers. After completion of sorting, brinjal growers brought their fruits into assemble market. About 52% growers brought their fruits by keeping them in bamboo baskets. Among them, 32.8% used newspaper, soft cloth or banana leaves as lining material in their bamboo basket. The other local transport containers were gunny bag (17.3%), plastic made bag (21.3%), and nylon netted bag (6.6%). About 81.4% bepari collected brinjal from local market and only 18.6% baparies collected brinjals directly from

growers' field. Almost 66.7% bepari did not follow sorting and 84.3% did not practice grading. Washing with water was done by 35.2% collectors. Packing was done in gunny bag (36.3%), plastic bag (51.2%), synthetic netted bag (7.6%) and plastic crate (2.2%). Almost 92.8% bepari transported brinjal through truck. In most time, brinjals was sent to distant market with other fresh agricultural products i.e. mixed loading was reported as 61.8% respondents. Among the respondents, 50% retailers mentioned that they sorted out damaged fruits, if it required.

Table: 16. Postharvest practices of brinjal in the value chain

<b>Post-harvest Practices (Grower)</b>	<b>% responses</b>
Harvesting Time: Morning Afternoon	73.3 26.7
Harvesting stage: Observing growth and size at marketable stage determined by own experience	100
Harvesting method: Hand picking	100
Storing place and method: Under tree/shade for very short time Under shed for very short time	78.4 21.6
Sorting out Insect, pest attacked and damaged brinjal Not Sorted	75.4 24.6
Grading: According to size and quality Not graded	2.7 97.3
Washing Washing with water Washing with sanitizing agent Without wash	5.2 0.0 94.8
Packaging Bamboo basket Gunny bag Plastic bag/sack Synthetic netted bag Plastic crate	52.7 17.3 21.2 6.6 2.2
Using lining material: Used paper/cloth/banana leaves/other plant parts Not used	32.8 67.2
Marketing place: Local Market Direct selling from the field Both of the above	69.8 11.1 19.1
Transporting: Van/Tomtom/Nochimon/babt taxi Bicycle Curved van Truck (for direct selling)	71.4 16.7 4.2 7.7
Mode of Transport: Single loading (only Brinjal)	52.2

Mixed loading	47.8
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<b>Post-harvest Practices (Collectors/Bepari)</b>	<b>% responses</b>
Purchasing place:	
Direct from Growers' field	18.6
From local Market	81.4
Storing place:	
Under tree/shade	16.7
Under shed	83.3
Sorting	
Sorted out insect, pest attacked, damaged and diseased brinjal	33.3
Not Sorted	66.7
Grading:	
Graded according to size and quality	14.7
Not Graded	84.3
Washing	
Washing with water	35.2
Washing with sanitizing agent	0.0
Not like washing but watering in packaging	38.8
Without wash	27.0
Packaging	
Bamboo basket	2.7
Gunny bag	36.3
Plastic bag/sack	51.2
Synthetic netted bag	7.6
Plastic crate	2.2
Lining	
With leaves/papers (for plastic crate user), etc.	5.6
Without lining	94.4
Transporting	
By truck	92.8
Top roof on bus	7.2
Mode of Transport:	
Single loading (only brinjal)	39.2
Mixed loading	61.8

<b>Post-harvest Practices (Wholesaler)</b>	<b>% responses</b>
Purchasing:	
From Collectors	39.7
Not purchased but taken commission only	61.3
Storing place under shed	100
Sorting	
Sorted	10.7
Not Sorted	89.3
Grading	
Graded	5.5
Not graded	94.5

<b>Post-harvest Practices (Retailer):</b>	<b>% responses</b>
Purchasing from wholesalers	100
Storing place	
Under shed/Retail shop	78.3
Open selling	22.7
Sorting	
Sorted	50.0
Not Sorted	50.0
Grading:	
Graded	3.7
Not Graded	96.3

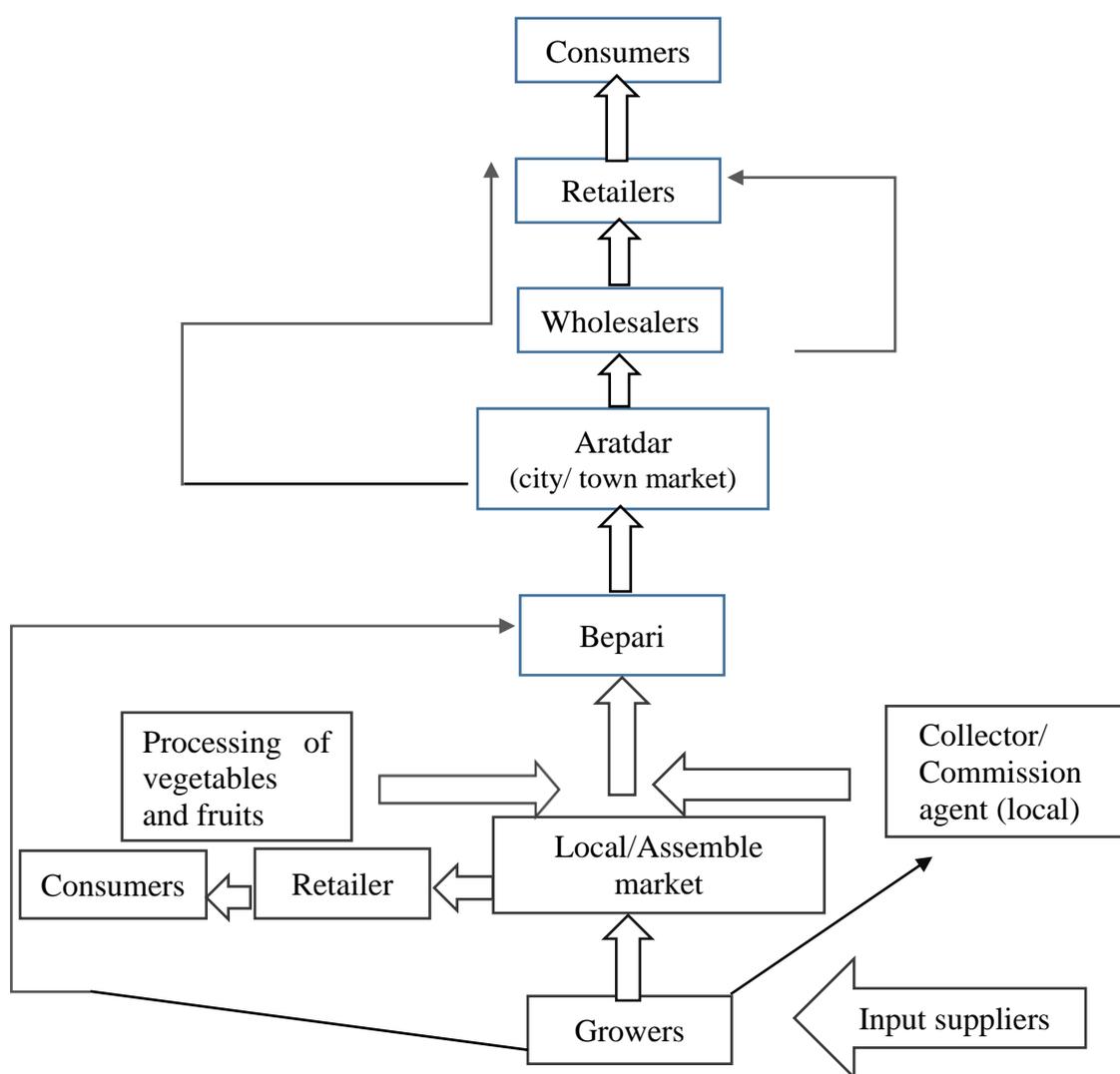


Fig. 51. Flow diagram of Fruit and vegetable supply and value chain from Rajshahi and Bogura growing areas to city/town market (Dhaka, Gazipur and other areas).

**Existing supply and value chain:** The activities of present project were not led directly in improving of value chain; rather it was designed on intervening of improved practices in the value chain. Accordingly, value chain analysis in other, where the values were added and what were the shares of added values in existed chain were not investigated in details. However, what was the existed chain was known from value chain actors and is shown in

Fig. 51. Usually, the growers gathered their harvested fruits and vegetables at local assembles markets, collectors and beparies came in this market and collected and bought the fresh commodities to supply city/town wholesale market via local and distant market aratdar. In Rajshahi and Bogura area, some beparies (traders) directly contracted to growers and collected the fruits and vegetables directly from the orchard and field. Some amounts of harvested commodities were sold directly to the local retail market (Fig. 51).

**Constraints and problems in value chain:** Constraints and problems associated to fruits and vegetables value chain in the study area are shown in Fig 52 and table 16. At growing level, farmers faced a lot of problem in smooth marketing of fruits and vegetables. About 85.2% of the respondents noticed that there were lack of improved pre and postharvest technologies and facilities improved harvesting and handling methods, washing methods and facilities, improved packaging techniques and packing materials, low cost tools and facilities, safe and suitable sanitary measures, packaging techniques and facilities, etc. About 80.2% of them told that they needed suitable pack house. They (95.6%) mentioned they needed suitable storage facilities in their locality. They (78.2) noticed that they faced problem in getting proper price by some traders’ syndicate. They (82.5%) suffered in fund crisis and costly transport service to send their commodities to city market directly by their own initiative.

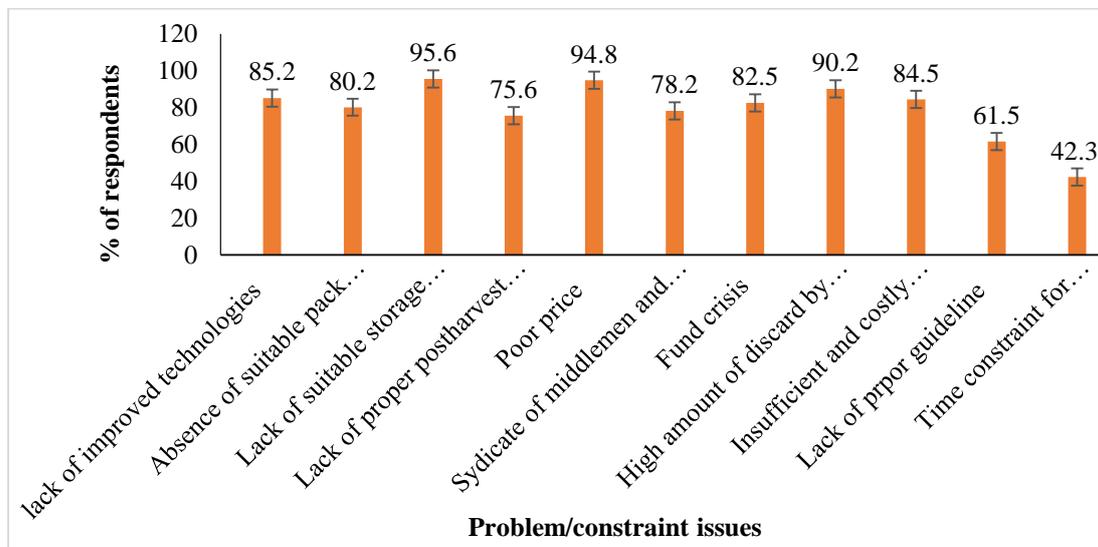


Fig. 52. Problem and constraints of fruits and vegetable growers in the value chain

When we took interview, most of the respondents at marketing actors mentioned that lack of storage facilities, lack of suitable pack house, costly transport and improved packaging (plastic crate) were their major problem. They were not much aware in maintaining safety and quality, not much interested in accepting improved practices as they thought that these might require extra lost, thus they would get less profit. However, they problems or constraints existed in the value chain were ranked in combination with respondents’ opinion and investigation carried by the survey and is shown in table 16. The major problems were high postharvest loss, lack of improved technologies, pack house, storage facilities, less interest in adopting improved technologies needed training, and lack of clean and suitable market and lack of information on market linkage and access.

Table 16. Problem and constraints associated with market actors (bepari, wholesaler, trader) in the value chains of target crops

Sl. No.	Problem/Constraint issue	Rank
1	High postharvest loss	1
2	lack of improved technologies and facilities (washing, sanitizing, sorting, packaging)	3
3	Lack of suitable pack house	2
4	Lack of suitable storage facilities	4
5	Lack of proper postharvest technologies	5
6	Lack of suitable spaces and clean market facilities	9
7	Low profitability	8
8	Costly transport facilities and	7
9	Lack of proper guideline	12
10	Lack of improved loading and unloading technologies	10
11	In-sufficient training	6
12	lack of information on market linkage and access	11

**Scope and opportunities of intervening of improved practices:** The scope and opportunities of intervention of improved practices was assessed and listed in table 17. It was comprehended with consideration of existing pre and postharvest practices, especially emphasized on postharvest handling, packaging and transportation practices which were found and compiled through conducted survey and constraints and problems related and linked to postharvest losses of targeted crops value chain.

Table 17. Scope and opportunities of intervention of integrated and improved practices in the value chain of fruits and vegetables

Sl No.	Technologies/practices and capacity building	Remarks/activities
1	Improved production practices	BARI recommended practices
2	Pre-harvest bagging (mango and banana)	With Recommended methods
3	Introducing pheromone trap technology for controlling of fruit fly of mango and brinjal)	BARI technologies
4	Improved harvesting tool for mango	BARI mango harvester
5	De-sapping tool/tray for mango)	BARI mango de-sapping tool
6	De-handing tools for banana	Banana de-handing tool
7	Hot water treatment for mango	BARI hot water machine
8	Washing with safe sanitizers (CCa for mango and alum for banana)	With Recommended methods
9	Pack house knowledge and facilities	Establishment of pack house
10	Improved sorting, grading and packaging facilities	Pack house, related facilities and improved packaging material and methods (plastic crate, MAP, etc.)
11	Training of improved production and postharvest technologies and value chain management	Conducting training

From the aggregated data and information gathered by the survey, it was found that there was scope to intervene improved technologies through integration of best practices, in pre and postharvest phases, such as-

- a) Pre-harvest: Bagging (mango and banana) and Pheromone trap (Brinjal)
- b) Harvesting and Postharvest: Harvesting tools (mango), De-handling tools (banana), plastic crate as harvest container (all crops), hot water treatment (mango), alum-water washing (banana) and washing machine (banana and vegetables), plastic crate packaging (all crops), etc.
- c) Awareness creation: Personal hygiene, safety and Quality (all crops).

### **Establishment and Uses of Packhouse for Value Chain Based Postharvest handling processes of Fruits and Vegetables**

Packhouse is a physical structure where harvested produce is consolidated and prepared for transport and distribution to markets. Packaging is the main activity from which the name 'packhouse' is derived. But there are activities before and after packing together they are called packhouse operations. Packhouse operations include cleaning, sorting/grading, pre-treatments. Packhouse enables quality assurance activities that ensure product quality and quantity meet market requirements and losses are minimized during transport and distribution to markets. A packhouse can serve as a hub for coordination and governance of a farm-packhouse-market organization in which market demand dictates production and packhouse activities. The present study was done to strengthen the linkage between farm and market and to ensure better price offruits and vegetables vegetables for the marginal farmers. Thus, two pack houses were established in two sites; one at Baneswarbazar, Rajshahi and another in the village of Vatra under sherpur Upazilla of Bogura district.

Established pack houses were used for conducting planned research activities, pilot demonstration and hands on training on postharvest handling practices. Contract growers and suppliers' group used these pack houses to follow sorting, grading, washing, precooling and best practices of postharvest handling on fruits and vegetables. The experience gathered from these activities showed that the most complex aspects of postharvest management are social, rather than technical. Postharvest activities occurred at the end of the value chain, where the most money and trust is involved.



Fig. 53. Partial inside view along with postharvest handling activities in Baneswar bazar pack house, Rashahi



Fig. 54. Partial inside view along with postharvest handling activities in Vatra pack house, Bogura

During the project period, one truck mango from Rajshahi and one truck cauliflower and another truck brinjal from Bogura were sent to Gazipur wholesale market by growers-traders association involved with two pack houses. These fresh products were sent with maintenance of integrated improved practices. The growers were delighted with the good prices and the traders were pleased with the consistent quality provided by the farmers trained. At the end of project period, the packhouse of Rajshahi was handed over to Fruit Research Station of BARI, Binodpur, Rajshahi for technical and logistic support supervision. Vatra Uttarpara CIG (Phasol) Somiti will supervise Bogura packhouse. Growers and traders in respective area will be utilizing the pack house facilities under the supervision of pack house operating authority/committee.

#### **Intervention of postharvest technologies and best practices in the value chain:**

To develop integrated and improved postharvest handling practices in value chain, five experiments were conducted on target crops to select the best one. The results of the studies were as follows:

##### **a) Mango:**

#### **Postharvest Quality of Mango as affected by Traditional and Improved Practices Integrated in the value chain**

##### **Quality Evaluation**

It's fact that even by selecting a well-known mango variety, a consumer chooses good quality fruits by observing its colour, physical appearance, flavour and non-existence of quality defects or shriveling or squeezing of the fruits, spots and signs of blemish or rotting or any kind of physical damage on fruits. Considering the facts, these were determined or assessed and are shown in below.

**Quality maintenance of mango at harvest level:** Physical quality of the harvested fruits in pre-harvest bagged and non-bagged including improved management practices (IMP) along with TP is shown in Table 18. About 92.8 (IP-3) to 95.7% (IP-1) of non-bagged mangoes were harvested with long stalk when used 'BARI mango harvester' as harvesting tool. Statistically ( $P \leq 0.05$ ) similar numbers accounted 96.5-98.4% of bagged mangoes were harvested with 5-7 cm stalk attached to the fruit as because of all bagged mangoes were harvested manually. On the other hand, only 45.4% harvested non-bagged fruits were found with stalk when used traditional mango harvester (TP) for mango harvesting. Harvesting mango with long stem is very much important to avoid latex flow that smear on fruit skin and to reduce the stem end rot (Mazhar *et al.*, 2011).

Non-bagged fruits had cracks or bruise of about 6.8% due to dropping to the ground during harvest with traditional mango harvester, while it was 1.8-2.2% when used improved

harvesting tool (Table 18). On the other hand, no cracked or bruised fruit was found in bagged mangoes at harvest. Non-bagged mangoes both in TP and IP suffered from sap burn and scab infection. In TP, it was amounted to 28.6%, respectively, whereas this was 20.4 to 22.0%, respectively in non-bagged mangoes handled with IP. In case of bagged mango, it ranged 7.0-8.5% (Table 18). Both latex burn and scab infection of mangoes were pre-harvest defects, which noted marketable but at lower price compared to good quality fruit. Results of this study are in agreement with the findings of several researchers who reported that pre-harvest bagging protects the fruits from insect-pests, diseases, mechanical damage and reduces spraying of pesticides (Nagaharshitha *et al.*, 2014).

Table 18. Effect of pre-harvest bagging and harvesting method on quality management of mango in the contract grower's orchard

Treatment	Harvested mango with stalk (%)	Dropped mango (%)	Mangoes with latex burn (%)	Mangoes with scab infection (%)
TP	45.4 b	6.8 a	30.2 a	28.6 a
IP-1	95.7 a	1.8 b	26.6 a	22.0 a
IP-1A	94.6 a	2.2 b	24.5 a	20.6 a
IP-2	97.5 a	0.0 b	6.8 b	8.5 b
IP-2A	98.2 a	0.0 b	5.5 b	7.2 b
IP-2B	97.6 a	0.00	5.8 b	7.0 b
IP-3	92.8 a	2.00	26.5 a	20.4 a
IP-3A	96.5 a	0.00	6.0 b	7.5 b
IP-3B	98.4 a	0.00	6.5 b	8.2 b
F-value	0.05	0.05	0.05	0.05

Values within a column followed by the same letter (s) are not significantly different at 5% level;

TP= Traditional management practices; IP= Improved management practices;

IP-1: NBG+NDS+NHW+PC+T, IP-2: BG+DS+HS+PC+T, IP-2A: BG+DS+HWT+PC+T, IP-2B:BG+DS+HS+PC+T,IP-3: NBG+DS+NHW+PC+RV, IP-3A: BG+DS+HWT+PC+RV, IP-3B: BG+DS+HS+PC+RV; NBG=Non-bagged, BG=Bagged (pre-harvest), NDL=No de-latexing or de-sapping, NW= No washing, NHW=No hot water treatment, HW=Hot water treatment, PC=Plastic crate, T=Truck, RV=Reefer van (transport vehicle)

**Ripening status of mango:** No mangoes were found to be ripe at wholesale level. It was observed both in non-bagged and bagged fruits handling with TP and IP (Fig.55). Mangoes kept at ambient condition in retail shop started to ripe on day 2 at retail outlets exhibiting the maximum proportion (11.33%) of ripe fruits in non-bagged mangoes handled with IP including hot water treatment which increased rapidly with increase in ripening period, reaching 40.5, 77.5 and 95.6% on day 3, 5 and 7, respectively. Bagged mangoes showed a slower rate of ripening compared to non-bagged fruits (Table 18). On the day 3 at retail shop, about 21.6, 27.67 and 24.3% of pre-harvest bagged fruits were identified as ripe in IP excluding HWT, with HWT and sanitizer (0.00.00.01% CCa) mixed HWT, respectively. It reached up to 73.5, 51.2 and 51.5%, respectively on day 5 and 65.6, 82.2 and 70.33%, respectively on day 7. Mango kept in cool room took more time to ripe than those of kept at ambient condition. It was evident both in non-bagged and bagged fruits even with including of hot water treatment (Fig. 55).

Results of this study showed that both bagged and non-bagged mangoes exposed to hot water treatment and kept at ambient condition at retail shop had higher proportion of ripe fruits during retail display. Pre-harvest bagging resulted in delaying ripening and softening in mango in comparison to non-bagged fruits, was also reported by Hofman *et al.* (1997). The

faster ripening of mangoes from the IP may be attributed due to the effect of high temperature during HWT. Heat was known to increase respiration rate that might enhanced the ripening process of IPMP mangoes (Esguerra *et al.*, 2017).

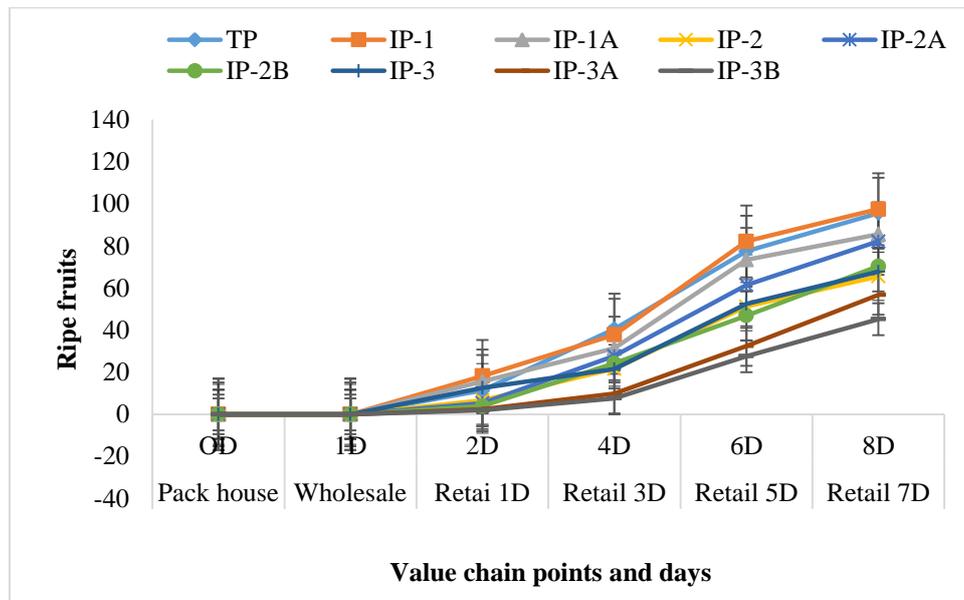


Fig.55. Ripening performance of mangoes handled with TP and IP at wholesale and retail period at ambient condition (27-33°C,85-90% RH) along with cool room (20±2°C, 80-85% RH) storage.

**Skin blemish:** Blemish on skin may or may not be associated with biotic agent, caused and expanded with time through physiological events and/or storage environment, however can be minimized with postharvest handling practices. Blemish on mango in different handling practices was observed and is shown in Fig.56. Incidence of blemish (% of displaying fruits was high in the mangoes handled with TP throughout the retailing period. In TP, about 8.37% of fruits had spots and blemish on retailing day 3. It increased up to 19.48, 39.38 and 65.5% on day 5, 7 and 9, respectively). It was recorded lower in the fruits handled with IP. It was observed less in percentage when the fruits were kept in cool room (Fig. 56).

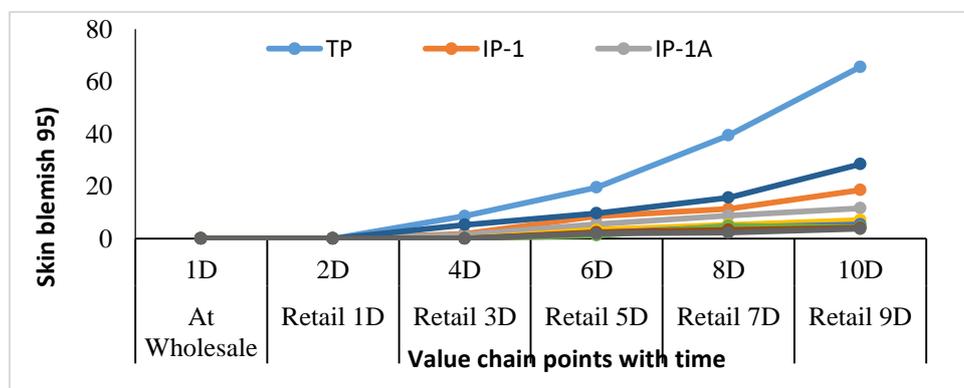


Fig. 56. Incidence of blemish and spots in the mangoes handled with TP and integrated treatments of IP during 9-days storage period.

**Decay and disease incidence:** No disease symptom was observed on the mangoes at wholesale level. It was evident both in bagged and non-bagged mangoes. At retail outlets however, stem end rot (SER) and anthracnose, two predominant postharvest diseases were found in mango cv. Langra, which caused damage in ripe fruits. The first disease symptom

appeared in non-bagged mangoes handled with TP on day 2 at retail showing 1.40% decayed fruits, which increased sharply with increase of ripening period, reaching 13.6, 28.5, 37.67% on retailing day 5, 7 and 9, respectively (Fig.48). Non-bagged mangoes that immersed in HWT showed significantly ( $P \leq 0.05$ ) lower disease infection compared to non-HWT fruits. Irrespective of with or without HWT, there was no decay on bagged mango up to 3 days. The first appearance of decay in bagged fruits was observed on day 5 comprising the incidence was only 1.88% reaching at 3.98% and 5.67% on day 7 and day 9, respectively. These mangoes handled with IP were not subjected to HWT. Bagged mangoes treated with HW or hot sanitizer were affected less with decay and it was very less for the fruits kept at cool condition (Fig 57). Sanitizers (CCa) might have some role in lowering decay (Fig. 57). It is agreed that the susceptibility of mango fruit to postharvest diseases increases during storage due to series of physiological changes occurring in the fruit favouring the establishment of the pathogens (Eckert *et al.*, 1996).

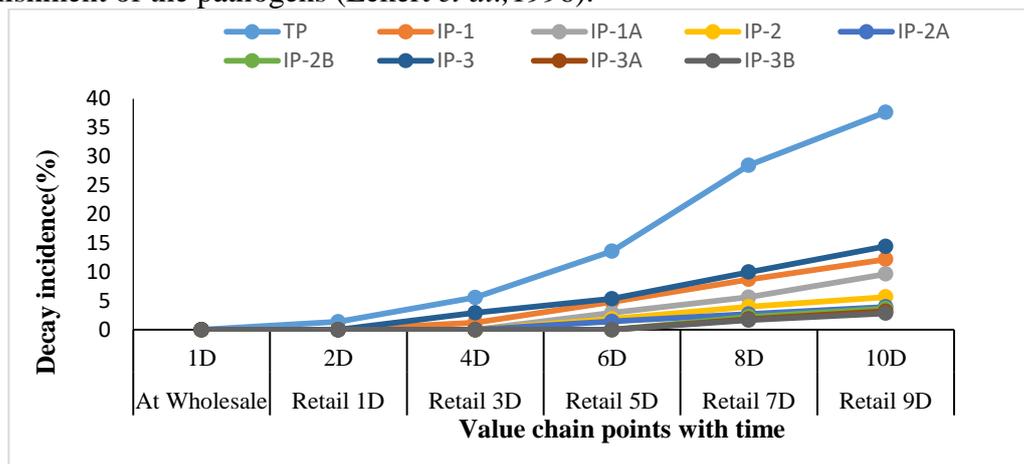


Fig. 57. Decay and disease incidence of mangoes handled with TP and IP at wholesale and retail period at ambient condition ( $27-33^{\circ}\text{C}$ ,  $85-90\%$  RH) along with cool room ( $20 \pm 2^{\circ}\text{C}$ ,  $80-85\%$  RH) storage. Vertical bars represent standard deviation. TP = Traditional practices; IP = Improved practices.

Bagged mangoes exhibited significantly ( $P \leq 0.05$ ) lower proportion of decayed fruits than that of non-bagged mangoes throughout the whole period at retail outlets indicating the effectiveness of pre-harvest fruit bagging in reducing the disease incidence. Pre-harvest bagging followed by postharvest HWT reduced the decay of mangoes cv. 'Langra' by 89.33% for 5 days retail period, while it was 86.18% in non-HWT bagged fruits on the same day. Interestingly, the differences between decay incidence of TP and IP handled fruits became wide with progression of retailing period. Fruit bagging before harvest and postharvest hot water treatment for 10 min at  $52-55^{\circ}\text{C}$  was also reported to reduce the anthracnose infection by 83% and SER by 100% (Aveno & Orden, 2004), which further supported by the present findings. Pre-harvest fruit bagging (Nagaharshitha *et al.*, 2014; Xu, *et al.*, 2010; Jakhar and Pathak, 2016) and improved harvesting method along with desapping technique (Mazhar *et al.*, 2011) were also effective in reducing postharvest rots of mango.

## Postharvest losses:

### Weight loss

Weight loss was recorded of 1.15-2.85% at the wholesale market, showing maximum loss in traditional postharvest handling practices (Fig.58). Weight loss of mango occurred mainly due to transpiration from the fruit surface during transportation and displaying periods at retail outlets at  $27-33^{\circ}\text{C}$ ,  $85-90\%$  RH. Both bagged and non-bagged mangoes handled either with TP or IP showed a progressive loss in weight along the value chain (Fig 58). In the retail

shops, the cumulative weight loss of 6.34% occurred in the traditionally handled non-bagged mangoes on day 5, reaching 8.81% and 12.24% on day 7 and 9, respectively. Whether it was bagged or non-bagged on trees, comparatively higher weight losses were recorded from hot water treated mangoes at retail shops. Weight losses were comparatively lower in cool room (Fig 58).

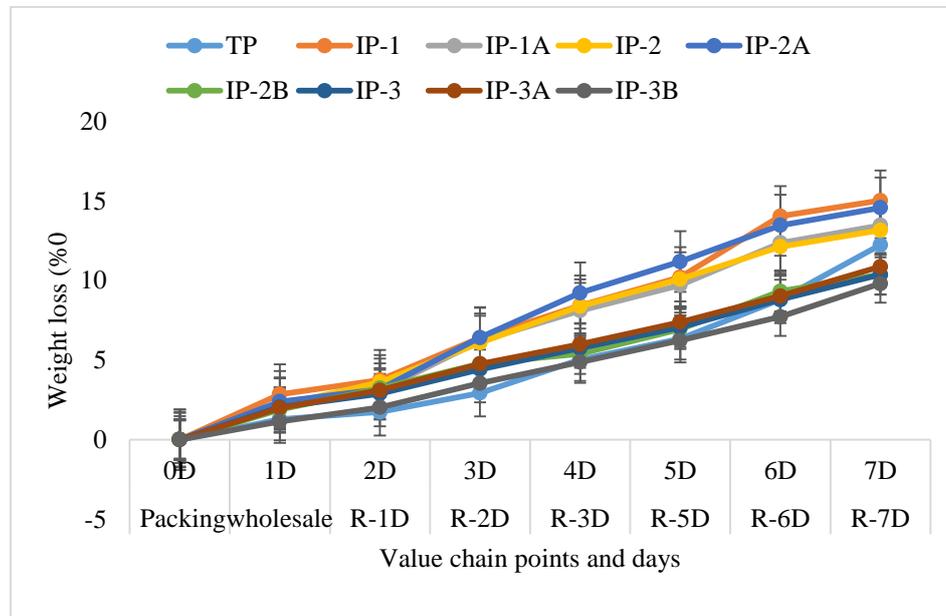


Fig. 58. Weight loss of mango in the value chain

**Postharvest losses of mango along the value chain:** The higher postharvest loss was recorded as 28.50%, at retail outlet. It was followed by the cumulative weight loss and harvest stage's losses of 12.24 and 6.8%, respectively (Fig. 59). At the wholesale market, on the other hand, no loss occurred mainly due to short staying time (10-12h) over there. The total postharvest loss of non-bagged mangoes that handled with TP from harvesting to the end of 4-days retail period was noticed 47.5%, whereas it was only 25.5% when handled with IP including hot water treatment. Because of pre-harvest bagging along with or without HWT was effective in reducing the incidence of decay, the proportion of unmarketable fruits was significantly ( $P \leq 0.05$ ) lower in the bagged mangoes. No losses of bagged mangoes were found at harvest as well as at the wholesale level except transpiration loss of 2.40%. The total postharvest losses of bagged mangoes handled with IP including HWT and hot sanitizer (0.00.00.01% CCa) were 17.3 and 12.6%, respectively along the value chain. In the cool chain system, the postharvest losses of mango were less than those of ambient condition, both in non-bagged and bagged fruits (Fig.59). Results of this study revealed that the retail outlet was the most critical stage with the higher postharvest loss of mango. Higher postharvest losses accounting of 43.8, 35, 25.1% were also found in the traditional value chain system of mango cultivars namely 'Dodo', 'Khirsapat' and 'Langra', respectively (Alam *et al.*, 2017; Rahman *et al.*, 2017).

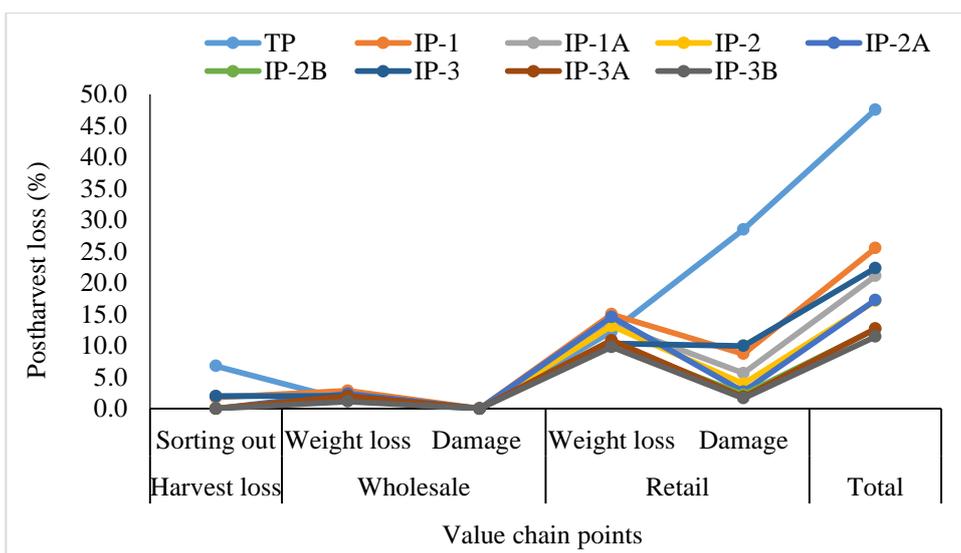


Fig. 59. Postharvest losses of mango in the value chain

Vertical bars represent standard deviation. TP= Traditional postharvest management practices; IP = Improved postharvest management practices.

Pre-harvest fruit bagging along with or without HWT reduced the postharvest losses of mango cv. ‘Langra’ by 63.64% and 63.95%, respectively, while it was 55.56% and 46.27%, respectively in non-bagged mangoes that handled with IP including with HWT and CCa mixed HWT, transported to city market and displayed at ambient condition at retail outlets (Fig. 60). Adding CCa (1%) as a sanitizer with hot water including other improved practices might be had extra role in reducing postharvest losses of bagged mangoes of 73.45% at retail shops. In a previous study, it was found that HWT reduced the microbial decay by 85% in mangoes cv. ‘Dodo’ (Msogoya and Kimaro, 2011). Better quality of mangoes with lower extent of decay and physical damage were also found at retail when they passed through improved management practices in the supply chain (Mazhar *et al.*, 2011).

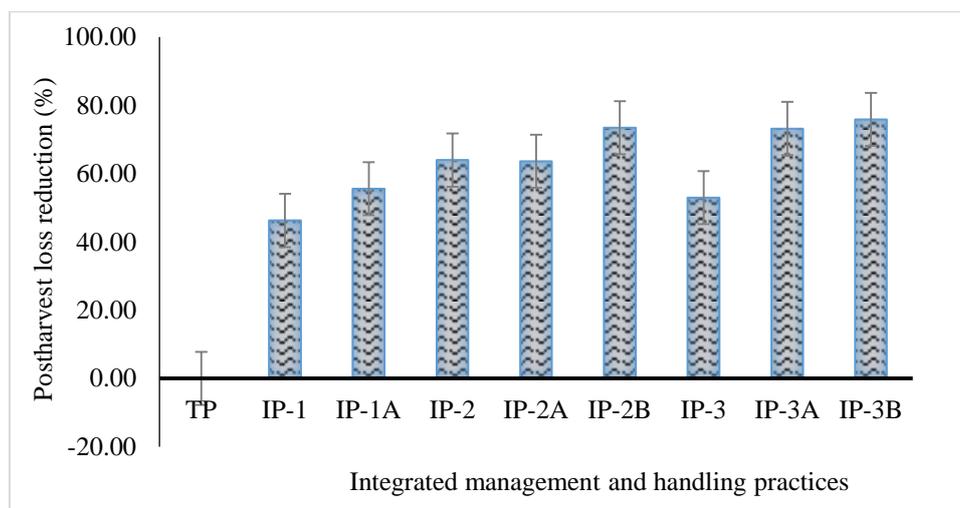


Fig. 60. Postharvest loss reduction of mango with integration of improved practices

### Quality evaluation of mango

**Firmness:** The firmness of all mangoes followed a decline trend during 9-day retail and storage period. The firmness of traditionally handled non-bagged mangoes reduced continuously from initial values of 6.45 to 0.88 kg-f/m<sup>2</sup> over the 9-days period. Likewise, the

firmness of bagged mangoes with IP declined almost similar trend at ambient condition at retail outlet. Both bagged and non-bagged mangoes subjected to HWT showed significantly ( $P \leq 0.05$ ) lower firmness in each day of retail compared to non-HWT mangoes. On day 5 which could be considered as suitable retailing day, firmness of non-bagged mangoes with TP was recorded as  $1.57 \text{ kg-f/m}^2$  and that of handled with IP was  $1.18 \text{ kg-f/m}^2$ . On contrary, it was  $1.45 \text{ kg-f/m}^2$  in bagged mangoes those were not treated with HW and that was  $1.31 \text{ kg-f/m}^2$  in the similar fruits those were treated with HW. The retention of firmness was higher in the mangoes transported in Reefer van and stored in cool room (Fig. 61) both in non-bagged and bagged ones, however, comparatively lower in hot water treated fruits but higher in the mangoes treated with mixing of 0.01% CCa in hot water (Fig. 61).

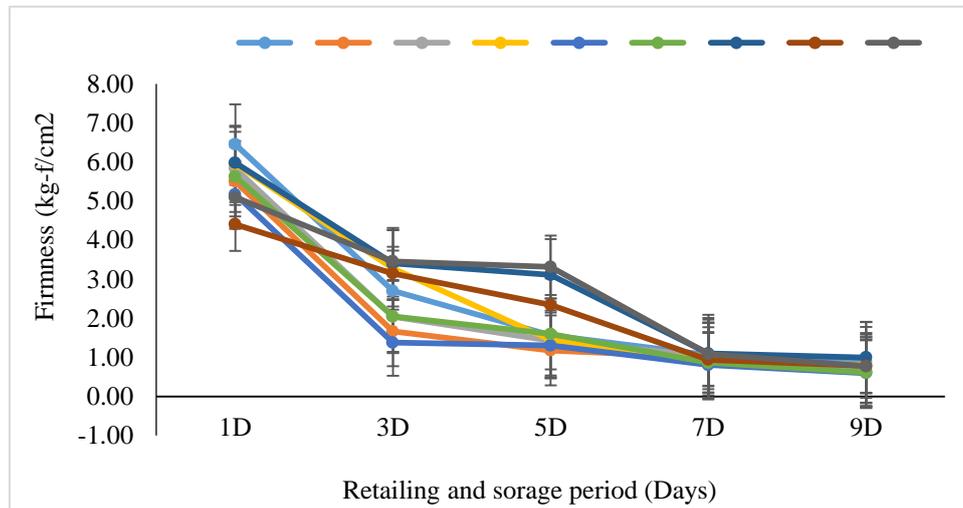


Fig. 61. Firmness of mango in different treatments during 9-days postharvest period

**Changes of mango skin colour:** Development of colour in the mangoes cv. Langra significantly ( $P \leq 0.05$ ) influenced due to pre-harvest fruit bagging and HWT at ambient condition at retail shops. The initial values of lightness ( $L^*$ ) found significantly ( $P \leq 0.05$ ) higher in bagged mangoes handled with IP showing  $L^*$  value of 69.70 compared to non-bagged mangoes handled with TP had the  $L^*$  values of 58.19 when HWT was not applied (Fig. 62). The  $L^*$  values of bagged mangoes handled with IP increased gradually till day 7 days at retail, reaching the maximum level of about 74.22 indicating bright skin colour and then it declined. In non-bagged mangoes with TP, on the other hand, showed a slow increase in  $L^*$  value, reaching 61.27 on 5 day at retail shop. Thus, the typical change in skin colour from green to yellow was lower in non-bagged mangoes during ripening. Nevertheless, non-bagged fruit immersed in HWT exhibited a moderate increase in lightness showing significantly ( $P \leq 0.05$ ) higher  $L^*$  value of 67.19 compared to non-HWT fruits on day 5. In contrast ambient storage,  $L^*$  value increased slower indicating slower rate of ripening of the fruits in cool room of  $20^\circ \pm 2^\circ \text{C}$ . Results of the present study revealed that pre-harvest fruit bagging markedly influenced the color development in mangoes cv. Langra, showing attractive yellow color with finish skin over non-bagged mangoes. Further, hot water treatment played role in ripening process of mango but hot sanitizing with CCa had some extent negative effect of slowing the process of colour development in mango. Enhancing the lightness of fruit skin due to pre-harvest fruit bagging also reported earlier in apple (Fan and Mattheis, 1998) and mango (Hofman *et al.*, 1997; Joyce, *et al.*, 1997).

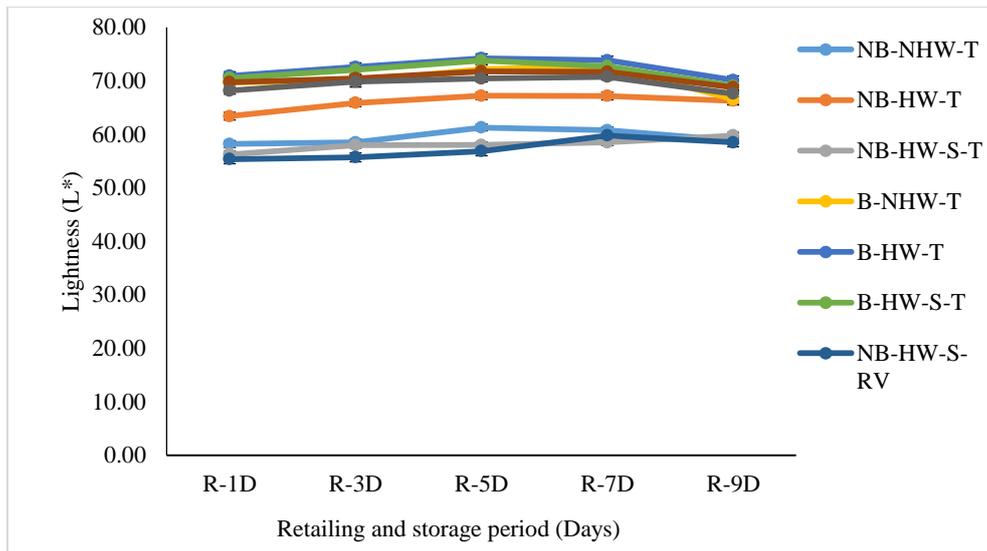


Fig. 62. Lightness of mango surface handled with TP and IP at 9-days postharvest period (27-33°C, 85-90% RH) along the mangoes handled with IP in cool room storage (20±2°C).

The  $a^*$  value of non-bagged mangoes handled with TP was about -17.12 indicating its greener skin colour, which was higher than that of bagged mangoes had the  $a^*$  value ranged -10.17 to -13.80 (Fig. 63). Both non-bagged and bagged mangoes handled with either TP or IMP exhibited a substantial decrease in  $a^*$  value during 9-day of retail period. However, the  $a^*$  value of bagged mangoes treated with HWT dramatically increased with ripening and reached to 1.89 on day 5 at retail period, indicating delayed decreasing on greenness. Similar kinds of trend were also found in non-HWT bagged and sanitizer (0.00.00.01% CCa) mixed HW treated mangoes. In contrast, non-bagged mangoes handled with TP showed a slow increasing of  $a^*$  values exhibiting ( $P \leq 0.05$ ) lower  $a^*$  values at ambient condition at retail period. Similar trend was found for the mangoes kept in cool room exhibiting slower increasing of  $a^*$  value both in non-bagged and bagged mangoes expressed their delaying changes in skin colour of greenness.

The  $b^*$  value of non-bagged mangoes on retail day 1 was about 30.07 indicating greener skin colour, which was lower than that of bagged mangoes handled with IP had the  $b^*$  value of approximately 36.72 (Fig. 64). Both non-bagged and bagged mangoes handled with either TP or IP exhibited a substantial decrease in hue angle during retail period. However, the  $b^*$  value of bagged mangoes treated with HWT dramatically increased with ripening and reached to 46.97 on 5 days of retail period, indicating more yellow the fruit skin. Almost similar results were also found in non-HWT bagged mangoes. In contrast, non-bagged mangoes handled with TP showed a slow decline of  $b^*$  values exhibiting significantly ( $P \leq 0.05$ ) higher  $b^*$  values compared to all other treatments throughout the retail period. The  $b^*$  value of non-bagged mangoes in cool room declined from 30.29 to 40.16 after 1 to 7 days of retail, respectively indicating still greenish skin color of mango. Also, bagged mangoes treated with HWT or CCa mixed HWT in cool room showed slowed changes in colour and after 7 days,  $b^*$  value declined in non-bagged mangoes at ambient condition at retail shop indicating its fall down from bright yellow to dull yellow colour. Bagging enhances the light sensitivity of fruit that stimulates anthocyanin synthesis when fruits are re-exposed to light after bag removal (Kim, *et al.*, 2010).

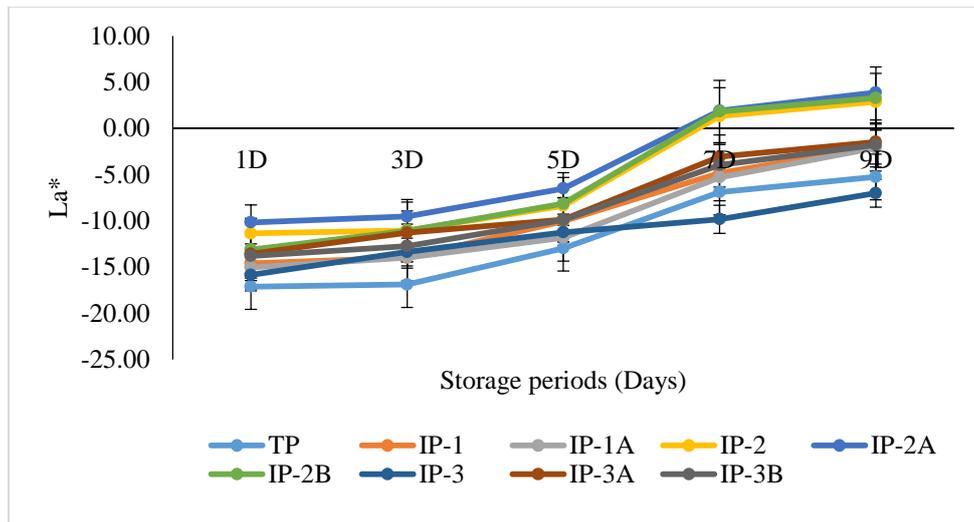


Fig. 63. Change in mango skin colour ( $a^*$  value; greenness) handled with TP and IP during 9-days postharvest period.

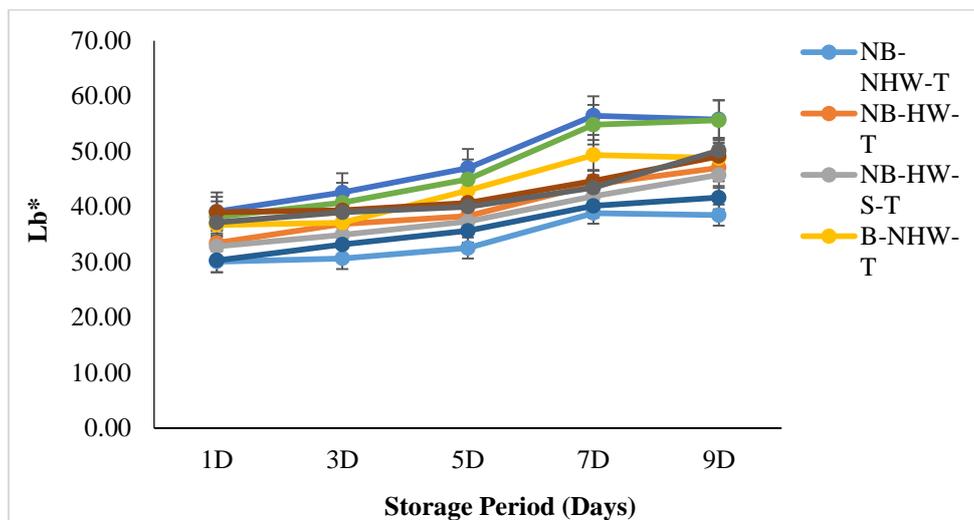


Fig. 64. Change in mango skin colour ( $b^*$  value; yellowness) handled with TP and IP during 9-days period (at retail period at ambient condition ( $27-33^{\circ}\text{C}$ ,  $85-90\%$  RH) along with IP in cool room storage ( $20\pm 2^{\circ}\text{C}$ ).

**Biochemical changes:** TSS (%) and titratable acidity (%) of mango are presented in Table 19 and Total sugar (%) and reducing sugar (%) is shown in Table 20. The TSS (%) increased and titratable acidity (%) decreased gradually with progression of time (Table 19). There were no significant differences among the treatments in changes of TSS (%) in a particular day, however, found to be increased slowly in CCa mixed hot water treated fruits irrespective of bagged and non-bagged fruits kept in cool room (IP-7, IP-8 and IP-9). It was also some extent slower in bagged fruits at ambient condition which were not treated with hot water and sanitizer mixed hot water. On the contrary, change in TSS (%) was comparatively rapid and higher in the fruits which were treated in clean hot water ( $55^{\circ}\text{C}$  for 5 minutes). The highest TSS on day 5 was 16.76 % and it was recorded from hot water treated, non-bagged fruits, reaching the maximum level of 20.4% at the end of 9 days at retailing shop. The movement of water and degradation of starch into soluble sugar in the mango flesh might be contributed to the increase of TSS during storage (Hossain *et al.*, 2014). Results of this experiment showed that pre-harvest bagging along with or without

HWT did not affect much on TSS contents in mangoes at harvest or at ripe stages. These results are in line with results found in different cultivars of mango (Haldankar *et al.*, 2015; Nagaharshitha *et al.*, 2014; Singh, *et al.*, 2017) and pear (Huang *et al.*, 2009).

Table 19. Total soluble solid and titratable acidity (%) of mango in traditional and improved postharvest practices at retail shop along with mango handled with IP and kept in cool room

Treatments	TSS (%)					Titratable acidity (%)				
	1D	3D	5D	7D	9D	1D	3D	5D	7D	9D
TP	6.66	11.44	15.46	16.58	17.3	1.41	0.94	0.70	0.66	0.40
IP-1	8.04	16.26	16.76	17.6	20.4	1.25	0.78	0.57	0.54	0.37
IP-1A	7.70	15.38	16.4	17.4	17.52	1.25	0.87	0.59	0.54	0.39
IP-2	7.34	10.16	16.30	18.18	17.3	1.51	1.18	0.78	0.63	0.44
IP-2A	8.04	14.06	15.16	18.3	18.48	1.44	0.94	0.68	0.63	0.29
IP-2B	8.22	14.52	14.84	14.92	15.14	1.54	1.21	0.81	0.65	0.39
IP-3	7.10	12.38	13.20	18.12	18.2	1.44	1.41	1.05	0.91	0.88
IP-3A	7.82	10.14	13.44	17.04	17.4	1.36	1.30	1.25	1.06	0.98
IP-3B	7.52	12.48	14.36	15.38	16.58	1.59	1.59	1.45	1.36	1.28
LS	NS	NS	NS	NS	NS	NS	*	*	*	*

TP= Traditional management practices; IP= Improved management practices;

IP-1: NBG+NDS+NHW+PC+T, IP-2: BG+DS+HS+PC+T, IP-2A: BG+DS+HWT+PC+T, IP-2B:BG+DS+HS+PC+T,IP-3: NBG+DS+NHW+PC+RV, IP-3A: BG+DS+HWT+PC+RV, IP-3B: BG+DS+HS+PC+RV;

NBG=Non-bagged, BG=Bagged (pre-harvest), NDL=No de-latexing or de-sapping, NW= No washing, NHW=No hot water treatment, HW=Hot water treatment, HS=Hot sanitizing i.e. hot water treatment with 0.01% calcinated calcium (supplied by DU), PC=Plastic crate, T=Truck, RV=Reefer van (transport vehicle)

Biochemical analysis (Fig. 65) showed that the contents of titratable acidity (TA) in non-bagged mangoes handled with traditional practices was higher than that of handled with TP including hot water and hot sanitizer treatment along the entire value chain. The initial TA of 1.41% was recorded in non-bagged mangoes, declined gradually reaching 0.40% at the end of 9-day retail period (Table 19). The initial acidity (%) in bagged fruits was higher than that of non-bagged fruits but decreased with time and became almost similar to non-bagged fruits on day 9 at ambient condition. This decreasing of acidity was slower in the cool room even for hot water treated fruits (Table 19). The lowest titratable acidity on day 3, 4 and 5 were recorded as 0.78%, 0.54% and 52%, respectively and it was recorded from the fruits which were treated with hot water, packed in PC and kept at ambient condition in retail shops (Table 19). The decrease in TA in mangoes might be due to the consumption of organic acid in respiration during retail period (Clark, *et al.*, 2003). These results are in line with the results of Sebe (2016) who reported that HWT results lower TA in Keitt mango compare to control fruits.

The total sugar (%) as well as reducing sugar (%) content was found to be increased with time, but slower in cool room and comparatively earlier at ambient condition with exception of the fruits treated in hot water with CCa. It was slower for the sanitizer treated fruit both in cool room and ambient condition. Total sugar (%) and reducing sugar (%) were found to be increased higher in the fruits treated with clean hot water. It was evident both for bagged and non-bagged fruits at ambient condition (Table 20). The above all results in biochemical changes indicated that hot water had positive effect on increasing of TSS (%) and sugar contents, might be beneficial in ripening of fruits.

The initial ascorbic acid contents in non-bagged fruits were lower than that of pre-harvest bagging fruits (Fig. 66). All bagged and non-bagged mangoes showed a rapid decline in the ascorbic acid contents particularly after 3 days and onwards during the ripening at retail. However, the rate of change showed higher in non-bagged mangoes followed by bagged mangoes that immersed in HWT and kept at ambient condition at retail shop exhibiting lower level of 78.6 mg 100g<sup>-1</sup> at the end of 9-day retail period, whilst it was 81.4 mg 100g<sup>-1</sup> in traditionally handled non-bagged mangoes (Fig. 65).

Table 20. Total sugar and reducing sugar content of mango in traditional and improved postharvest practices in 9-days postharvest period

Treatments	Total sugar (%)					Reducing sugar (%)				
	1D	3D	5D	7D	9D	1D	3D	5D	7D	9D
TP	14.37	17.96	20.13	23.81	24.46	2.93	3.33	3.35	4.65	5.52
IP-1	17.86	22.40	23.69	28.67	34.34	3.31	4.45	4.72	7.02	7.07
IP-1A	15.41	15.49	17.67	20.67	26.10	3.55	3.92	3.99	4.51	4.59
IP-2	12.97	15.45	18.30	22.57	24.46	2.71	3.07	3.31	4.69	4.85
IP-2A	13.66	15.53	20.49	24.71	29.14	3.31	3.55	3.87	4.86	6.80
IP-2B	12.73	13.82	16.92	18.04	24.40	3.30	3.40	3.70	4.67	5.56
IP-3	14.03	15.36	15.94	16.10	22.10	2.66	3.03	3.03	3.59	4.25
IP-3A	12.40	12.65	16.74	19.40	20.77	3.53	3.55	3.63	3.89	4.28
IP-3B	10.47	10.91	16.01	18.74	22.33	2.61	3.03	3.31	3.69	4.14
LS	NS	*	*	*	*	*	NS	NS	*	*

TP= Traditional management practices; IP= Improved management practices;  
 IP-1: NBG+NDS+NHW+PC+T, IP-2: BG+DS+HS+PC+T, IP-2A: BG+DS+HWT+PC+T. IP-2B:BG+DS+HS+PC+T,IP-3: NBG+DS+NHW+PC+RV, IP-3A: BG+DS+HWT+PC+RV, IP-3B: BG+DS+HS+PC+RV; NBG=Non-bagged, BG=Bagged (pre-harvest), NDL=No de-latexing or de-sapping, NW= No washing, NHW=No hot water treatment, HW=Hot water treatment, PC=Plastic crate, T=Truck, RV=Reefer van (transport vehicle)



Fig. 65. Pictorial view on biochemical analysis of mango in Postharvest laboratory

The changes in ascorbic acid were furthermore slower in cool chain storage than that of mangoes kept at ambient condition. In spite of applying hot water treatment, CCA had some positive effect on retention of ascorbic acid which was an evident in this study (Fig 66). The lowering of ascorbic acid in bagged and non-bagged fruits might be due immersion of mangoes in HWT for 5 min at 55°C as fruits and vegetables express a gradual depletion in ascorbic content with increase in temperature and storage duration (Lee and Kader, 2000). It is agreed that the ripening process of fruit is usually associated with gradual or rapid depletion of ascorbic acid during storage (Hossain *et al.*, 2014).

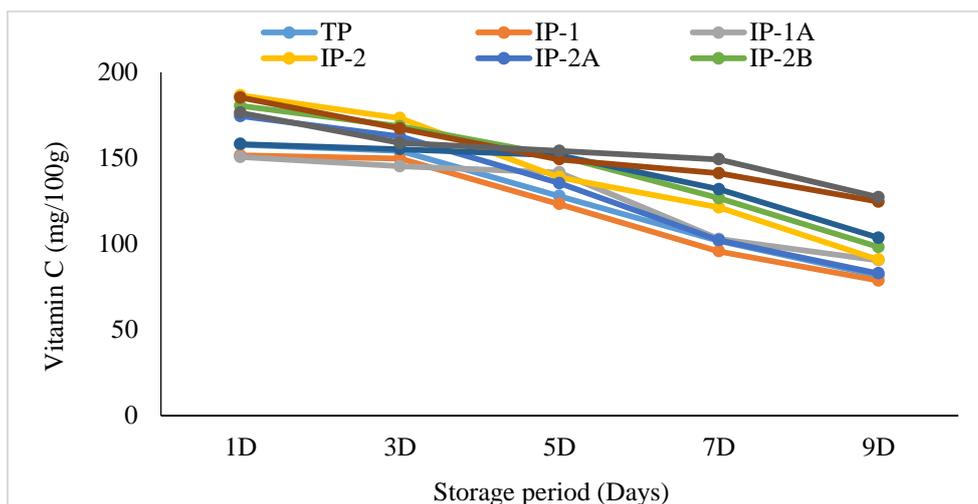


Fig. 66. Vitamin C content of mango during 9-days postharvest period

**Marketability:** It found that the marketability of mango fruits var. Langra mostly be relied on maturity expressing surface signs and/or attractive skin colour along with intact structure of the fruits free from physical injury, damage and decay. Accordingly, marketability was judged by observing external looking of the fruits and is shown in Fig. 67. Bagged mangoes handled with IP obtained higher score (3.67) on day 1 which boosted with HWT and hot sanitizer (0.00.00.01% CCa) and retained some marketable acceptability more than 9 days. Out of 5, it scored 3.67 on day 1, gradually increased to 5.00, indicating it's highly acceptable marketable quality on day 5 and then declined. On the other hand, non-bagged mangoes handled with TP got minimum score (3.00) on day 1 and lost marketability after 6 days, earlier than other treatments. HWT was found to be useful in getting slightly higher score for non-bagged mangoes comprising 3.80 on day 4 when they attained in full ripening condition. It was also beneficial in retention of marketability of these mangoes for additional days, recorded 8 in this study. In cool chain system, marketable quality of non-bagged and bagged mangoes handled with IP increased slowly and retained acceptability more days than those of mangoes kept at ambient condition at retail outlets. (Fig. 67)

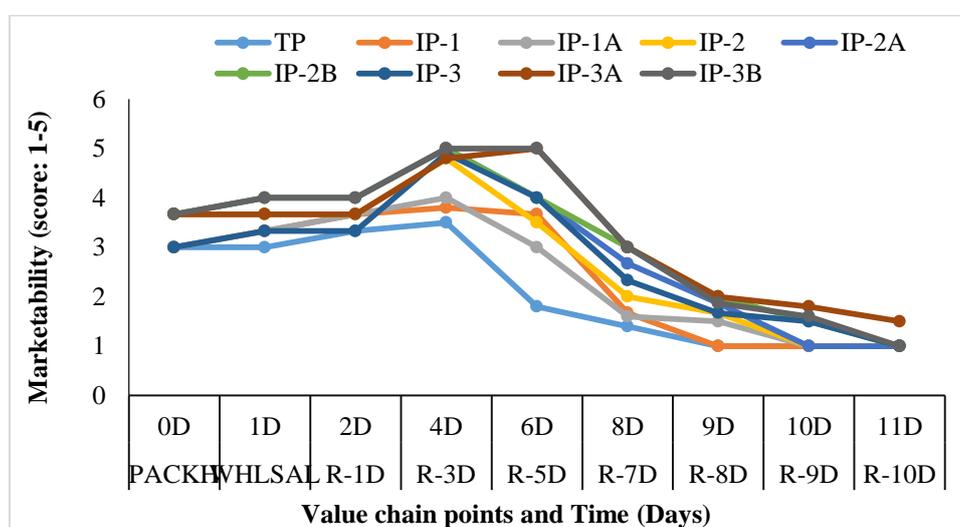


Fig. 67. Marketability of mango during 11-days postharvest period

**Sensory Quality:** Judging marketability by external traits only is not enough for getting the real quality of fruits to be marketing. Also sensory quality should be considered.

Consequently, organoleptic test was done (Fig. 68; showing pictorial view) on skin and flesh colour, flesh texture and taste of the mangoes displayed in retail shops and stored in cool room, and the scores obtained by the fruits are presented in Table 21 and 22. Bagged mangoes obtained higher score in skin colour throughout the storage period and it increased further with HWT and again by hot sanitizer (0.00.00.01% CCa). The obtained scores in non-bagged mangoes found to be increased up to 5 days and then declined sharply and those of bagged mangoes increased up to 7 days and then declined gradually. Almost similar trend was observed for flesh colour except the mangoes kept in cool room. In the cool chain system of maintaining  $20\pm 2^{\circ}\text{C}$ , the changes in flesh colour of the mangoes handled with IP was not so rapid and colour remained pale yellow; accordingly, they got poor scores, certainly by bagged mangoes in spite of treating with HW or hot sanitizer (Table 21).

Table 21. Preference of skin colour and Flesh colour of mango in traditional and improved postharvest practices in 9-days period

Treatments	Skin colour (score: 1-9)					Flesh colour (score: 1-9)				
	1D	3D	5D	7D	9D	1D	3D	5D	7D	9D
TP	4.00	5.00	6.00	4.00	1.40	5.8	7.50	7.8	7.00	4
IP-1	5.20	5.50	6.80	6.67	2.33	5.6	7.40	8.2	7.60	5
IP-1A	5.57	6.00	7.00	6.8	2.67	5.5	7.00	7.6	7.20	5.33
IP-2	6.00	7.50	8.80	7.67	4.67	5	7.00	7.8	6.70	5.67
IP-2A	7.00	7.67	9.00	8.00	5.00	5.4	7.40	7.8	7.00	6
IP-2B	7.20	7.41	8.80	8.33	5.33	5.5	7.00	7.6	7.20	5.8
IP-3	6.56	6.20	6.65	6.00	4.20	4.67	6.00	6.5	6.70	5.6
IP-3A	7.67	7.60	8.40	8.52	6.00	4.5	4.67	5	5.20	4.67
IP-3B	7.87	8.20	8.90	8.60	6.40	4	4.33	5	5.00	4.33

TP= Traditional management practices; IP= Improved management practices;

IP-1: NBG+NDS+NHW+PC+T, IP-2: BG+DS+HS+PC+T, IP-2A: BG+DS+HWT+PC+T. IP-2B: BG+DS+HS+PC+T, IP-3: NBG+DS+NHW+PC+RV, IP-3A: BG+DS+HWT+PC+RV, IP-3B: BG+DS+HS+PC+RV; NBG=Non-bagged, BG=Bagged (pre-harvest), NDL=No de-latexing or de-sapping, NW= No washing, NHW=No hot water treatment, HW=Hot water treatment, PC=Plastic crate, T=Truck, RV=Reefer van (transport vehicle)

The scores for flesh texture and taste were taken for non-bagged mangoes from the first day at retail shop up to the end of their decay and spoilage. On the other hand, it was not taken for bagged mangoes till the retailing day 3 as it observed not to fit for well consumption. Initially, higher scores were obtained by non-bagged mangoes for flesh texture; however, it became lower with storage time. On the other hand, bagged mangoes got comparatively lower score initially, obtained higher scores for flesh texture in later, comprising the highest score as 8.50 on day 5 in the fruits treated with HW (Table 21). The scores for taste was higher in non-bagged mangoes initially, increased to 8.00 on day 5 and then decreased but retained satisfactory up to 7 days of retailing (Table 22). HWT enhanced further taste and getting higher scores in these mangoes and it was also evident for bagged mangoes in this study. Mangoes produced and handled with IP including preharvest bagging and HWT obtained comparatively higher score (7.8) for taste on day 5 and it was higher (7.8) on 7 days for the similar type of bagged fruits but not treated with HW. Results revealed in this study that taste of bagged mangoes was slightly lower initially, however increased with time and almost close to non-bagged mangoes on day 5 of retailing i.e. 6 days after harvesting and afterwards (Table 22). In the cool chain system, on the other hand, however, the scores for taste were low and remained minimum till the end of 9 days of storage, probably because of non-suitability of the temperature of  $20\pm 2^{\circ}\text{C}$  for ripening of physiologically matured mangoes, particularly for the fruits which were subjected to preharvest bagging. Also, HWT

with calcinated calcium might affect negatively in ripening as well as taste of bagged mangoes stored in the cool room.

Table 22. Preference of skin colour and Flesh colour of mango in traditional and improved postharvest practices in 9-days period

Treatments	Flesh texture (score: 1-9)					Taste (score: 1-9)				
	1D	3D	5D	7D	9D	1D	3D	5D	7D	9D
TP	6.6	7.00	6.8	6.00	Decay	5.80	7.60	8	6.80	Decay
IP-1	7.5	8.00	7.8	6.60	Decay	6.00	7.60	8.4	7.40	Decay
IP-1A	7.6	8.00	7.7	6.70	5.00	5.60	6.80	8.0	7.80	6.80
IP-2	ND	7.80	8	7.00	6.00	ND	5.50	7.2	7.30	7.00
IP-2A	ND	7.00	8.50	8	5.80	ND	5.70	7.8	7.40	6.80
IP-2B	ND	6.90	8.40	7.8	6.00	ND	5.40	7.0	7.20	6.00
IP-3	ND	7.00	8.00	7.8	6.40	ND	5.00	5.6	5.70	5.20
IP-3A	ND	6.80	7.80	7	6.50	ND	4.67	4.67	5.20	4.67
IP-3B	ND	7.00	7.00	7.2	6.80	ND	4.00	4.5	5.00	4.33

1D=One day (First day), 3D=3 days, 5D=5 days, 7d=7 days and 9D=9 days, at retail shop.

ND=Not done.

TP= Traditional management practices; IP= Improved management practices;

IP-1: NBG+NDS+NHW+PC+T, IP-2: BG+DS+HS+PC+T, IP-2A: BG+DS+HWT+PC+T. IP-2B:BG+DS+HS+PC+T,IP-3: NBG+DS+NHW+PC+RV, IP-3A: BG+DS+HWT+PC+RV, IP-3B: BG+DS+HS+PC+RV; NBG=Non-bagged, BG=Bagged (pre-harvest), NDL=No de-latexing or de-sapping, NW= No washing, NHW=No hot water treatment, HW=Hot water treatment, PC=Plastic crate, T=Truck, RV=Reefer van (transport vehicle)

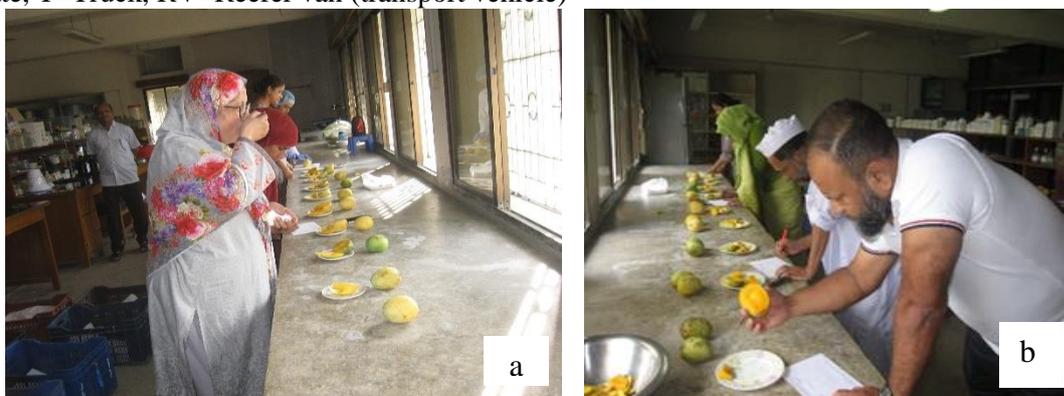


Fig. 68. Pictorial view of organoleptic test on ripe mango by the scientists (panel of judges) at 6 days after harvesting

**Shelf life:** Shelf life was recorded based on external quality of the fruits and is shown in Fig. 69. The highest marketable life (11 days only) was recorded for the mangos those were produced and handled with IP including preharvest bagging, HWT at 55°C for 5 minutes, transported by reefer van to city market (B-HW-RV) and then kept in cool room at 20±2°C. It was followed by similar type fruits treated with 1% calcinated calcium mixing HW and kept in same cool room had the shelf life of 10.33 days. The lowest shelf life (6.33 days) was recorded for the fruits handled with TP which were nor bagged, packed in PC, transported by truck to city wholesale market market and then sent and kept at ambient condition at retail outlets. At retail shops, the highest shelf life (9.67 days) was found for the mangoes handled with IP including preharvest bagging, treated with 0.00.00.01% CCa mixed hot water and then packed and transported in similar way, ultimately displayed at retail outlets. Also, hot treated bagged mangoes had higher shelf life (9.33 days) at retail shop (Fig. 69). As the fruits stored in cool room did not ripe properly (Fig. 69) poor scorer in flesh colour and taste (Table

21 and 22), they should not be considered to sale in markets, hence IP-2A and IP-2B i.e. IP-4 and IP-% (Fig. 69, pictorial view showing of IP-5) were the best treatments of integrated practices including preharvest bagging and HWT or CCa mixed HWT for enhancing shelf life of mango var. Langra.

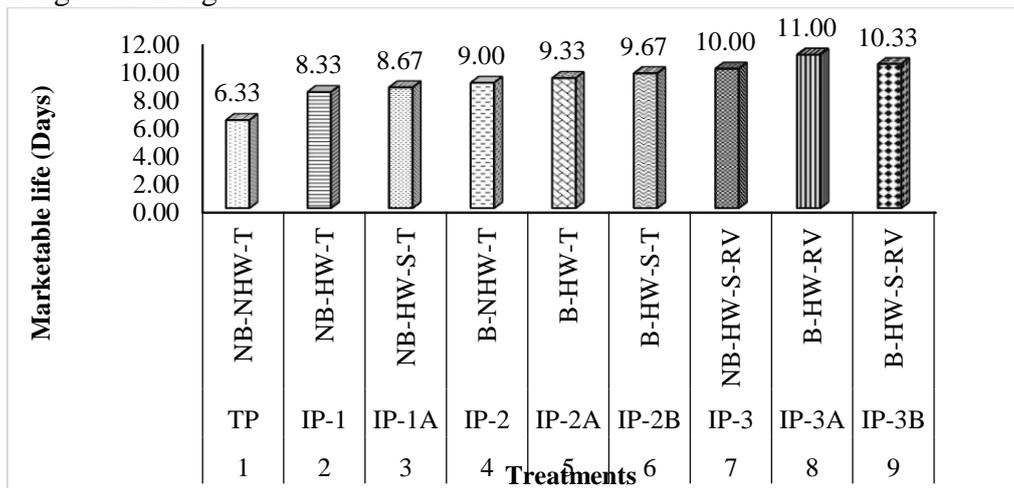


Fig. 69. Shelf life of mango handled with TP and integrated improved methods

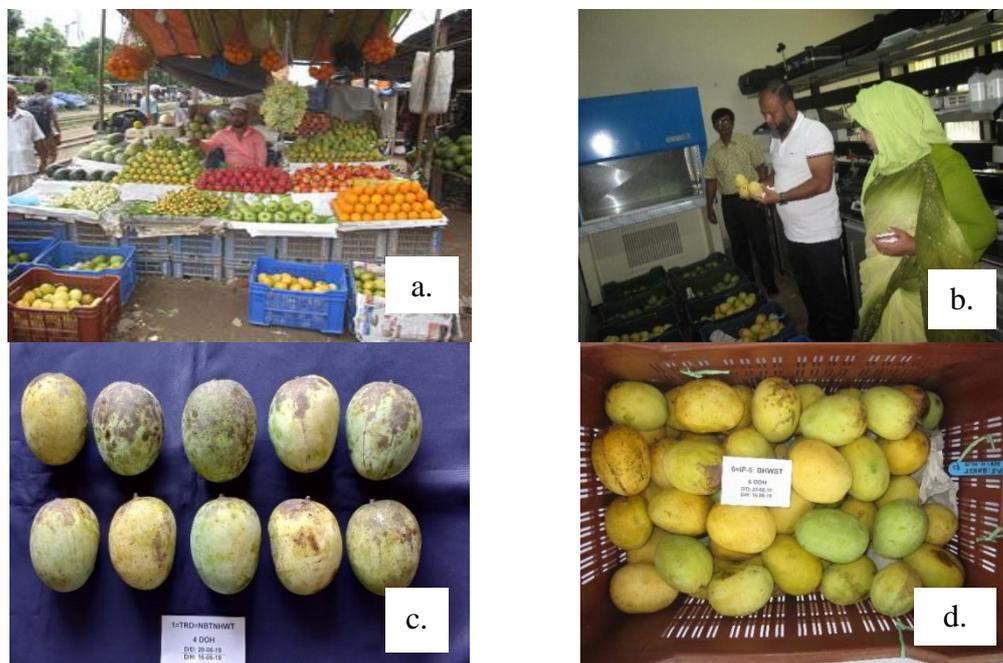


Fig. 70. Pictorial view related to shelf life recording of mango: a. transported mango displayed at retail shop b. quality and shelf life assessment of mango by the scientists in cool room laboratory of PHTS c. mango after 4 days which was handled with TP d. mango after 6 days which was handled with IP including preharvest bagging, HWT mixed with 0.00.00.01% CCa.

Results of the present study revealed that the integration of IP with preharvest bagging, HWT or 0.00.00.01% CCa mixed HWT at 55 for 5 minutes, packing the mangoes in PC and transported the packed mangoes to city market and displayed in retail shop in PC was more profitable that resulted in reduction in loss by preventing the transpiration and mechanical damage and diseases and decay and about 100% mangoes could be sold at retail outlets.

**b) Banana:**

**Postharvest Quality of Banana as affected by Traditional and Improved Practices Integrated in the value chain**

**Quality evaluation**

Usually, a consumer chooses a good quality riped banana by observing it's peel colour whether it turns into yellow or not, feeling or seem acceptable softness of the finger, physical appearance and non-existence of quality defects like spots and signs of blemish or rotting or any kind of physical damage found on it. When he buy a hand or more than one hands of banana, he considered abovementioned facts collectively for all of the fingers at a glance. Considering these, the following traits were assessed or evaluated in integrated approach of improved practices along with traditional one in this study:

**Ripening status of banana:** Appearance of yellow colour and softness of banana are the general consideration of judging ripening status for a table type cultivar like 'Sagor'. Thus, no Bananas were found to be ripe at wholesale level and first day at retail shop (Table 23). All the fingers (100%) remained green in IP on day 3. In the same day, about 5.28% and 1.48% of the fingers in TP were categorized as moderately (MR) and fully ripe (FR), respectively and 78.25% of the fingers showed ripening initiation i.e. colour breaking (CB) (Table 23). The peak day of ripening of banana at retail shop was day 5. No fruits in the treatments of IP and even in TP remained green in this day. About 15.03% of the fingers were categorized as over ripe in TP in day 5. On the other hand, there were no over ripe fingers in IP on that day. In retail day 7, ripening initiated fingers in IP-1, IP-2, IP-3, IP-4 and IP-5 were recorded as 38.39%, 47.79%, 44.70%, 47.20% and 44.33%, respectively (Table 16). No fruits remained in expressing of colour breaking or ripening initiation in TP, rather 30.58% of the fingers in TP became over ripe in day 7. On the contrary, no fingers attained over ripe in the treatments of IP in retail day 7 at ambient condition (Table 24). The highest number of moderately ripe bananas was recorded as 39.56% in IP-1 on 10 day. It was 17.26% as minimum in IP-1 and that was 19.07% in TP on day 10 (Table 17). The maximum (39.31%) and minimum (11.17%) number of over ripe fingers were counted from the treatments, TP and IP-3, respectively.

Table 23. Ripening status of banana in TP and IP on first day and 3rd day at retail shop in Gazipur city

Treatments	Retail 1D					Retail 3D				
	FG	CB/INI	MR	FR	OR	FG	CB/INI	MR	FR	OR
TP	100	0	0	0	0	78.25	14.98	5.28	1.48	0.00
IP-1	100	0	0	0	0	100.00	0.00	0.00	0.00	0.00
IP-2	100	0	0	0	0	100.00	0.00	0.00	0.00	0.00
IP-3	100	0	0	0	0	100.00	0.00	0.00	0.00	0.00
IP-4	100	0	0	0	0	100.00	0.00	0.00	0.00	0.00
IP-5	100	0	0	0	0	100.00	0.00	0.00	0.00	0.00
LS	NS	NS	NS	NS	NS	NS	*	*	NS	NS

1D=First day at retail shop (2 days after harvesting), 3D=3rd day at retail shop (4 days after harvesting);

FG=Fully green (banana fingers), CB/INI=Colour breaking/Initiation of yellow colour, MR=Moderately ripe, FR=Fully ripe, OR=Over ripe; TP=Traditional practice, IP=Improved practices;

TP-1: NDH-NW-NP-BH-T, IP-1: DH-WWH-WMAP-PC-T, IP-2:DH-AWH-NMAP-PC-T, IP-3:DH+AWH+PC with MAP, IP-5:DH+WWM-WM+PC without MAP; NDH=No De-handing, DH=De-handing, NW=No washing, WWH=Washing with water, AWW=Alum (1% w/v) i.e. KAl(SO4)<sub>2</sub> water wash, NP=No packaging, BH=heaping whole bunch on truck, PC=Plastic crate, MAP=Modified atmospheric packaging, T=Truck (Transport vehicle); LS=Level of significance.

Table 24. Ripening status of banana in TP and IP on 5th day and 7th day at retail shop

Treatments	Retail 5D					Retail 7D				
	FG	CB	MR	FR	OR	FG	CB	MR	FR	OR
TP	0	34.19	26.65	24.13	15.03	0.00	0.00	35.60	33.82	30.58
IP-1	0	69.35	30.65	0.00	0.00	0.00	38.39	38.69	22.92	0.00
IP-2	0	72.72	27.28	0.00	0.00	0.00	47.79	34.78	17.44	0.00
IP-3	0	66.86	33.14	0.00	0.00	0.00	44.70	42.05	13.26	0.00
IP-4	0	72.98	27.02	0.00	0.00	0.00	47.20	39.23	13.57	0.00
IP-5	0	73.85	26.15	0.00	0.00	0.00	44.33	38.17	17.50	0.00
LS (%)	NS	*	NS	*	*	NS	*	*	*	*

5D=5th day at retail shop (6 days after harvesting), 7D=7th day at retail shop (8 days after harvesting);

FG=Fully green (banana fingers), CB/INI=Colour breaking/Initiation of yellow colour, FR=Fully ripe, MR=Moderately ripe, OR=Over ripe; TP=Traditional practice, IP=Improved practices;

TP-1: NDH-NW-NP-BH-T, IP-1: DH-WWH-WMAP-PC-T, IP-2:DH-AWH-NMAP-PC-T, IP-3:DH+AWH+PC with MAP, IP-5:DH+WWM-WM+PC without MAP; NDH=No De-handing, DH=De-handing, NW=No washing, WWH=Washing with water, AWW=Alum (1% w/v) i.e.  $KAl(SO_4)_2$  water wash, NP=No packaging, BH=heaping whole bunch on truck, PC=Plastic crate, MAP=Modified atmospheric packaging, T=Truck (Transport vehicle); LS=Level of significance.

Table 25. Ripening status of banana in TP and IP on 9th day at retail shop

Treatments	Retail 9D (10 days after harvesting)				
	FG	CB/INI	MR	FR	OR
TP	0.00	0.00	19.07	41.62	39.31
IP-1	0.00	11.31	17.26	54.17	17.26
IP-2	0.00	17.60	25.45	41.86	15.10
IP-3	0.00	17.61	22.16	49.05	11.17
IP-4	0.00	10.54	23.69	48.04	17.74
IP-5	0.00	13.81	39.56	31.43	15.20
LS	NS	NS	*	*	*

FG=Fully green (banana fingers), CB/INI=Colour breaking/Initiation of yellow colour, MR= Moderately ripe, FR=Fully ripe, OR=Over ripe; TP=Traditional practice, IP=Improved practices;

TP-1: NDH-NW-NP-BH-T, IP-1: DH-WWH-WMAP-PC-T, IP-2:DH-AWH-NMAP-PC-T, IP-3:DH+AWH+PC with MAP, IP-5:DH+WWM-WM+PC without MAP; NDH=No De-handing, DH=De-handing, NW=No washing, WWH=Washing with water, AWW=Alum (1% w/v) i.e.  $KAl(SO_4)_2$  water wash, NP=No packaging, BH=heaping whole bunch on truck, PC=Plastic crate, MAP=Modified atmospheric packaging, T=Truck (Transport vehicle); LS=Level of significance.

When it considered total ripe fruits including moderately ripe, fully ripe and over ripe fingers, it was clear that ripening of banana happened earlier and end sooner in TP than those of handled with IP including alum wash and packed in PC with or without MAP (Fig. 71). About 65.81% fingers were found to be ripe on day 5 in TP. It was ranged from 27.02 % 30.65% in in IP (Fig. 71) in the same day. In the day 7, 100% fingers were ripe in TP. On the contrary it was from 52.21% to 61.61% in the treatments of IP (Fig. 71).

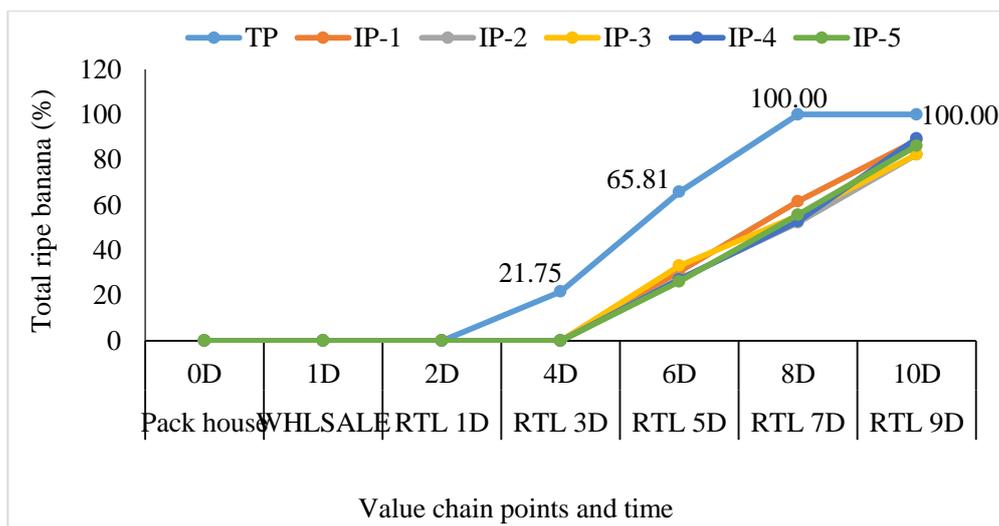


Fig. 71. Ripening performance of Bananas handled with TP and IP at wholesale level and retail period at ambient condition (27-31°C, 75-80% RH). TP=Traditional practices, IP=Improved practices; Vertical bars represent standard deviation. WHSALE=Wholesale level.

**Changes of banana skin colour:** The ripening associated colour changes in banana peel measured by chromameter is shown in Fig 72, 73 and 74. The initial values of lightness ( $L^*$ ) found almost similar in TP and IP handled bananas as they were harvested at physiologically mature green stage. Lightness ( $L^*$ ) increased and Chroma ( $C^*$ ) increased and hue angle ( $h^\circ$ ) decreased with advancement of time, however, the progression of increasing of lightness ( $L^*$ ) and chroma ( $C^*$ ) and declining of hue angle ( $h^\circ$ ) were rapid in the fingers handled with TP followed by those of handled with IP including water wash. In the rest of the integrated practices of improved methods, this progression and declining were comparatively slower than those of bananas handled with TP. These differences were found to be wide between 5 to 10 days of retail period. Lightness ( $L^*$ ) and chroma ( $C^*$ ) value and hue angle ( $h^\circ$ ) obtained in the treatments of IP and TP were almost similar on 10 and 11 days. The initial value of lightness ranged from 49.78 to 50.58 (Fig. 72) from the bananas sampled from wholesale house and that of chroma in the treatments were 37.64 to 38.54 (Fig. 73). The lightness ( $L^*$ ) reached to 65.96 in IP-5 and chroma was higher as 45.58 from the bananas of TP at 11th days retailing storage, however, they were statistically identical with rest of the treatments (Fig. 72 & 73).

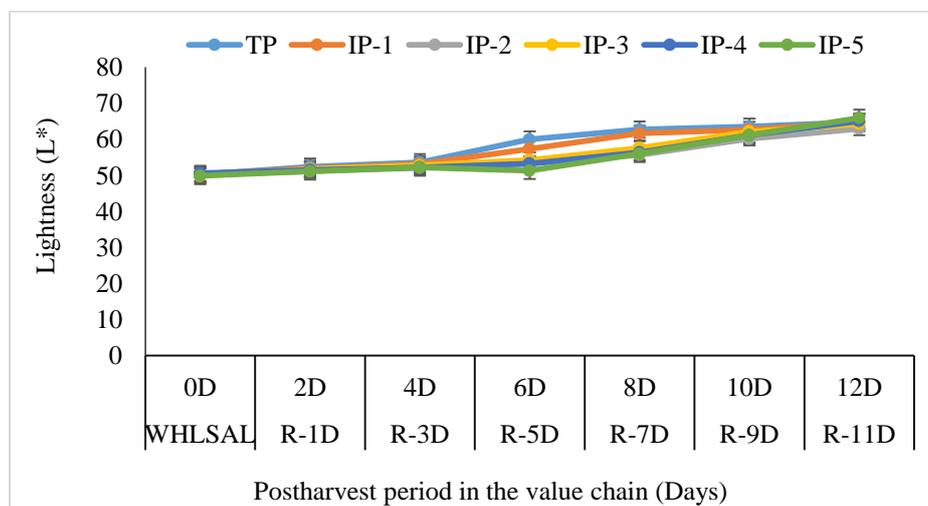
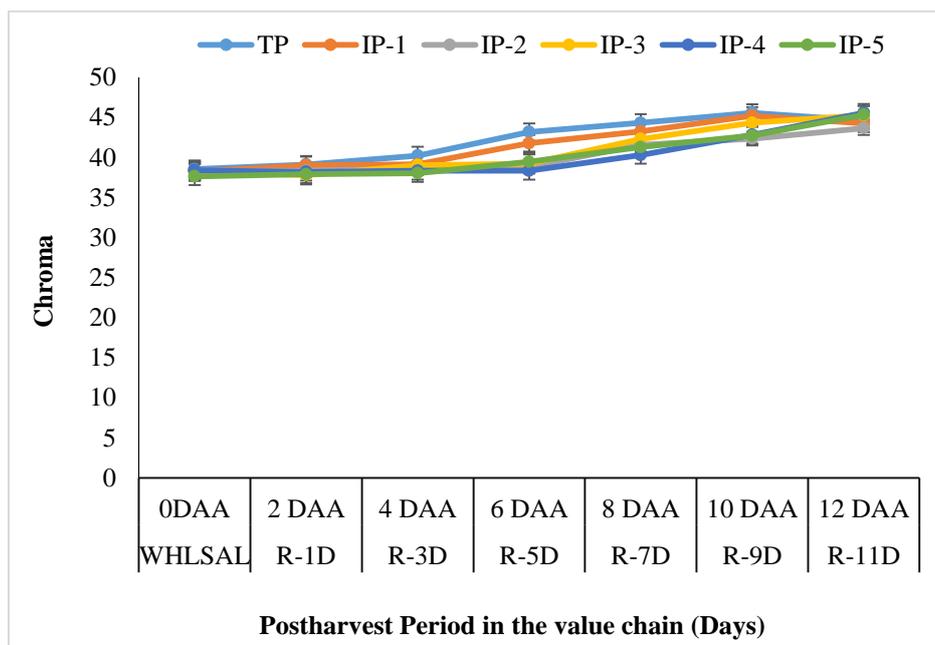


Fig. 72. Lightness of banana peel during postharvest period in the value chain.



DAA=Days after arrival

Fig. 73. Chroma (C\*) of banana peel during postharvest period in value chain.

The initial  $h^\circ$  angle was approximately 121 (Fig. 74). Banana fingers both in TP and IP showed a significant decrease in hue angle during 12 days postharvest period in the value chain. However, integrated improved practices delayed the decline of  $h^\circ$  angle up to 9 days (Fig. 74). Declining of  $h^\circ$  angle from 121.44 to 91.44 on retailing day 5 indicated earlier ripening initiation in TP and  $h^\circ$  angle as 77.52 on retailing day 7 denoted complete yellowing of most of the matured fingers in the bunch of bananas in TP. On the other hand,  $h^\circ$  angle decreased to more or less 78 in the fingers in most of the treatments of IP on retailing day 9 showed their delayed ripening pattern in this study.

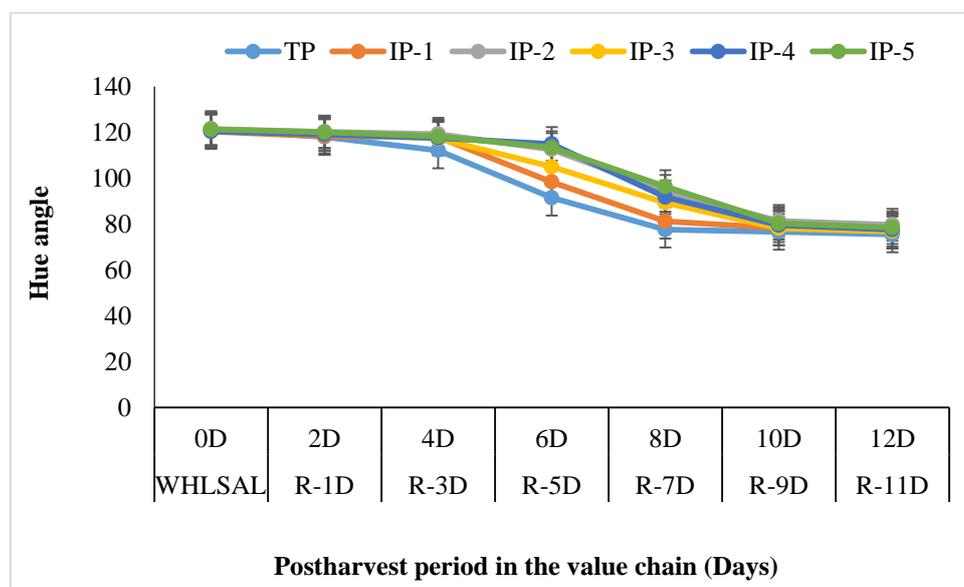


Fig. 74. Changes in hue angle ( $h^\circ$ ) of banana peel during postharvest period in the value chain.

**Firmness:** The firmness of all Bananas followed a decline trend during 9-day retail and storage period. The firmness of traditionally handled non-bagged Bananas reduced continuously from initial values of 3.66 to 0.64 kg-f/m<sup>2</sup> over the 11-days period. Likewise, the firmness of bananas in IP declined almost similar trend till 5 days retail period. After 5 days, it declined sharply in TP but some extent gradually or slowly in IP, particularly in the fingers washed in clean water or with alum water through washing machine and packed with or without PC (Fig. 75). Sharp and early declining of firmness of the fingers in TP indicated their earlier ripening status as they become soft earlier than those of the bananas handled with IP. Firmness of banana was found be decreased with ripening was also reported by Liew and Lau (2012), Amin *et al.* (2015) and Rahmam *et al.* (2016). Liew and Lau (2012) recorded firmness 3.55 kg-f/cm<sup>2</sup> from green stage fingers in Cavendish banana. It declined with time as 0.60 kg-f/cm<sup>2</sup> as the best edible stage of ripeness as they found. The results of present study were some extent in line with them.

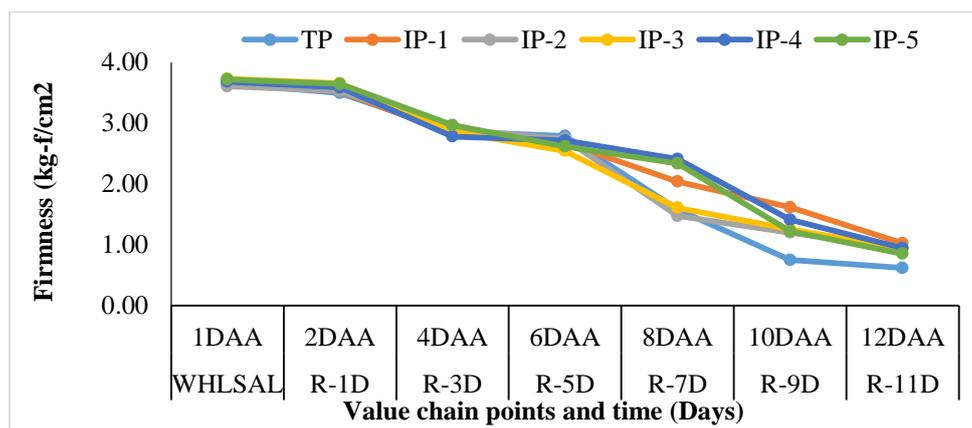


Fig. 75. Firmness of banana during 11-days postharvest period

**Biochemical changes:** TSS (%) was measured every day after arrival of banana at wholesale market and shifted to retail outlet and is shown in Fig. 76. TSS (%) increased in all the treatments of IP along with TP after 4 or 5 retail days; however, it reached not so sharply and was lower than those of the fingers handled with IP. The highest TSS (%) on 8 day was recorded as 8.34% from IP-5 and increased further and became 14.4% which was maximum in this treatment on retail day 11 (Fig. 76). In the same period, it was minimum as 6.56% on 8 day and 12.16% on 10 day in TP. Titratable acidity (%), Total sugar (%) and reducing sugar (%) were determined on 5, 7, 9 and 11 days at retail period as the fingers in most of the treatments exhibited ripe in sufficient numbers (Table 11) on this day and none of the fruits in TP were found to be in colour breaking stage on day 3.

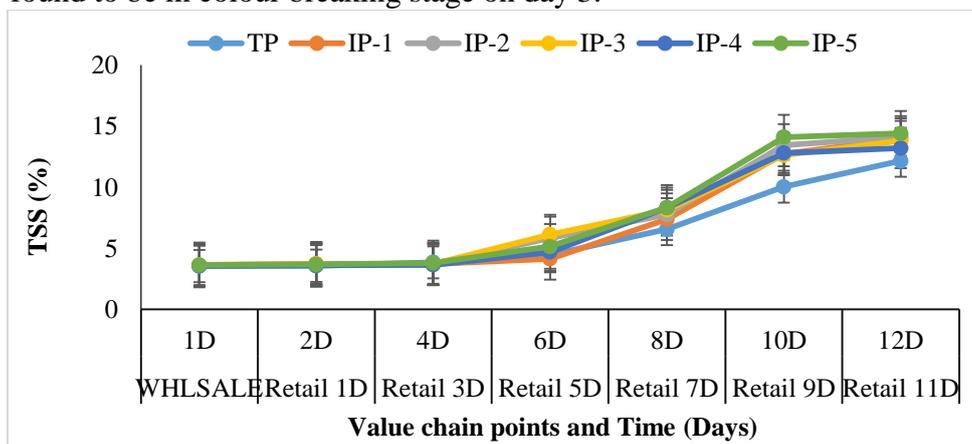


Fig. 76. TSS (%) of banana during 9-days postharvest period

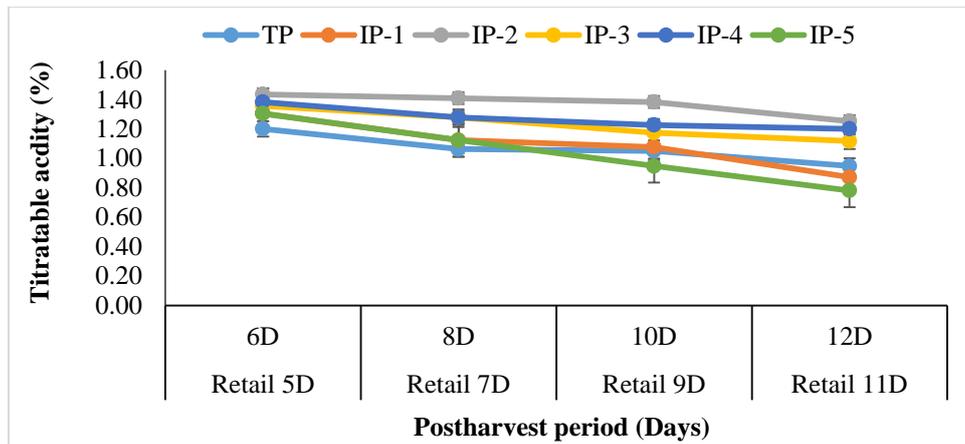


Fig. 77. Titratable acidity (%) of banana in during 9-days postharvest period

Fig. 77 shows that TA (%) decreased and total sugar (%) and reducing sugar increased with time. It was the usual trend in banana fingers both in TP and all in the integrated practice handled with IP. The highest TA (%) was recorded on day 5 as 1.44% in IP-2 and it remained higher in IP-2 up to the end of 11 days retail period (1.25%). The lowest TA (%) on day 10 was as 0.95% in IP-5 and it was also minimum (0.78%) on day 11 in the same treatment (Fig. 68). The total sugar (%) was maximum in IP-5 throughout the retail period comprising 5.33%, 11.83%, 14.09% and 17.28% on day 5, day 7, day 9 and day 11 respectively ((Fig. 78). Also, the RS (%) was higher in IP-5 which was almost similar to those of IP-3 (Fig. 79). Banana fingers handled with IP-4 had comparatively lower TS (%) after 7 days. In TP, TS (%) and RS (%) were computed moderate in 11 days retail period (Fig. 80 & 81). The decrease in TA and increase of total sugar in Bananas might be attributed to the utilization of organic acid in various bio-degradable reactions and hydrolysis of starch into accumulation of sugar and was reported as 0.49% TA and 21% TS at 9 days of storage in Amritsagor banana by Zomo *et al.* 2014).

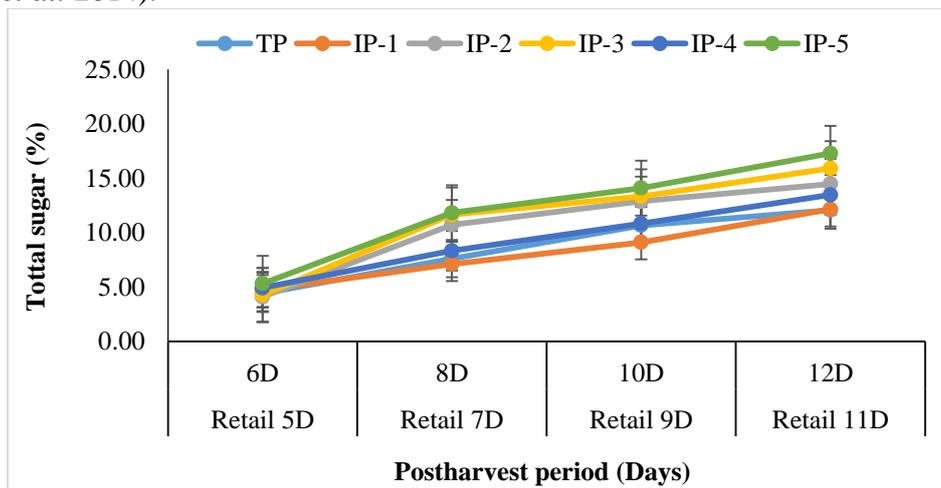


Fig. 78. Total sugar (%) of banana in integrated treatments of IP along with TP during 9-days postharvest period

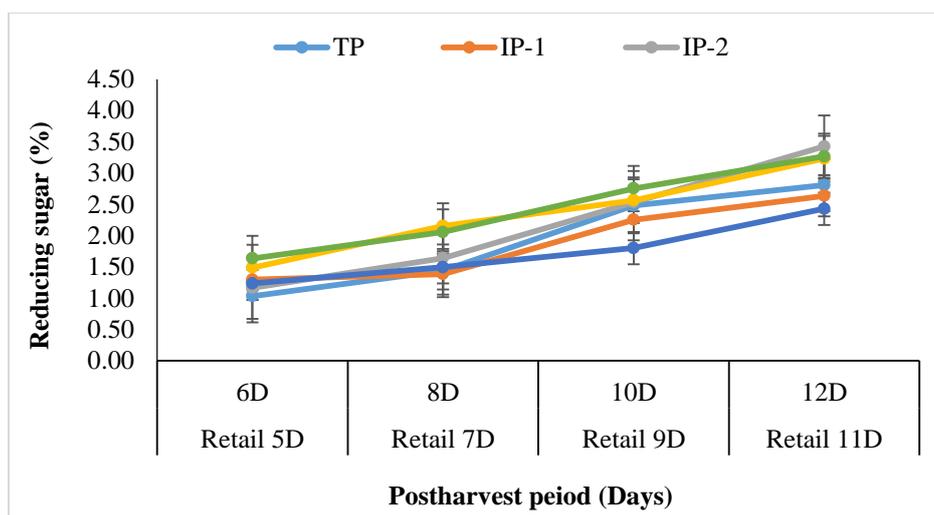


Fig. 79. Reducing sugar (%) of banana in integrated treatments of IP along with TP during 9-days postharvest period

**Recovery of good quality (sound) fruits at wholesale level:** The recovery of sound (no damage) and mechanically-damaged banana upon arrival at wholesale market is shown in table 26. Bananas handled with IP including de-handing, washing and packing in PC with or without MAP had significantly ( $P \leq 0.05$ ) higher recovery of sound fingers than those of handled with TP including no de-handing, no washing and loaded the whole bunch in truck. Average recovery of sound bananas was found about 94% to 98.0%, which handled with IP including de-handing, washing and PC packing with or without MAP. On the other hand, it was 73.2% when handled with TP in where no de-handing was followed and loading the whole banana bunch by heaping of a huge numbers of bunches on truck. About 7.60% of the fingers in TP were observed to be cracked and broken at wholesale house. Higher compressed mark was found on the fingers in TP comprising 10.2% at wholesale house. Also, bruising sign was found higher (27.33%) in the fingers handled and transported with traditional system. On the other hand, compressed and bruising were lower in almost all of the integrated handling practices in improved system ranged 1.65% to 3.67% and 2.33% to 5.67%, respectively (Table 26).

Table 26. Proportion of sound and mechanically damaged banana at wholesale level

Treatments	Sound banana	Mechanically damaged banana (%)		
		Broken/cut/cracks	Compressed/Pressed	Bruising
TRD: NW-NDH-NP-BH-T	73.2 c	7.60 a	10.20 a	27.33 a
IP-1: DH-WW-WMAP-PC-T	94.0 b	0 b	3.67 b	5.67 b
IP-2: DH-AW-W-PC-T	94.5 b	0 b	3.50 b	5.33 b
IP-3: DH-AWT-MAP-PC-T	98.3 a	0 b	1.65 c	2.67 c
IP-4: DH-AW-M-WMAP-PC-T	97.5 a	0 b	2.50 bc	6.25 b
IP-5: DH-AW-WM-MAP-PC-T	98.2 a	0 b	1.33 c	2.33 c
Level of significance (%)	0.05	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP-1: NDH-NW-NP-BH-T, IP-1: DH-WWH-WMAP-PC-T, IP-2:DH-AWH-NMAP-PC-T, IP-3:DH+AWH+PC with MAP, IP-5:DH+WWM-WM+PC without MAP; NDH=No De-handing, DH=De-handing, NW=No washing, WWH=Washing with water, AWW=Alum (1% w/v) i.e.  $KAl(SO_4)_2$  water wash, NP=No packaging, BH=heaping whole bunch on truck, PC=Plastic crate, MAP=Modified atmospheric packaging, T=Truck (Transport vehicle); LS=Level of significance.



Fig. 80. Pictorial view of showing: a. mechanical damage in the banana handled with TP and b. and c. absence or less damage in the fingers handled with IP during transportation.

**Decay and rotting incidence:** No decay or disease symptom found in the bananas at wholesale level and till the 4 days at retail outlet. It was evident both in the fingers handled with TP and IP. Decay or disease sign (Fig. 80 showing pictorial view) was found in 2.56% fingers in TP on retail day 5 and it increased progressively with time comprising as 9.72%, 19.33% and 23.67% in 7, 9 and 11 days, respectively (Fig. 81). About 1.67% fingers in IP-1 including water wash had some signs of decay on retail day 5. It reached to 3.33% and 4.67% in the same treatment in day 9 and day 11, respectively. The rest of the treatments of integrated improved practices had minimum decay throughout the retail period. The higher incidence of decay of bananas in TP at latter days probably due to exposing to microorganisms through compressed and bruising marks ensued in transportation. Crown rot was observed as the most decay responsible disease during postharvest storage which supported the statement made by Siriwardana *et al.* (2016).

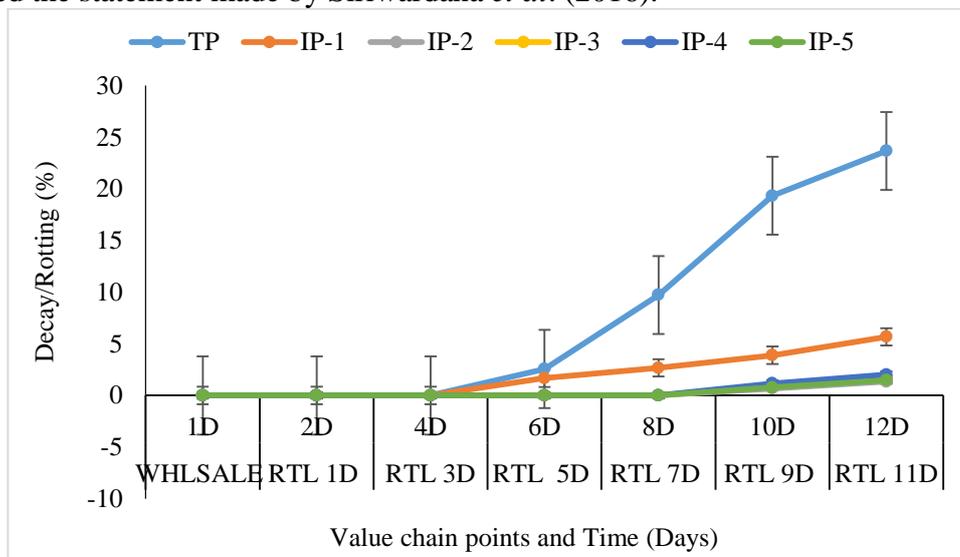


Fig. 81. Decay and rotting incidence (%) of Bananas handled with TP and IP at wholesale and retail period at ambient condition (27-31°C, 75-80% RH).



Fig. 82. Pictorial view (clockwise) of showing: a. decay and rotting incidence (%) in the banana handled with TP and b. and c. absence or less decay in the fingers handled with IP during postharvest period.

**Postharvest losses:**

**Weight loss**

Weight loss was recorded of 1.02-2.59% at the wholesale market, showing maximum loss in traditional postharvest handling practices (Fig. 83). Weight loss of banana occurred mainly due to transpiration from the fruit surface during transportation and displaying periods at retail outlets at 27-31°C, 75-80% RH. Both the fingers handled with TP and IP showed a progressive loss in weight along the value chain (Fig. 83). In the retail shops, the cumulative weight loss of 6.56% occurred in the traditionally handled without de-handled bananas on day 5, reaching 8.23% and 10.62% on day 7 and 9, respectively. Comparatively higher weight losses were also recorded from the fingers handled with IP including water wash and packing in PC without MAP. Weight losses were minimum (4.02% and 6.35% on retail day 7 and 9, respectively) in the fingers handled with IP including de-handling, alum water wash and packing in PC with MAP of 1% perforated polyethylene sheet (Fig. 83). Kamal *et al.* (2019) recorded higher weight loss with storage time as 19.60% weight loss in Amritsagor banana with control treatment at 9 days.

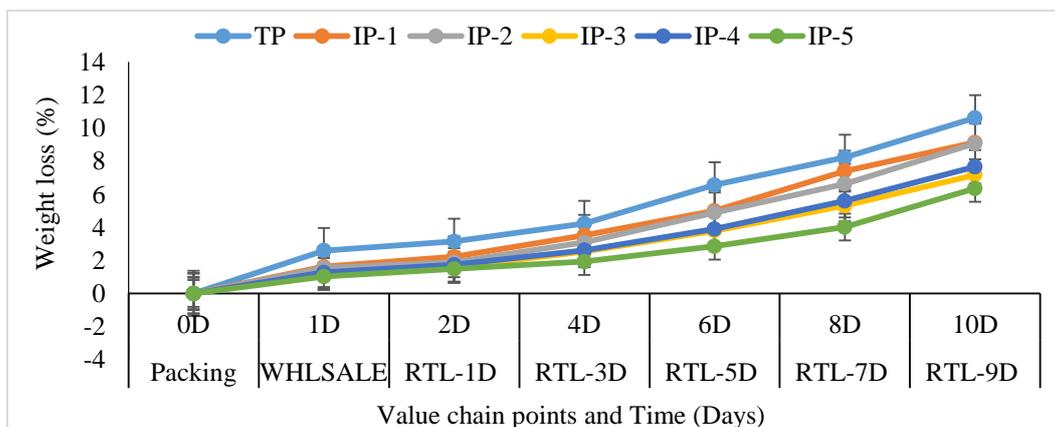


Fig. 83. Weight loss of banana in the value chain

**Postharvest losses of banana along the value chain:** The higher postharvest loss was recorded as 29.95% in TP handled bananas at retail outlet. It was followed by the decay and rotting loss and cumulative weight loss of 19.33% and 10.62%, respectively in the same treatment (Fig. 84). At the wholesale market, on the other hand, actually no losses occurred mainly due to short staying time (10-12h) over there, however, the total losses occurred during transportation but calculated at wholesale level was maximum as 20.39 for the bananas handled with TP in which no de-handing and washing were done and wholes bunches were loaded and heaped in truck. This high loss in TP was mainly due to cracking and compression happened in the heaped bunches during transportation. The cracking and compressed losses were recorded high in TP as mentioned in Table 28. The total postharvest loss of this treatment was 50.3% at the end of 9 days retail period (Fig. 84). It became further high at 11 days but did not consider in counting as the bananas of TP lost their shelf life. Bananas that handled with IP including de-handing, water wash and packing in PC without MAP was noticed total postharvest loss as 18.3% after 9 days, whereas it was only 9.5% when handled with IP including alum water wash and packing PC with MAP of 1% perforated polyethylene sheet.

Results of this study revealed that the retail outlet was the most critical stage with the higher postharvest losses found in banana. However, this higher loss was actually the resultant of physical injury happened during the transportation of banana bunches through truck. Heaping and loading huge number of bunches in transport vehicle was the major cause of physical damage during transportation. Compressed and bruising marks in the fingers made them susceptible to disease infestation. Thus, decay and rotting (%) was more in the banana handled with TP. In a study, the total postharvest loss in the supply chain was reported as 26.5% where 56% of the loss was occurred in the retail level (Mebratie *et al.*, 2015). The postharvest loss of banana associated with storage and marketing is reported to be prominent and reaches up to 80% as in the case of Rwanda (WFLO, 2010). Significant mechanical damage in bananas has been reported during farm and pack house operations (Mvumi *et al.*, 2016), due to improper packing of bananas (Ekanayake and Bandara, 2002; Hailu *et al.*, 2013), rough handling of packages and bunches (Dadzie and Orchard, 1997; Wasala *et al.*, 2014) and during distribution (Da Costa *et al.*, 2010).

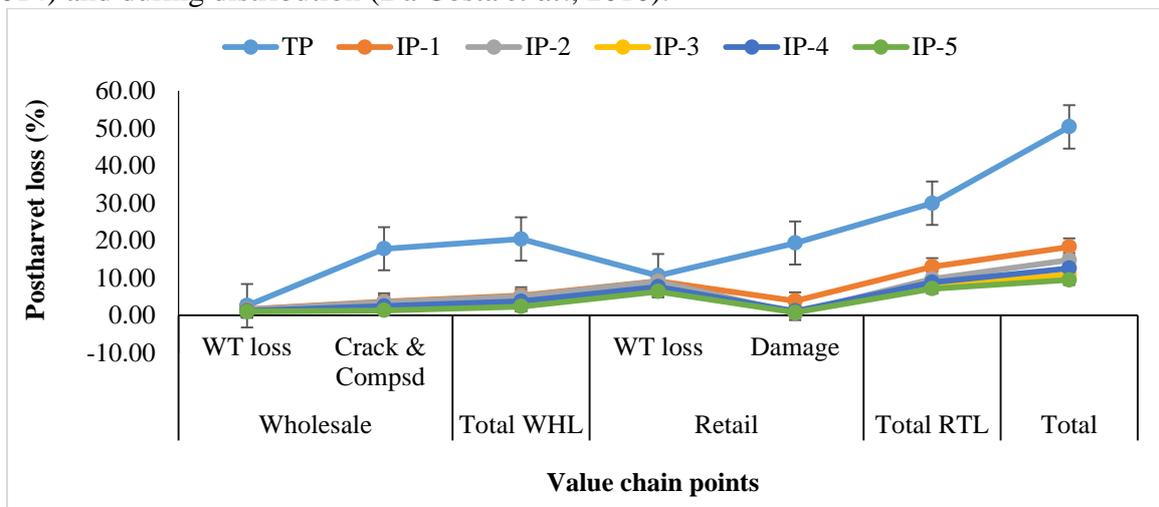


Fig. 84. Postharvest losses of banana in the value chain

TP=Traditional postharvest management practices; IP = Improved postharvest management practices. Vertical bars represent standard deviation.

Integrated treatments of improved practices reduced postharvest losses of banana cv. 'Sagor' by from 63.64% to 81.17%, The highest loss reduction (81.17%) was calculated from IP including de-handing of banana, alum water wash (1% w/v) of detached hands and packed

the washed hand in PC with MAP. It was the lowest for the banana hands those were washed with clean water and packed in PC without MAP. De-handing of banana and plastic crate might have positive role in reducing cracks, compression and bruising. Accordingly, decay and rotting might be occurred less and could not be extended more in integrated improved practices. MAP in PC had role in minimizing weight loss. Alum water (1% w/v) washing was beneficial in removing of latex flow, might had some role in minimizing decay and spoilage as it has antiseptic quality. Better quality of Bananas with lower extent of decay and physical damage were also found at retail level when they passed through improved management practices in the supply chain (Dadzie and Orchard, 1997; Mvumi *et al.*, 2016; Macheke *et al.*, 2013). According to their observation, improving field transport conditions, careful handling of bunches and careful packing of bananas is critical for ensuring the fruit quality throughout the supply chain.

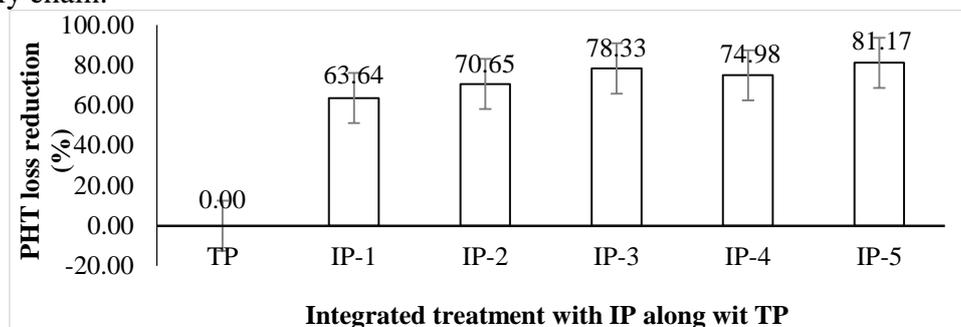


Fig. 85. Postharvest loss reduction of banana with integration of improved practices

### Marketable quality and storage studies

**Marketability:** It found that the marketability of banana fruits cultivar ‘Sagor’ mostly be relied on peel colour and softness nature of fingers and attractiveness along with free from physical injury, damage and decay. Usually, the consumers choose a banana hand by observing the whole fingers on it. They like a banana hand with mixed of fully ripe and moderately ripe fingers. Accordingly, marketability was judged by observing external looking of the fingers altogether. From Table 23 to 25 and Fig. 86, it was found that the fingers remained green in IP up to 4 days. On the other hand, ripening of fingers in TP initiated between the retailing day 3 to 4. Thus, the preference score was higher in the fruits handled with TP on 6 day but fell down sharply within very short time. Higher preference score in the treatments of IP was recorded between 5 to 9 days. The highest score of 4.67 was obtained by IP-3, IP-4 and IP-5 on retailing day 7. Fig. 86 revealed that the retention of marketable quality was comparatively longer in improved practices.

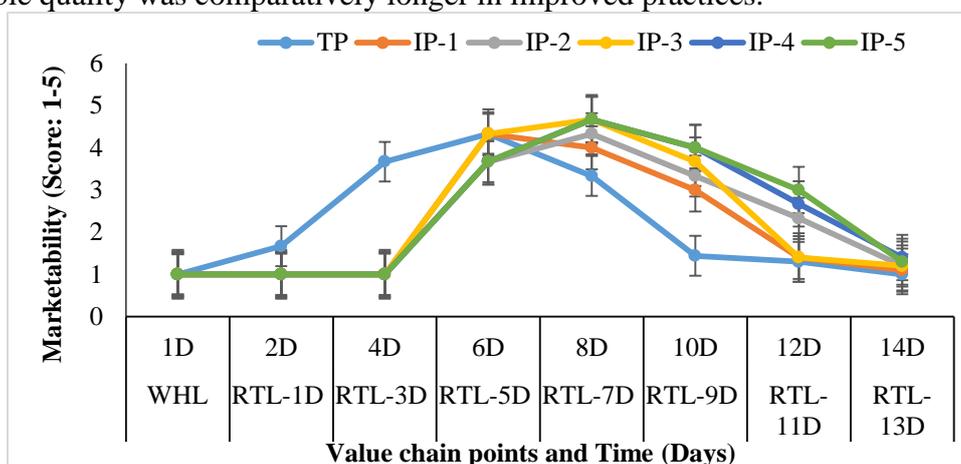


Fig. 86. Marketability of banana during 14-days (13 days retail) postharvest period

**Shelf life:** Shelf life was recorded based on external quality of the fruits and ripening status of the fingers along with less incidence of decay and excessive softness and is shown in Fig. 87. The highest shelf life (11 days only) was recorded for the bananas those were produced and handled with IP including de-handing and de-sapping, washed in alum water wash through washing machine and packed in PC with MAP (the treatment, IP-5) and loaded the single crop in truck for transportation to city market. Also, the bananas in IP-3 and IP-4 had same shelf life (11 days) in this study. The lowest shelf life (8.33 days) was recorded for the bananas handled with TP which were nor de-handed, rather loaded the full bunch by heaping in truck to transport city wholesale market. No washing was followed in this treatment. Also, de-handed banana washed with clean water and packed in PC without MAP had lower shelf life (9.67 days).

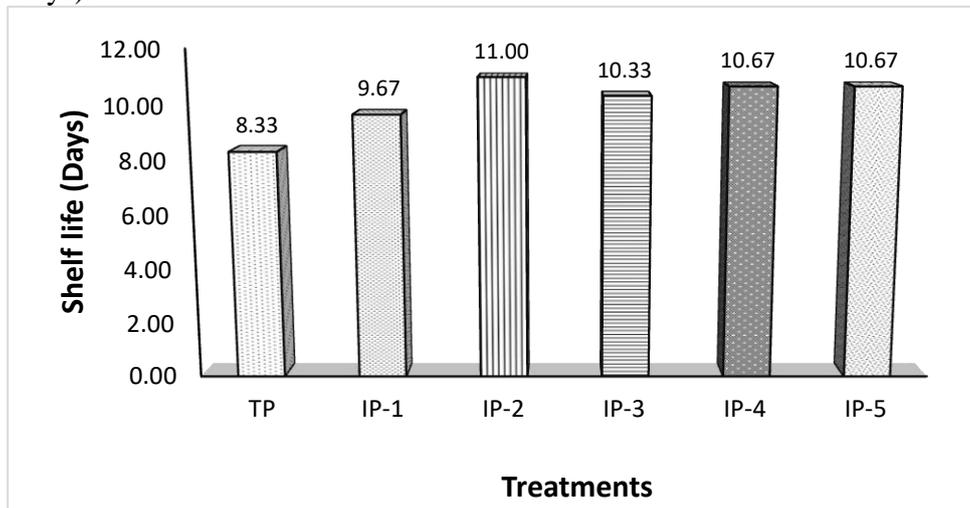


Fig. 87. Shelf life of banana in integrated postharvest practices



Fig. 88. Pictorial view of showing comparatively better-quality banana which was handled with IP having higher shelf life in retail outlets

Results of the present study revealed that the integration of improved practice (IP) with careful harvesting of banana by observing and judging of optimum maturity of second hands in the bunch, de-handing by BARI de-handing tool (special type Da), washing with alum water and packing in PC with or without MAP (1% perforated polyethylene sheet) and transported the packed bananas to city market was an effective protocol which resulted 63.64% to 81.17% reduction in loss by preventing the transpiration and mechanical damage and diseases and decay and about 94-98% bananas could be sold at retail outlets.

**c) Carrot:**

**Technical and Economic Feasibility of Integrated Improved Practices in Maintenance of Quality and Reducing Postharvest Losses in Carrot Value Chain**

**Quality Evaluation**

Usually, the freshness of carrot are chosen by looking its shape and size, colour, appearance, firmnes, and non-existence of quality defects such as peitiole and sepals withering, fruit withering and squeezing, and blemish or rotting creates negative impact to growers' choice. Considering the facts, these were determined or assessed and is shown below.

**Firmness:** Firmness of fruits and fruit and root type vegetables is an important quality assessment criterion that influence on consumer's decision in buying a fresh commodity. Firmness of carrot Var. Orange King in different treatments is shown in Fig. 89. On the day of arrival, the highest firmness (5.42 kg-f/cm<sup>2</sup>) was recorded from the carrots packed in plastic sack. It decreased slightly with extend of time and down to 4.55 kg-f/cm<sup>2</sup> on 10 days after harvesting i.e. on retail day 9. Almost similar type firmness was recorded from the carrots which were handled with IP including improved practices of washing and packaging Fig. 89).

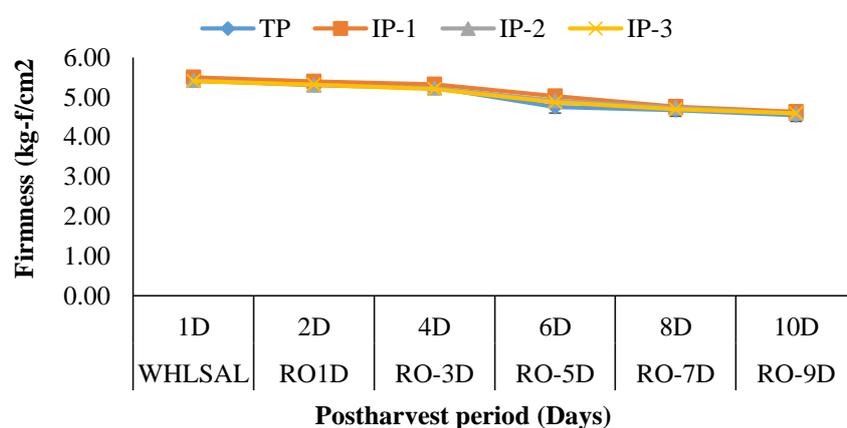


Fig. 89. Firmness of carrot in during 10-days postharvest period

WHLSAL=Wholesale level, RO=Retail outlet; D=Day, TP=Traditional practice IP=Improved practice; TP-1: TP+TW+PS, IP-1: IP+Cl wash+PC without MA, IP-2: IP+CCa wash+PC without MAP, IP-3: IP+CCa wash+WM+PC with MAP (PPS); TW=Traditional washing (manually, use of legs); PS=Plastic sack, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP= Modified atmosphere packaging (1% perforated polyethylene sheet). PPS =Perforated polyethylene sheet (1%).

**Decay/Rotting:** Decay due to biotic or abiotic factor is one of the limitations in maintenance quality of fruits in postharvest chains. In this study, bulk carrots packed in plastic sack was found to be infested higher in numbers than that of the fruits packed in plastic crate. The highest incidence (19.67%) of decay was observed in the carrots on 7 day in IP-3. It was 2.67% for the carrots washed in CCa and packed in PC without MAP (Fig. 90). Higher incidence of decay after 3 days in plastic crate with MAP might be attributed mostly due to higher accumulation of moisture inside MAP (PPS) and that of TP with plastic sack might be because of disposing with mechanical damage during handling and transportation. Carrots packed in IP lining with newsprint paper had the less decay probably because of having less or almost nil mechanical damages (Fig. 91; pictorial view showing decay in carrots in IP along with TP). Also, CCa might be useful a bit in reducing decay and rotting in IP systems. In a storage study with carrot cultivar New Kuroda, Cheena *et al.* (2016) recorded maximum

decay as 54.20% from untreated carrots compared to that of minimum (27.43% in the roots which was treated with 1% H<sub>2</sub>O<sub>2</sub>. Significantly maximum firmness (9.48 kg-f/cm) was obtained from the carrots treated with CaCl<sub>2</sub> by Cheera *et al.* (2016).

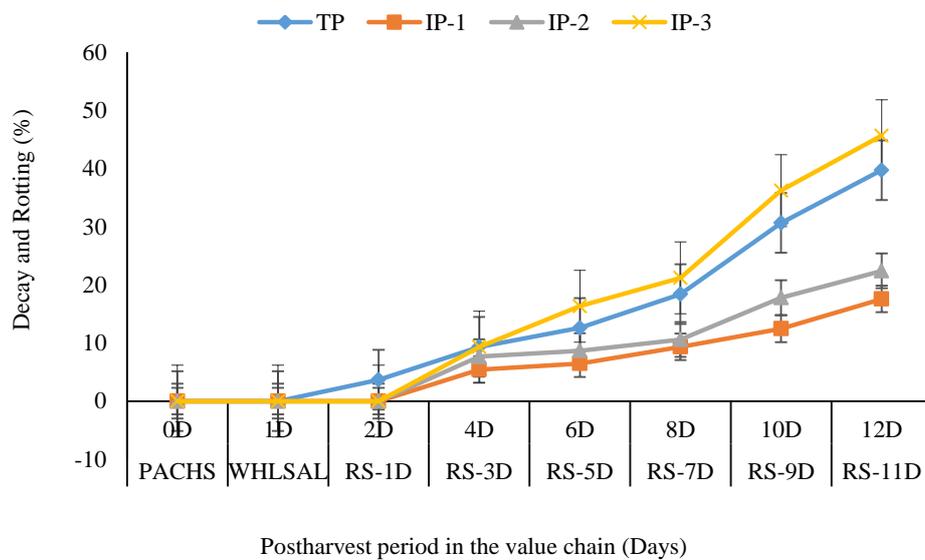


Fig. 90. Incidence of decay and rotting of carrots in 5-days postharvest period TP=Traditional practice, IP=Improved practice, PACHS=Packhouse, WHSAL=Wholesale



Fig. 91. Pictorial view of showing decay and rotting status of carrot during postharvest period: a. Higher decay in TP, b. Less decay in the carrots handled with IP including chlorine wash and packing in PC lining with newsprint paper, c. less decay in the carrots in IP including CCa (1%) wash and packing the carrots in PC lining with newsprint paper, d. Higher decay in the carrots washed with 0.00.00.01% CCa and packed in PC with MAP (1% perforated polyethylene sheet).

**Nutritional Status:** TSS (%) and titratable acidity (%) of carrot are presented in Table 27. Total sugar (%) and reducing sugar (%) are shown in table 28 and vitamin C content (mg/100g) is presented in Fig. 83. The TSS (%) and titratable acidity (%) increased and vitamin C content (mg/100g) decreased with progression of time (Table 27). The retention of

vitamin C, however, found to be more in the carrots in improved practices compared to traditional practices (Fig. 92). TSS (%) increased and titratable acidity (%) decreased in all the integrated practices which supported the results obtained by Brunda and Bhadraiah (2015) and Cheena *et al.* (2016).

Table 27. Total soluble solid and titratable acidity (%) content of carrot in traditional and improved postharvest practices in 10-days postharvest period

Treatments	TSS (%)						Titratable acidity (%)					
	1D	2D	4D	6D	8D	10 D	1D	2D	4D	6D	8D	10 D
TP	8.40	8.66	8.78	8.82	8.84	8.9	0.43	0.46	0.51	0.61 a	0.59 a	0.54
IP-1	8.48	8.72	8.86	8.84	8.92	8.94	0.43	0.48	0.48	0.43 b	0.54 ab	0.54
IP-2	8.28	8.56	8.82	8.88	8.94	8.94	0.48	0.54	0.54	0.46 b	0.48 b	0.54
IP-3	8.38	8.62	8.68	8.80	8.84	8.94	0.46	0.56	0.54	0.46 b	0.56 ab	0.56
LS (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS

Values in each column followed by the same letter (s) are not differed significantly. TP= Traditional practices, TW=Traditional washing method, D=Days after harvesting

Table 28. Total sugar and reducing sugar content of carrot in traditional and improved postharvest practices in 10-days postharvest period

Treatments	Total sugar (%)						Reducing sugar (%)					
	1D	2D	4D	6D	8D	10D	1D	2D	4D	6D	8D	10D
TP	20.28	20.59	20.77	19.91	23.21	23.52	4.30	4.33	4.43	4.46 a	4.50 ab	4.52
IP-1	20.20	20.36	20.50	20.18	22.55	23.95	4.32	4.34	4.40	4.40 ab	4.55 a	4.58
IP-2	20.20	20.50	20.33	20.30	22.55	23.69	4.26	4.30	4.32	4.34 b	4.43 b	4.56
IP-3	20.26	20.43	20.36	20.20	23.59	23.86	4.23	4.32	4.33	4.48 a	4.57 a	4.58
LS (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS

Values in each column followed by the same letter (s) are not differed significantly.

TP= Traditional practices, TW=Traditional washing method PS=Plastic sack, IP= Improved practice, CCa=Calcinated calcium, WM=Washing machine, PC= Plastic crate; MAP= Modified atmosphere packaging (1% perforated polyethylene sheet). PPS =Perforated polyethylene sheet (1%).

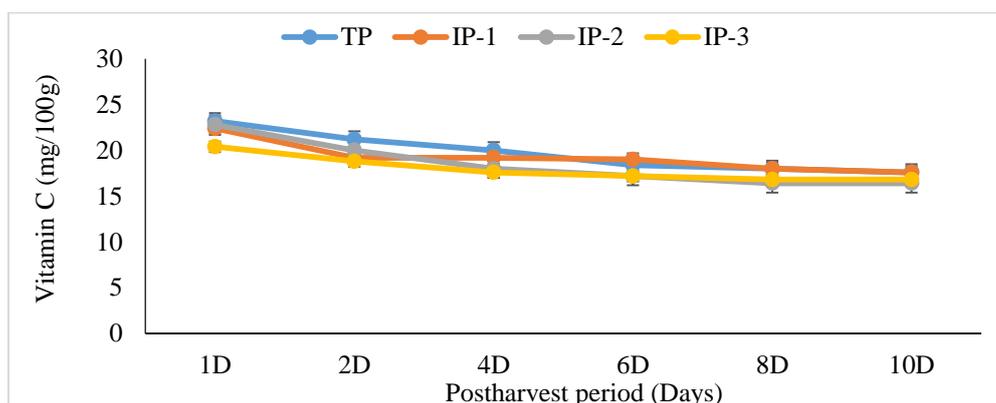


Fig. 92. Vitamin C content of carrots during 10-days postharvest period

**Marketability:** Marketability of carrots in different integrated practices are shown in Fig. 93. It was observed that the marketability preference was dependent on retaining firmness and freshness of carrot roots along with less incidence of quality defects like decay or rotting, withering and shriveling of carrot roots accordingly the preference score remained acceptable up to 7 days (Fig. 93) for the carrots those were washed with CCa (1%) mixed water and packed in PC without MAP. It lost marketability after eight days of storage (Fig. 93) for the carrots those were washed and packed in plastic crate with MAP (1% PPS). It was followed by TP including traditional wash with water and packed in PS.

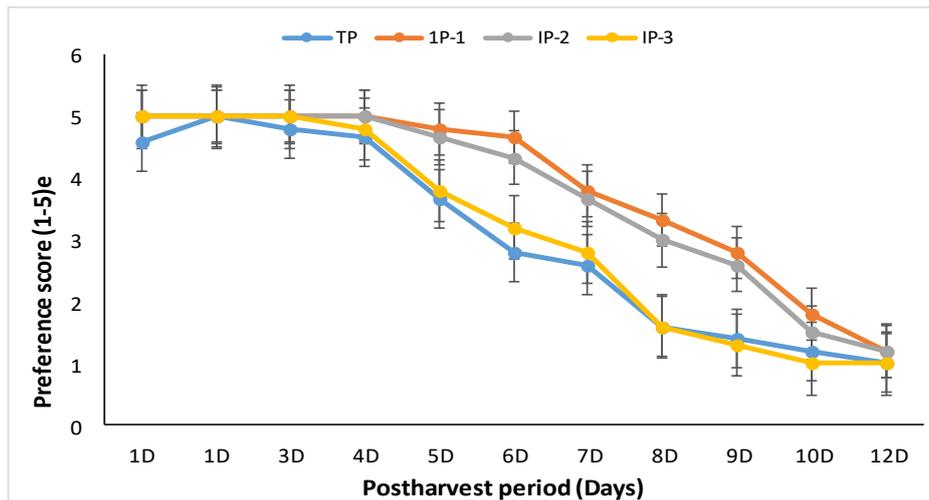


Fig. 93. Marketability of carrot during 12-days postharvest period

**Marketable life:** The marketable life of carrot in IP along with TP is shown in Fig. 94. Carrots washed with NaOCl mixed water (Cl wash) in washing house and packed in plastic crate without MAP had the highest marketable life (10.33 days) followed by (9.67 days) those of washed in CCa mixed water in washing machine and packed in PC without MAP but lining with clean newsprint paper. The lowest marketable life (8.00 day only) was recorded for the carrots those were wshed with CCa through washing machine and packed in PC with MAP (1% PPS), It was very close to TP which had the marketable life 8.33 days (Fig. 94).

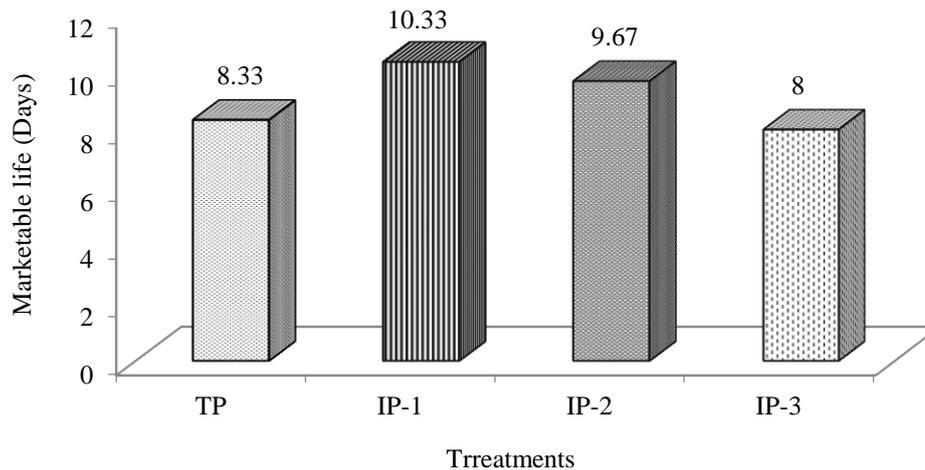


Fig. 94. Marketable life of carrot handled with IP along with TP

### Postharvest losses

**Weight loss:** Weight loss was recorded as 0.58-0.94% at the wholesale market which increased with time in retail shop (Fig. 95). It was maximum for the carrots those were washed manually first and then second time washing was done with 150 ppm NaOCl in washing house and packed in PC to transport to city market through a truck, a common transport vehicle. Carrots washed with calcinated calcium through washing machine and packed in plastic crate with MAP of 1% perforated polyethylene sheet had the minimum weight loss (0.58%) at wholesale house and throughout the displaying period of 9 days at

retail shop (Fig. 95). When washing was done with 1% calcinated calcium in washing house packed in PC without MAP but lining with newsprint paper, weight loss was recorded as 0.94% at wholesale house. It is mentioned that before washing in NaOCl in washing house, firstly, surface dirt was removed through traditional practicing of washing by using of human legs and water pouring. In case of retailer's shop, maximum weight loss was recorded from the carrots wash with NaOCl and packed in PC lining with NPP (without MAP) comprising 1.25%, 2.35%, 3.65%, 4.58% and 6.44% on 1st, 3rd, 5th, 7th and 9th day at retail shop (Fig. 95). In case of traditional practicing of washing manually and packing in plastic made sack, weight loss of carrots was found to be moderate and reached up to 4.94% on day 9 at retail shop (Fig. 95). The weight loss was computed minimum for the integrated treatment in where washing was done with CCa in washing machine and then packed in PC with MAP (Fig. 95). Transpiration is the main cause of weight loss in agricultural products during storage and MAP is beneficial in reducing weight loss, thus, weight loss of carrot was recorded minimum in MAP by Workneh *et al.* (2011) and Ayhan *et al.* (2016).

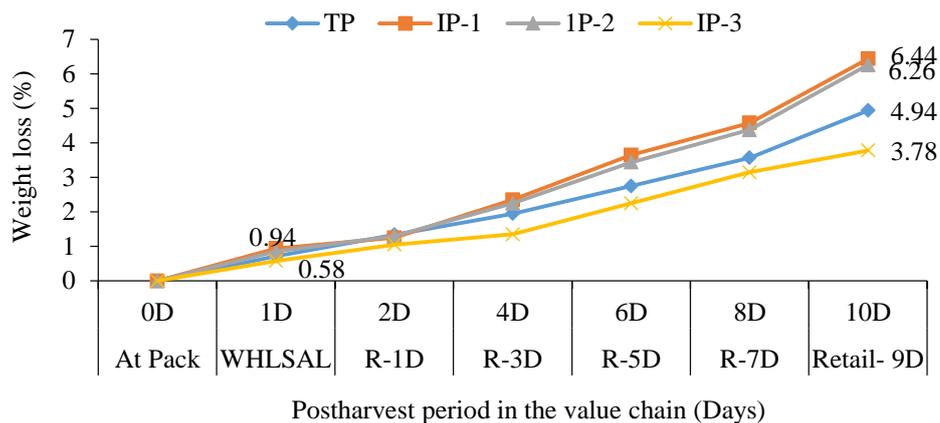


Fig. 95. Weight loss of carrot during postharvest period in the value chain

**Recovery of good quality (sound) fruits at wholesale level:** The recovery of sound (no damage) and mechanically-damaged carrot upon arrival at wholesale market is shown in table 29. Carrots packed in plastic crates had significantly ( $P \leq 0.05$ ) higher recovery of sound fruits than those of packed in plastic sacks. Average recovery of sound Carrots was found about 98.4%, which handled with IP and packed in PC with MAP. PC without MAP had also higher recovery of good quality carrots (97.8%).

Table 29. Proportion of sound and mechanically damaged Carrot at wholesale market

Treatments	Sound Carrot (%)	Mechanically damaged Carrot (%)		
		Bruising	Compression	Cracks
TRD: TP+TW+ PS	74.53	9.4	8.6	7.47
IP-1: IP+Cl wash+PC without MAP	97.4	2.6	0	0
IP-2: IP+CCa wash+PC without MAP	97.8	2.2	0	0
IP-3: IP+CCa wash in WM+PC with MAP	98.4	1.6	0	0
Level of significance (%)	0.05	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP= Traditional practices, TW=Traditional washing, PS=Plastic sack, IP=Improved practice, CCa=Calcinated calcium, WM=Washing machine, PC= Plastic crate; MAP= Modified atmosphere packaging (1% perforated polyethylene sheet).

At wholesale level, the incidence of mechanical damage in the form of compression and crack for the carrots packed in the plastic sacks was 8.6% and 7.47%, respectively. On the

other hand, it was zero for the carrots packed in PC with MAP or without MAP (Table 29). Higher recovery of good quality carrots in PC might be because of low or nil compression damage. Plastic crates are rigid and highly recommended as packaging containers for tomato and other fresh vegetables since they provide adequate protection against compression damage (Esguerra *et al.*, 2016; Rapusas and Rolle, 2009). This kind of suitability of plastic crate was also found for carrot in this study.

**Recovery of sound Carrots at the retail outlets:** By integrating IP comprising CCa as sanitizers and plastic crates as packaging container along with and without MAP, the recovery of sound and highly marketable carrots in retailing day 1, amounted to 94.05 and 94.15 %, respectively (Table 30), It decreased on day 7, reaching 69.7% and 81.4% for the mentioned two treatments, respectively. In contrast, the recovery of sound carrots which handled with TP and packed in plastic sacks was 72.53% on day 1 which decreased to 61.87% and 55.42% on day 5 and day 7, respectively (Table 30). At the end of 7-day retailing period, the highest recovery of sound carrot was computed from the integrated treatment IP-1 in where carrots were washed with NaOCl mixed water in washing house and then packed in plastic crate without using MAP but lining with fresh and clean newsprint paper. Before washing in NaOCl, surface dirt was removed with traditional washing practice.

Table 30. Proportion of sound Carrot at retail outlets

Treatments	Sound Carrot at retail outlets (%)			
	Day 1	Day 3	Day 5	Day 7
TP: TP+TW+ PS	72.53	66.2	61.87	55.42
IP-1: IP+Cl wash+PC without MAP	93.14 a	92.33	86	84.2
IP-2: IP+CCa wash+PC without MAP	94.15 a	92.18	83.3	81.4
IP-3: IP+CCa wash in WM+PC with MAP	94.05 a	93.85	83.15	69.7
Level of significance (%)	0.05	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP= Traditional practices, TW=Traditional washing method PS=Plastic sack, IP= Improved practice, CCa=Calcinated calcium, WM=Washing machine, PC= Plastic crate; MAP= Modified atmosphere packaging (1% perforated polyethylene sheet). PPS =Perforated polyethylene sheet (1%).

**Incidence of fully damaged carrots at retail shop:** Quality defects like cracking, blemish and decay and rotting of the carrots were observed during the displaying at retailer's shop and storage at the laboratory. The altogether carrots which had signs of crack, decay and rot and considered as fully damaged, is shown in table 31. The highest incidence of fully damaged carrots amounted 24.33% on day 7.6% for the roots handled with TP that caused by cracking, compression and bruising effect during transportation and subsequent handling (Table 31). IP including chlorine wash and then packing in PC lining with clean newsprints paper had the lowest number of fully damaged carrots throughout the retailing period (5.45% and 6.25% on day 5 and day 7, respectively). The fully damaged carrots were also minimum in the IP including CCa wash and PC packing lining with similar kind of newsprint paper (Table 31).

Table 31. Fully damaged carrot (compressed + cracked+ rotted) at retail display

Treatments	Fully damaged carrot at retail outlets (%)			
	Day 1	Day 3	Day 5	Day 7
TP: TP+TW+ PS	16.07	19.4	21.33	24.33
IP-1: IP+Cl wash+PC without MAP	0	0	5.45	6.25
IP-2: IP+CCa wash+PC without MAP	0	0	7.5	8.4
IP-3: IP+CCa wash in WM+PC with MAP	0	0	9.3	15.7
Level of significance (%)	0.05	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP= Traditional practices, TW=Traditional washing method PS=Plastic sack, IP= Improved practice, CCa=Calcinated calcium, WM=Washing machine, PC= Plastic crate; MAP= Modified atmosphere packaging (1% perforated polyethylene sheet). PPS =Perforated polyethylene sheet (1%).

**Incidence of less damaged carrots at retail shop:** Carrots which were bruised but retained at least some quality of marketability which were appraised as less marketable. It is shown in table 32. The treatment, TP had the highest incidence (11.4%) of less damaged carrots on day 1 and throughout the retail period (Table 32). The lowest incidence of less damaged roots was accounted for IP-1 followed by IP-2 and IP-3. Relatively higher incidence of less damage as well as fully damage were recorded from the treatment, IP-3 where washing was done once with CCa mixed water through washing machine and then packed the washed carrots with MAP (1% PPS)

Table 32. Less damaged carrots (bruised and less marketable) at retail display.

Treatments	Less damaged carrot at retail outlets (%)			
	Day 1	Day 3	Day 5	Day 7
TP: TP+TW+ PS	11.4	14.4	16.8	20.25
IP-1: IP+Cl wash+PC without MAP	6.86	7.67	8.55	9.55
IP-2: IP+CCa wash+PC without MAP	5.85	7.82	9.2	10.2
IP-3: IP+CCa wash in WM+PC with MAP	5.95	6.15	7.55	14.6
Level of significance (%)	NS	NS	NS	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP= Traditional practices, TW=Traditional washing method PS=Plastic sack, IP= Improved practice, CCa=Calcinated calcium, WM=Washing machine, PC= Plastic crate; MAP= Modified atmosphere packaging (1% perforated polyethylene sheet). PPS =Perforated polyethylene sheet (1%).

**Recovery of marketable Carrots at retail outlets:** Total marketable fruits consisted of sound carrots and fruit exhibiting slight bruising and abrasion, is shown in table 33. During the 7-day retail display, the proportion of total marketable carrots handled with IP and packed in PC with MAP remained 100% on day 1 and day 3 (Table 33). However, it decreased slightly on day 5 when PC with or without MAP was used as packaging container. In contrast, carrots handled with TP and packed in PS exhibited significantly ( $P \leq 0.05$ ) the lowest proportion of marketable fruits compared to those IP. The recovery of marketable carrots followed TP and packed in plastic sack was 83.93% on day 1, which decreased 78.67% on day 5 and 75.67% on day 7, respectively. Comparatively lower recovery of marketable carrots in PC with MAP (IP-4) on day 7 was due to discarding of higher number of decay and rotted carrots, probably because of higher accumulation of moisture inside the PPS that favored microbial infestation.

Table 33. Total marketable carrot at retail outlets.

Treatments	Total marketable carrot at retail outlets (%)			
	Day 1	Day 3	Day 5	Day 7
TP: TP+TW+ PS	83.9	80.6	78.67	75.67
IP-1: IP+Cl wash+PC without MAP	100	100	94.55	93.75
IP-2: IP+CCa wash+PC without MAP	100	100	92.5	91.6
IP-3: IP+CCa wash in WM+PC with MAP	100	100	90.7	84.3
Level of significance (%)	0.05	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

**Total losses in whole value chain:** Fig. 96 shows the proportion of postharvest loses of carrot at each stage of value chain. At wholesale level, there were no unmarketable roots, which handled with IP including washing and plastic crate packing with or without MAP. In contrast, 16.07 % carrots were found to be cracked and severely compressed when they were

handled with TP with traditional washing and packing in plastic sack. Thus, the cumulative losses of carrots in the entire value chain were calculated and showed that the highest total loss of 46.06% (cracks and Compression 16.07%+ transpiration/weight loss 5.66%+unmarketable/fully damaged 24.33%) was obtained in fruits packed in plastic sacks and lowest loss of 13.63% was recorded in carrot washed with CCa (1%) in washing machine and packed in plastic crate lining with newsprint paper (without MAP) (Fig 96). In this practice, reduction of calculated loss in 7 days retailing period was 70.41%. Findings of this study are in agreement with Fernando (2006) and Rahman (2019). Fernando (2006) reported that the introduction of plastic crate as packaging container in the supply chain reduced postharvest losses of vegetables from 30% to 50% during handling and marketing.

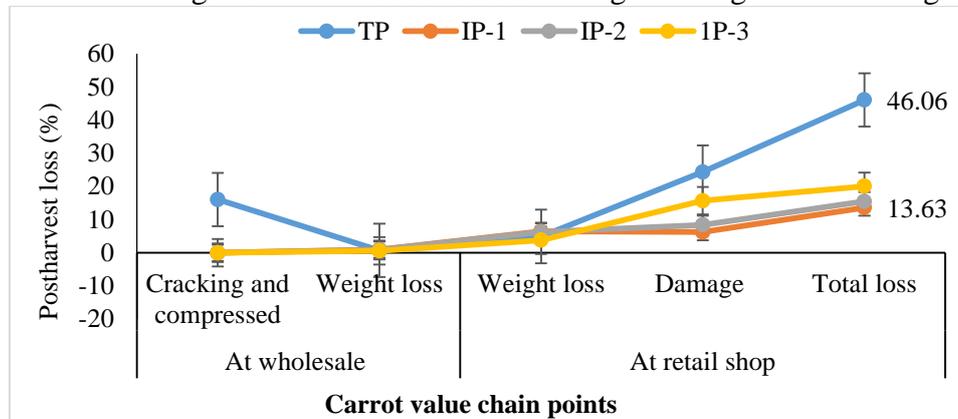


Fig. 96. Efficacy of improved practices in reducing postharvest losses of carrot at different stages of value chain

### Partial budget analysis for estimating profitability of plastic crate with integrated practices

A simple profitability tool such as partial budget analysis was used to analyze the expected changes in returns because of postharvest technology intervention like the use of plastic crates. Assuming that one trader can be handled 1000 kg of carrot per week and that the carrots are packed in plastic sacks during transportation from Bogura to Gazipur wholesale market by a commercial truck. From the results of the present study, the loss of carrot due to mechanical and rotting damage through cracking and compression amounted to 243 kg of carrot per week (Table 34). Partially mechanical damaged carrot, on the other hand was 203 kg, which can be sold at lower price (BDT 30 kg<sup>-1</sup>). In contrast, the use of plastic crates with MAP as packaging container, there was no cracking and compression. However, 96 kg (9.55%) carrot was found partially damage but marketable and thus, the complete loss of carrot was only 63 kg (6.25%) due to transpiration and storage spoilage (Table 34).

Table 34. Effect of packaging containers in reducing postharvest loss of carrots during transportation and subsequent handling.

Treatments	Sound Carrot		Compressed/bruised Carrot		Unmarketable Carrot		Total Price
	Amount (kg)	Price (BDT)	Amount (kg)	Price (BDT)	Amount (kg)	Price (BDT)	
TP: TP+TW+ PS	554	22168	203	6075	243	0	28243 (60.83%)
IP-1: IP+Cl wash+PC without MAP	842	33680	96	2865	63	0	36545 (87.81%)
IP-2: IP+CCa wash+PC without MAP	814	32560	102	3060	84	0	35620 (86.48%)
IP-3: IP+CCa wash in WM+PC with MAP	697	26280	146	4380	157	0	30660 (70.33%)

NB: Retail market price: Good quality Carrot= BDT 40 kg-1; partially damaged Carrot = BDT 30 kg-1. BDT= Bangladeshi taka; PC= Plastic crate; MAP= Modified atmosphere packaging (1% perforated); Figures in the parenthesis indicate the percentage recovery of total price.

**Added returns:** The retail prices of good quality and partially damaged carrots were estimated to BDT 40 and 30 kg-1, respectively. Thus, the estimated gross income with the use of plastic sack would be 28243.00. With integrated improved practice including washing carrots in NaOCl (150 ppm) mixed water mixed water followed by packing in plastic crate lining with clean newsprint paper, the loss was 63 kg, hence the estimated gross income would be BDT 36545. Therefore, the additional gross income per week as a result of performing improved practice would amount to BDT (36545– 28243) =8302.00 BDT and that for washing carrots with calcinated calcium mixed water (1%) and packaging in plastic crate in similar way, the loss was 8.4% and estimated gross income would be BDT 35620. The additional gross income for the latter practices would be BDT= (35620-28243) =7377.00 (Table 35).

**Added cost:** Use of plastic crates entails depreciation cost of plastic crates and opportunity cost of capital invested in purchasing plastic crates. For 1000 kg of Carrots, 50 plastic crates are needed which cost BDT 16,000 @ BDT 320 crate-1. Plastic crates normally last for 10 years. So, the depreciation cost is BDT 1600 year-1 or BDT 30.76 week-1 at 10% depreciation cost. Salvage value is 0. The opportunity cost of capital is based on the assumption that the interest rate is 10% and is computed as follows:

$$I = \frac{[16,000 + (16,000 - 1600)]}{2.0} \times 0.1$$

$$= \text{BDT } 1520 \text{ year-1 or } 29.23 \text{ week-1}$$

Calcinated calcium is an organic compound and it can be used safely. For washing and packaging of 1000 kg carrots, required amount of calcinated calcium (0.01%) would be 500g/500 liter of water, cost 1000.00 and one labour week-1 cost 550 BDT (one person/day cost: BDT 550 day-1). Total cost for washing practices would amount to BDT 1550.

The reduced cost in terms of labour for sorting carrots due to mechanical damage and postharvest spoilage or rotting with the use of plastic sack was BDT 1100 (2 man-day week-1 at BDT 550 day-1). With an additional gross income of BDT 7377 week-1 plus reduced labour cost of BDT 1100 week-1, one small trader who uses plastic crate will gain an additional weekly income of BDT (8477-1610) =BDT 6867 as shown in Table 35.

Table 35. Partial budget analysis for testing the profitability of CCa-washing and plastic crate packing of carrot (with 100% reduction in loss at wholesale level).

A. Total gain (BDT)		B. Total loss (BDT)	
Added income:		Added cost:	
Additional gross income	7377.00	Depreciation	30.76
		Opportunity cost of capital	29.23
		Cost for sanitizer and labour	1550.00
Reduced cost			
Savings in labour for sorting	1100.00		
Total A	8477.00	Total B	1610.00
Additional weekly income = BDT (8477.00 – 1610.00) = BDT 6867.00			



Fig. 97. Pictorial view of carrots indicating had higher shelf life (10 days) and retained good quality of carrots in IP including NaOCl and CCa washing and packing in PC without MAP

Results of this study showed that carrots could be washed properly and safely with 0.01% calcinated calcium through washing machine. Plastic crate lining with newsprint paper was the most suitable container in which carrot could be packed and transported to distant market safely. Thus, physical damage could be avoided maximum and subsequent decay and postharvest losses might be prevented with integration of improved practices (IP) including CCa washing and plastic crate packaging.

#### d) Cauliflower:

### Technical and Economic Feasibility of Improved Postharvest Handling Practices in Cauliflower Value Chain

#### Quality Evaluation

Usually, the good quality cauliflower are chosen by looking it's curd compactness and appearance and non-existence of quality defects such as curd lossening, presence of spots and signs of blemish or rotting on curd and withering and discoloration. Considering the facts, these were determined or assessed and is shown below.

**Firmness:** Compactness, in other words, firmness is an important quality assessment criterion that influence on consumer's decision in buying of fresh cauliflower from a retail outlet. Firmness of cauliflower in different treatments is shown in Fig. 98. On the day of arrival at destination of Gazipur from Bogura Pack house site, the highest firmness (1.08 kg-f) was recorded from the cauliflower curds those were covered by its's face with newsprint paper and packed in plastic bag (Fig. 98) to be dispatched. It decreased gradually with extend of time and down to 0.98 kg-f on 5 days after harvesting. The retention of firmness was comparatively higher (1.94 kg-f) in the cauliflowers those were packed in plastic crate whether it kept in MAP or perforated (1%) polyethylene bag or covered the curd face with newsprint paper (Fig. 98).

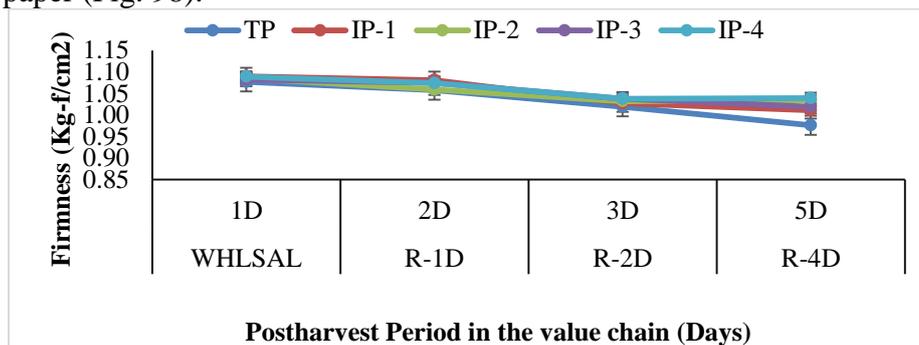


Fig. 98. Firmness of cauliflower in different treatments during 5-days postharvest period

**Curd loosening:** Compactness of cauliflower curds were found to be reduced with progression of storage or selling time. It had influence on consumer's choice. Considering the point, incidence of compactness lost, in other word, loosening of curds was observed and is shown as percentage in Fig 99. It was high for the cauliflowers packed in synthetic netted bag. About 40% curds were found be loosened in synthetic netted bag packaging after 3 days of harvesting. It became 70% on 5days. This type of incidence was less in the cauliflowers in plastic crate with MAP (Fig. 99)

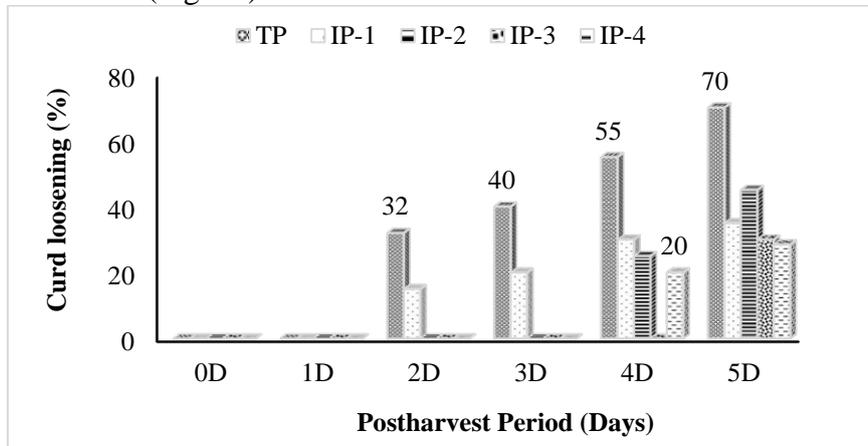


Fig. 99. Incidence of curd loosening of cauliflower during 5-days postharvest period  
 TP=Traditional practices, IP=Improved practices. D=Day: TP:TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP)  
 NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

**Blemish and spots:** Black and brown type blemish and spots were found on cauliflower curd with advancement of storage or display time. The incidence (%) of blemish and spots is shown in Fig. 100. It was high for the cauliflowers those were packed in synthetic netted bag. About 37.5% of curds in synthetic netted bag had spots and blemish at retailer's shop after 3days of harvesting. It was less in the curds in plastic crate. Though the blemish on curds in MAP was less than Non-MAP packaging of curd with newsprint covering at 3rd day, it became higher afterwards (Fig. 100) probably because of excessive accumulation of moisture inside MAP.

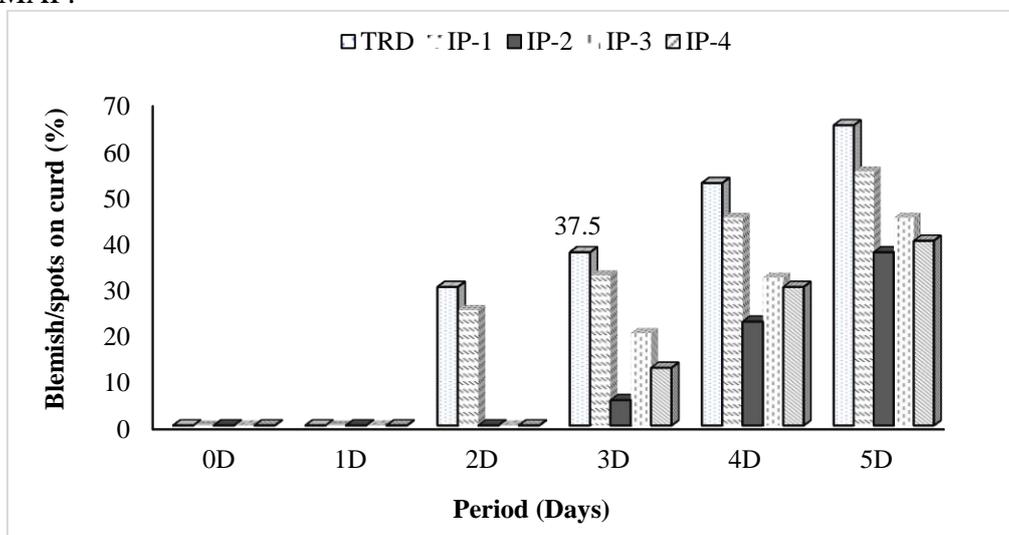


Fig. 100. Incidence of blemish and spots of cauliflower during 5-days postharvest period

**Decay/Rotting:** Decay due to biotic or abiotic factor is one of the limitations in maintenance quality of fresh vegetables in postharvest chains. In this study, higher incidence of decay was observed in the cauliflowers which were packed in synthetic netted bag whether the curd face was covered by newsprint paper or kept the whole cauliflower in perforated polyethylene bag (Fig. 101). The rotting incidence was recorded as 30% for the curds covered by newsprint paper and packed in synthetic netted bag on 3<sup>rd</sup> day. It was 35.5% for the curds those were kept in perforated polyethylene bag (1%) inside the same type plastic sack on on 3<sup>rd</sup> day. On the other hand, there were no signs of rotting on the curds in plastic crate within 3<sup>rd</sup> days of harvesting. More or less decay was found in the curds for all of the treatments except the curds covered by newsprint paper and packed in plastic crate on 4<sup>th</sup> day (Fig. 101). Higher incidence of decay after 3 days in traditionally packed cauliflowers might be attributed mostly due to predisposing with mechanical damage during handling and transportation. Cauliflowers packed in IP had the less decay probably because of having less or almost nil mechanical damages.

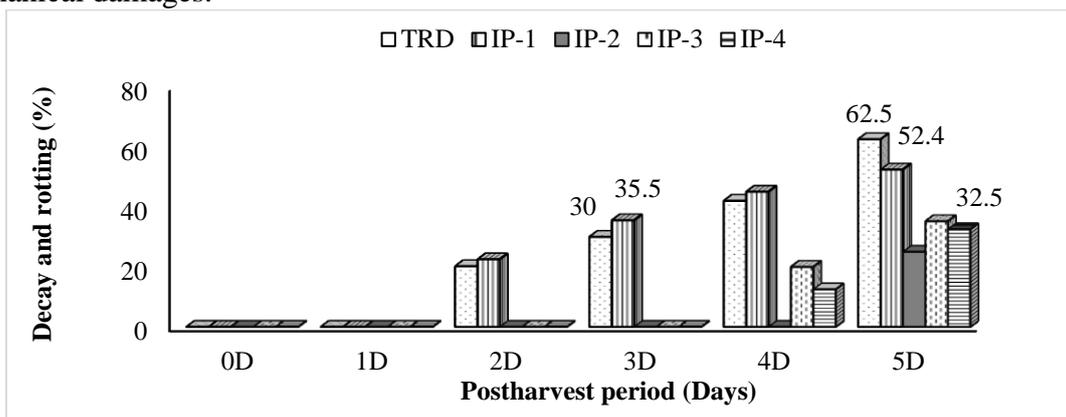


Fig. 101. Incidence of decay and rotting of cauliflowers in 5-days postharvest period



Fig 102. Pictorial view (clockwise) showing blemish and spots and decay in the cauliflowers: a. cauliflower curd packed in SNB in TP (on the day of arrival from pack house site) b. blemish and decay found in the curds packed in SNB in TP (on 4 days) c. Curds covered by newsprint paper and packed in PC (on the day of arrival) d. No spots and decay were found in the curds covered by NPP and packed in PC in IP-2 (till 4 days).

**Nutritional Status:** TSS (%), titratable acidity (%) and total sugar (%) of cauliflower curds are presented in Table 36. The TSS (%) and titratable acidity (%) decreased and total sugar (%) increased with progression of time (Table 36). There was no significant difference among the treatments in changes of TSS (%), titratable acidity (%) and total sugar content of cauliflower curds during 5-days of storage or selling period (Table 36).

Table 36. Total soluble solid, titratable acidity (%) and total sugar content of cauliflower in traditional and improved postharvest practices in 5-days period

Treatments	TSS (%)			Titratable acidity (%)			Total sugar (%)		
	1D	3D	5D	1D	3D	5D	1D	3D	5D
TP	5.41	5.31	5.24	0.55	0.54	0.65	19.74	18.57	18.32
IP-1	5.43	5.37	5.25	0.55	0.52	0.69	19.26	18.68	18.28
IP-2	5.39	5.28	5.26	0.54	0.56	0.68	19.39	18.74	18.59
IP-3	5.45	5.34	5.27	0.56	0.56	0.67	19.09	18.62	18.14
IP-4	5.46	5.36	5.25	0.55	0.58	0.65	18.67	17.67	17.25
LS (%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

1D=One day, 3D=3 days, and 5D=5days, at retail shop.

TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

**Marketability:** Marketability of cauliflowers in different integrated practices is shown in Fig. 103. It was observed that the marketability preference was dependent on retaining compactness and freshness of curds along with less incidence of quality defects like loosening and decay or rotting and withering of petioles parts under leaves, accordingly the preference score remained acceptable more than 4 days for the cauliflowers those were packed in plastic crates with MAP or without MAP but covered the curd face with clean newsprint paper (Fig. 103). Initially, cauliflowers those were kept in perforated polyethylene bag and packed in plastic crate also had higher marketability but lost scores earlier than those of covered with newsprint paper or MAP packaging (Fig. 103). In their report, Larsen and Hagen (2016) mentioned that ‘realistic storage’ including 3 days at room temperature, had the highest effect on development of black spots (mold) on the cauliflower heads, whereas limited effect was found for the different packaging materials on black spot development, thus, cauliflowers loss their marketability rapidly at ambient condition.

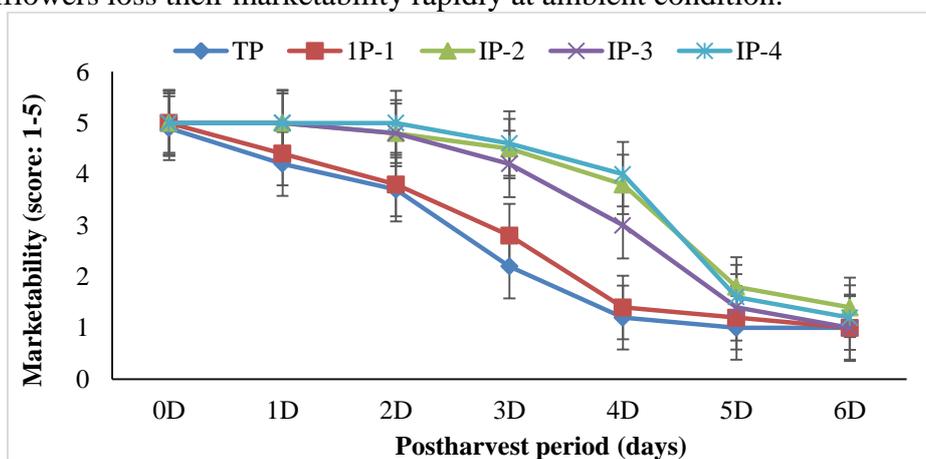


Fig. 103. Marketability of cauliflower during 7-days postharvest period

**Marketable life:** Marketable life of cauliflower in IP along with TP is shown in Fig. 104. Curd covered with newsprint paper and packed in plastic crate had the highest marketable life (5.00 days) followed by those of packed in plastic crate with MAP sheet (4.67 days) and 1% perforated polyethylene bag in plastic crate (4.33%). The lowest marketable life (3.00 days only) was recorded for the cauliflowers covered the curds by newsprint paper and packed in plastic sack, probably because of failure of protecting the curds from bruising and compression during transportation and shifting, subsequently more incidence of blemish and decay during the display period (Fig. 104).

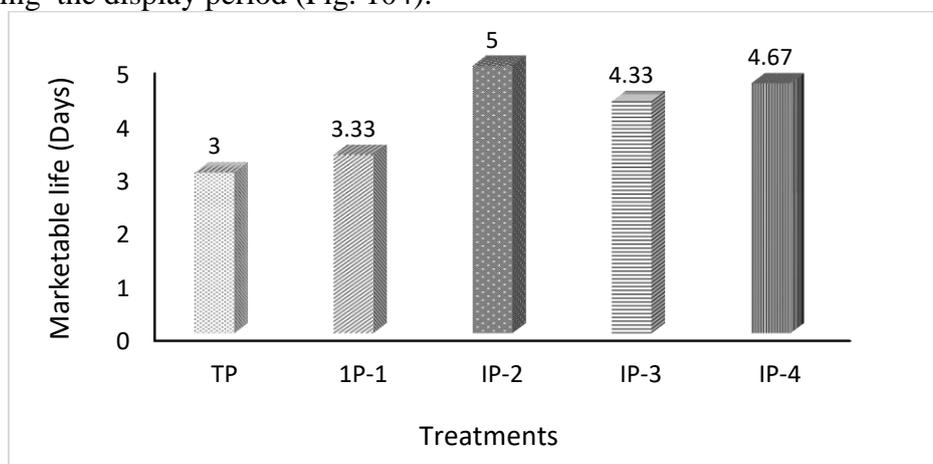


Fig. 104. Marketable life of cauliflower in integrated postharvest practices

**Weight loss:** Weight loss was recorded of 0.46-3.08% at the wholesale market, showing maximum loss in traditional postharvest handling practices where curds were covered with old newspaper and packed in plastic made netted bag to be transported (Table 37). Cauliflower produced with improved production practices and packed in plastic crate prior keeping it in 1% perforated polyethylene bag had the lowest (0.46%) weight loss at wholesale market. It was followed by the integrated treatment wherein trimmed cauliflowers were packed in 1% perforated polyethylene bag in synthetic netted bag. Curds kept under MAP of 1% perforated polyethylene sheet in plastic crate had moderately weight loss (1.02%) and which were covered with newsprint paper in plastic crate had higher (1.77%) but lesser weight loss than that of kept in plastic sack with similar way of newsprint paper covering of curd. Weight loss of fruits might be occurred mainly due to transpiration during transportation and displaying for sale at retail outlets. Larsen and Hagen (2016) obtained 10% weight loss for unpackaged cauliflower till 3 days storage.

Table 37. Weight loss of cauliflower at wholesale market and retail outlets

Treatment	Cumulative weight loss (%)			
	At wholesale market	Day 1 at retail outlet	Day 2 at retail outlet	Day 3 at retail outlet
TRD: TP+NPP+SNB	3.08 a	5.07a	7.1 a	8.91 a
IP-1: IP+PPB+SNB	0.74 d	1.59 c	2.41 c	3.33 c
IP-2: IP+NPP+PC without MAP	1.77 b	2.26 b	3.62 b	4.9 b
IP-3: IP+PPB+PC without MAP	0.46 e	0.93 d	1.31 d	1.93 d
IP-4: IP+PC with MAP (PPS)	1.02 c	2.21 b	3.23 b	4.29 b
Level of significance (%)	0.05	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TRD: Traditional, TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

Similar feature was observed in retailer's shop throughout the display period for 5 days (Fig. 105). Curds those were covered with fresh and new newsprint paper and packed the cauliflowers in plastic crate lost weight relatively higher than those of kept in perforated polyethylene bag in plastic crate. Though the weight loss was comparatively higher in this treatment (IP-4), blemish and decay (%) were nil or very minimum till 3days or even up to 4-days which was mentioned in Fig 96. On the other hand, at 2 days and afterwards, weight loss (%) was less but blemish and decay (%) were high in the curds which were kept in perforated polyethylene bag particularly when packed in synthetic netted bag, Results of this experiment are in agreement with Nasrin *et al.* (2008) who reported that cauliflowers lost maximum weight of 13.3% when kept in unpackaged condition whereas, it was only 3% when kept them in 1% perforated polyethylene bag on day 6 of storage at ambient condition.

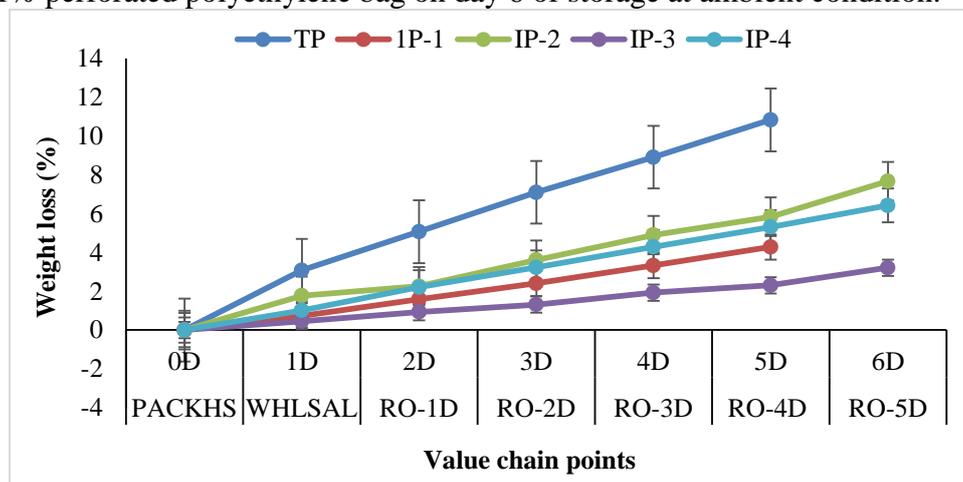


Fig. 105. Weight loss of cauliflower in the value chain;

**Recovery of good quality (sound) fruits at wholesale level:** The recovery of sound (no damage) and mechanically-damaged cauliflower upon arrival at wholesale market is shown in Table 38. Cauliflowers packed in plastic crates had significantly ( $P \leq 0.05$ ) higher recovery of sound curds than those of packed in plastic net bags. Average recovery of sound cauliflowers was found about 98.0%, which handled with IP including MA packaging in PC. IP with curd covering by newsprint paper and packing in PC had also higher recovery (97.4%). On the other hand, it was 65.5% when handled with TP including curd covering by newsprint paper and packing in synthetic netted bag (Table 38).

Table 38. Proportion of sound and mechanically damaged cauliflower at wholesale market.

Treatments	Sound cauliflower	Mechanically damaged cauliflower (%)	
		Bruising and/or Compression	Cracks
TRD: TP+NPP+SNB	65.5 c	20.3 a	15.2 a
IP-1: IP+PPB+SNB	79.2 b	8.3 b	12.5 a
IP-2: IP+NPP+PC without MAP	97.4 a	2.6 c	0 b
IP-3: IP+PPB+PC without MAP	98.0 a	2.0 c	0 b
IP-4: IP+PC with MAP (PPS)	98.2 a	1.8 c	0 b
Level of significance (%)	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TRD: Traditional, TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

At wholesale level, the incidence of mechanical damage in cauliflowers in the form of compression and crack was found 20.3% and 15.2%, respectively when packed in the synthetic netted bags. In case of perforated polyethylene bag in SNB, 12.5% cauliflowers were found to be cracked and 8.3% curds had signs of compression. On the other hand, no incidence of crack or severe bruising and compression was found in the cauliflowers which were packed in PC with MAP or without MAP but covering the curd with fresh newsprint paper (Table 38).

**Recovery of sound cauliflowers at the retail outlets:** Integrated IP comprising plastic crates as packaging container with MAP, the recovery of sound and highly marketable cauliflowers amounted to 94.2% on day 1 (Table 39), which decreased slightly on day 2, reaching 90.2 and 71.2%, respectively. Similar feature was observed for the cauliflowers curds which were covered with new newsprint paper in PC. (Table 39). In contrast, the recovery of sound cauliflower which handled with TP and packed in synthetic netted bags was 74.2%, 51.8% and 41.5% on day 1, day 2 and day3, respectively, which was significantly ( $P<0.05$ ) lower than those of IP with MAP or newsprint paper covering curds. Among the four treatments, integrated IP including plastic crate with newsprint paper curd covering technique showed significantly ( $P\leq 0.05$ ) the highest recovery of sound cauliflower during 3-day retail display which was followed by plastic crate without MAP (Table 39).

Table 39. Proportion of sound cauliflower at retail outlets.

Treatments	Sound cauliflower at retail outlets (%)		
	Day 1	Day 2	Day 3
TP+NPP+SNB	61.5 c	48.2 d	37.5 c
IP+PPB+SNB	74.2 b	51.8 d	41.5 c
IP+NPP+PC without MAP	94.2 a	87.5 a	75.6 a
IP+PPB+PC without MAP	92.6 a	78.2 c	67.5 b
IP+PC with MAP (PPS)	95.2 a	90.2 a	71.2 a
Level of significance (%)	*	*	*

Values in each column followed by the same letter (s) are not differed significantly.

TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

### Postharvest losses:

**Incidence of damaged cauliflowers at retail outlets:** Incidence of damage were counted altogether and found that significantly ( $P\leq 0.05$ ) the highest fully damaged cauliflowers amounted 18.2% for the cauliflowers handled with TP (Table 40). The incidence of damage in traditionally handled cauliflowers sharply increased, reaching 24.5% on day 2 and 45.2% on day 3 at retail shop. This damage was found to be appeared with blackish and brown spots on curds and decay and rotting of the curds probably because of predisposing to microorganism due to higher initial bruising and compression injury during transportation and handling. On the contrary, significantly ( $P<0.05$ ) the lowest (6.8%) damaged cauliflowers were recorded in IP with PC packing wherein curds were covered/wrapped with clean NPP. PC with MAP of 1% PPS had 8.4% fully damaged curds and that of 1% PPB packaging had 11.3% fully damaged curds on day 3. Partially damaged cauliflowers were considered as partially marketable and recorded as 20.3% in TP on day 1 which increased up to 27.3% on day 2 but decreased on day 3 (45.2%) as of the progression of brown spots and decay in some curds and then they were considered as fully damaged (Table 41). On the other

hand, it increased in IP with time due to appearance of brown spots and decaying signs in some sound curds, however less in count as considered as partially damaged (Table 41).

Table 40. Fully damaged cauliflower (blemished+ spotted+ decayed/rotten) at retail display.

Treatments	Fully damaged cauliflower at retail outlets (%)		
	Day 1	Day 2	Day 3
TP+NPP+SNB	18.2	24.5	45.2
IP+PPB+PNB	15.3	20.9	41.8
IP+NPP+PC without MAP	0	0	6.8
IP+PPB+PC without MAP	0	0	11.3
IP+PC with MAP (PPS)	0	0	8.4
Level of significance (%)			

TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

Table 41. Partially damaged cauliflower at retail display

Treatments	Partially damaged cauliflower at retail outlets (%)		
	Day 1	Day 2	Day 3
TP+NPP+SNB	20.3 a	27.3 a	17.3
IP+PPB+SNB	10.5 b	27.3 a	16.7
IP+NPP+PC without MAP	5.8 c	12.5 c	17.6
IP+NPB+ PC	7.4 c	21.8 b	21.2
IP+PC with PPS MAP	4.8 c	9.8	20.4
Level of significance (%)	*	*	

Values in each column followed by the same letter (s) are not differed significantly.

TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

**Recovery of marketable cauliflowers at retail outlets:** The proportion of total marketable cauliflowers handled with IP and packed in PC with MAP remained 100% on day 1 and day 2 (Table 42). However, it decreased slightly on day 3 (Table 42). In contrast, cauliflowers handled with TP and packed in plastic bag exhibited significantly ( $P \leq 0.05$ ) the lowest proportion of marketable fruits compared to those with integrated IP. The recovery of marketable cauliflowers in TP including synthetic netted bag was 81.8% on day 1, which decreased into 75.5% on day 2 and 54.2% on day 3 at retail outlets. Total marketable fruits consisted of sound cauliflowers and fruit exhibiting slight compression and abrasion.

Table 42. Total marketable cauliflower at retail outlets.

Treatments	Total marketable cauliflower at retail outlets (%)		
	Day 1	Day 2	Day 3
TP+NPP+SNB	81.8	75.5	54.8
IP+PPB+SNB	84.7	79.1	58.2
IP+NP+PC without MAP	100	100	93.2
IP+NPB+ PC	100	100	88.7
IP+PC with PPS MAP	100	100	91.6
Level of significance (%)	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

**Total losses in whole value chain:** Fig. 106 shows the proportion of postharvest losses of cauliflower at each stage of value chain. At wholesale level, there were almost no unmarketable fruits, which handled with IP including washing and plastic crate packing with or without MAP. In contrast, 15.2 % cauliflowers were found to be cracked when they were handled with TP with using newsprint paper wrapping of curds and packing with plastic netted sac. Thus, the cumulative losses of cauliflowers in the entire value chain were calculated and showed that the highest total loss of 45.59% (cracks 15.2 % + transpiration/weight loss 8.91%+decay damage 21.9%) was obtained in fruits packed in plastic bags and lowest loss of 6.8% was recorded in cauliflower packing in plastic crate with covering of curds by fresh and clean newsprint paper during transportation and subsequent handling and displaying retail shop for at 3-days period (Fig 97). Findings of this study are in agreement with Fernando (2006) and Rahman (2019). Fernando (2006) reported that the introduction of plastic crate as packaging container in the supply chain reduced postharvest losses of vegetables from 30% to 50% during handling and marketing.

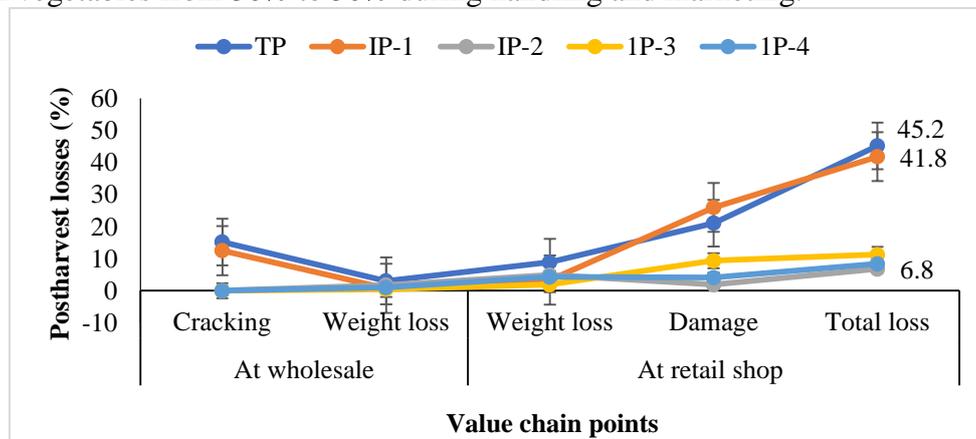


Fig. 106. Efficacy of improved practices in reducing postharvest losses of cauliflower at different stages of value chain

Integrated treatments of improved practices reduced postharvest losses of cauliflower by from 7.52% to 84.96% (Fig. 98). The highest loss reduction (84.96%) was calculated from IP including newspaper covering of the curd face and packing in plastic crate without MAP. Which was followed by without newspaper covering and curds packed in PC with 1% perforated polyethylene sheet. Reduction of losses was less in the cauliflower curds those were kept in 1% perforated thin polyethylene bag and packed in synthetic netted bag probably because of high incidence of blemish and brown spots. This damage might be due to the resultant of physical damage happened in the curds during transportation from pack house site to city market and higher incidence of subsequent decay probably due to higher infestation of diseases.

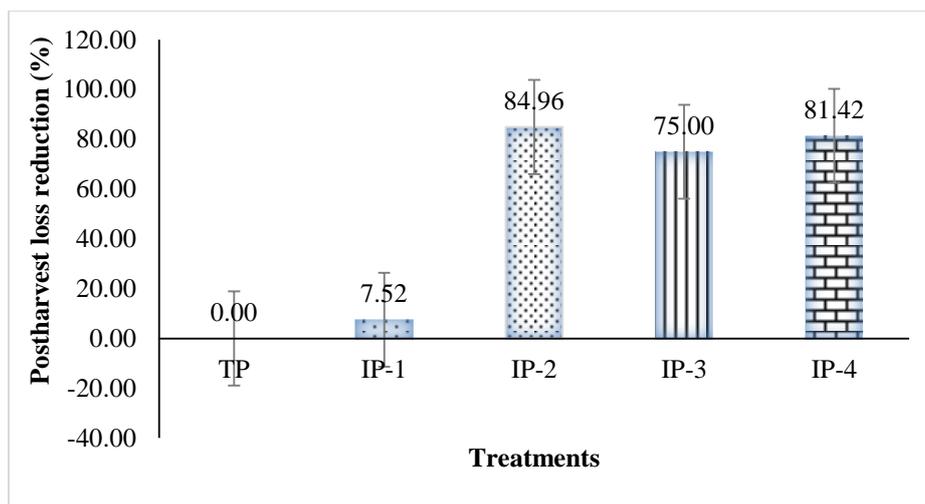


Fig. 107. Postharvest loss reduction of cauliflower with integration of improved practices



Fig. 108. Pictorial view showing cauliflower curd on 3 days after at retail shop (4 days after harvesting): a. higher softness development in the curds kept in 1%perforated polyethylene bag b. Appeared of few spots on the curds packed in PC with MAP (under 1% perforated polyethylene sheet).

### Partial budget analysis for estimating profitability of using plastic crate with integrated practices

A simple profitability tool such as partial budget analysis was used to analyze the expected changes in returns because of postharvest technology intervention like the use of plastic crates. Assuming that one trader can be handled 1000 kg of cauliflower per week and that the cauliflowers are packed in plastic bags during transportation from Bogura to Gazipur wholesale market by a commercial truck. From the results of the present study, the loss of cauliflower due to mechanical and subsequent quality damage like decay and curd loosening through cracking and compression amounted to 45.22%, which is equivalent to 452 kg of cauliflower per week (Table 43). Partially mechanical damaged cauliflower, on the other hand was 173 kg, which can be sold at lower price (BDT 30 kg<sup>-1</sup>). In contrast, the use of plastic crates with MAP as packaging container, there was less mechanical damage. However, 176-212 kg (17.6-21.2%) cauliflower was found partially damage but marketable and thus, the complete loss of cauliflower was only 68-113 kg due to transpiration and storage spoilage.

Table 43. Effect of packaging containers in reducing postharvest loss of cauliflowers during transportation and subsequent handling.

Treatments	Sound cauliflower		Compressed/ bruised cauliflower		Unmarketable cauliflower		Total Price
	Amount (kg)	Price (BDT)	Amount (kg)	Price (BDT)	Amount (kg)	Price (BDT)	
TP+NPP+SNB	375	15000	173	4325	452	0	19325(48.31%)
IP+PPB+SNB	415	16600	167	4175	418	0	20775(51.94%)
IP+NPP+PC without MAP	756	30240	176	4400	68	0	34640(86.6%)
IP+PPB (MAP)+ PC	675	27000	212	5300	113	0	32300(80.75%)
IP+PC with PPS (MAP)	712	28480	204	5100	84	0	33580(83.95%)

NB: Retail market price: Good quality cauliflower= BDT 40 kg-1; partially damaged cauliflower = BDT 30 kg-1. BDT= Bangladeshi taka; Figures in the parenthesis indicate the percentage recovery of total price.

TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP) TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

**Added returns:** The retail prices of good quality and partially damaged cauliflowers were estimated to BDT 40 and 30 kg-1, respectively. Thus, the estimated gross income with the use of plastic net bag would be 19325. With the use of plastic crate without MAP, the loss was only 6.8% kg, hence the estimated gross income would be BDT 34640. Therefore, the additional gross income per week as a result of using plastic crate without MAP but covering the curds newsprint paper (Table 36) would be amounted to BDT =(34640– 19325) = 15315.00 BDT and that for using plastic crate with of 1% PPS and 1% PPB would be BDT =(33580-19325) =14255.00 and (32300-19325)= 12975/00, respectively (Table 44).

**Added cost:** Use of plastic crates entails depreciation cost of plastic crates and opportunity cost of capital invested in purchasing plastic crates. Average holding capacity of common plastic crate was 10 kg for cauliflowers. For 1000 kg of cauliflowers, 100 plastic crates are needed which cost BDT 32,000 @ BDT 320 crate-1. Plastic crates normally last for 10 years. So, the depreciation cost is BDT 3200 year-1 or BDT 61.54 week-1 at 10% depreciation cost. Salvage value is 0. The opportunity cost of capital is based on the assumption that the interest rate is 10% and is computed as follows:

$$I = \frac{[32,000 + (32,000 - 3200)]}{2.0} \times 0.1$$

$$= \text{BDT } 3040 \text{ year-1 or } 58.46 \text{ week-1}$$

For wrapping and packing of 1000 kg cauliflower, required two labour week-1 cost 1650 BDT (one man's day cost of BDT 550 day-1). Total cost for wrapping and packing practices would amount to BDT 3300.

The reduced cost in terms of labour for sorting of cauliflowers due to mechanical damage and decay or rotting and other quality deterioration with the use of synthetic net bag was BDT 1100 (2 man-day week-1 at BDT 550 day-1). With an additional gross income of BDT 15,315 week-1 plus reduced labour cost of BDT 1100 week-1, one small trader who uses plastic crate and newsprint paper covering of curds will gain an additional weekly income of BDT 12,955 as shown in table 44.

Table 44. Partial budget analysis for testing the profitability of using plastic crates without MAP for cauliflower (with 100% reduction in loss at wholesale level).

A. Total gain (BDT)		B. Total loss (BDT)	
Added income:		Added cost:	
Additional gross income	15315.00	Depreciation	61.54
		Opportunity cost of capital	58.46
		Cost for wrapping and packing	3300.00
Reduced cost			
Savings in labour for sorting	1100.00		
Total A	16415.00	Total B	3420.00
Additional weekly income = BDT (16415.00 – 3420.00) = BDT 12955.00			

Similarly, the profitability of using plastic crates with MAP of 1% PPS for cauliflower packing and transportation to distant market till the end of 3 days retailing (with 100% reduction in loss at wholesale level) would be BDT= (14255+1100)–3420=11935.00 and that for using 1% PPB in plastic crate was BDT= (12975+1100)-3420=10655.00.

Results of this study showed the primary efficacy of IP with plastic crate packaging of cauliflower however; need to be designed and developed comparatively bigger size crates from the view point of more profitability and trade.

#### e) Brinjal:

#### Feasibility of Improved Practices in Maintenance of quality and Reducing Postharvest Losses of Brinjal in the Value Chain

##### Quantitative Evaluation

**Weight loss:** Weight loss was recorded of 0.75-1.31% at the wholesale market, showing maximum loss in brinjals packed in plastic sack through traditional practices where brinjals were produced with traditional production practices and were not sorted and washed after harvesting (Table 45). Brinjal produced with improved production practices and sorted and washed with calcinated calcium after harvesting and packed in plastic crate with 1% perforated polyethylene had the minimum weight loss at wholesale market. It was 0.66% when the brinjals was washed in washing house and 0.75% while washed them through washing machine (Table 45). Weight loss of fruits might be occurred mainly due to transpiration during transportation and displaying for sale at retail outlets.

Table 45. Weight loss (quantitative loss) of brinjal at wholesale market and retail outlets.

Treatment	Cumulative weight loss (%)			
	At wholesale market	Day 1 at retail outlet	Day 2 at retail outlet	Day 3 at retail outlet
TRD: TP+Without wash+ Plastic sack	1.31 a	2.92 a	4.65 a	6.42 a
IP-1: IP+ CW wash+ PC without MAP	0.84 b	2.36 b	4.14 b	6.16 b
IP-2: IP+CCa wash+PC with MAP	0.66 c	1.56 c	2.96 c	4.61 c
IP-3: IP+CCa wash in WM+PC with MAP	0.75 c	1.75 c	3.16 c	4.83 c
Level of significance (%)	0.05	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TRD=Traditional, TP=Traditional practices, IP=Improved practice, CW=Clean water, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP=Modified atmosphere packaging (1% perforated polyethylene sheet).

Similarly, the maximum weight loss of 2.92% occurred on day 1 at retail outlet for plastic sack, which increased up to 6.42% on day 3. Brinjals handled with improved practices comprising packed in PC with MAP showed consistently lowest weight loss at each stages of value chain, exhibiting 2.96% on day 2 and 4.61% on day 3 at retail outlet. Brinjals washed with washing machine and packed in similar way also had lower weight losses. Fig. 109 also shows the lower weight loss of brinjals in improved practices included PC with MAP till the whole period of 7 days period.

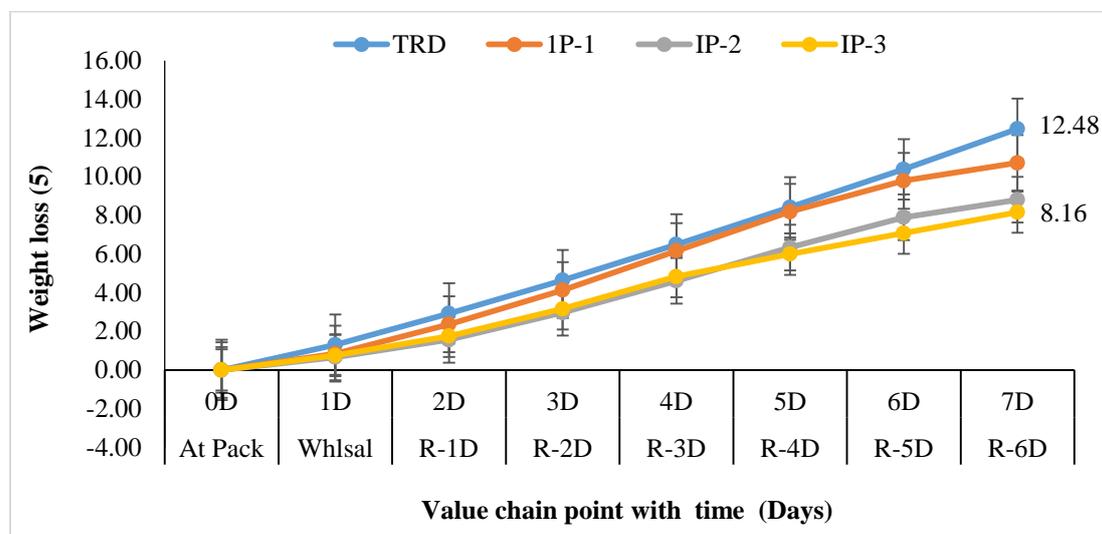


Fig. 109. Weight loss of brinjal in the value chain

Findings of this study showed the efficacy of MA packaging of brinjal in reducing the weight loss compared to other packaging containers. Results of this experiment are in agreement with Nasrin *et al.* (2008) who reported that brinjals lost maximum weight of 13.3% when kept in unpackaged condition whereas, it was only 3% when kept them in 1% perforated polyethylene bag on day 6 of storage at ambient condition.

**Recovery of good quality (sound) fruits at wholesale level:** The recovery of sound (no damage) and mechanically-damaged brinjal upon arrival at wholesale market is shown in table 46. Brinjals packed in plastic crates had significantly ( $P \leq 0.05$ ) higher recovery of sound fruits than those packed in plastic sacks. Average recovery of sound brinjals was found about 98.0%, which handled with IP and packed in PC with MAP. PC without MAP had also higher recovery (97.0%). On the other hand, it was 51.2% when handled with TP.

Table 46. Proportion of sound and mechanically damaged brinjal at wholesale market.

Treatments	Sound brinjal	Mechanically damaged brinjal (%)		
		Bruising	Compression	Cracks
TP+Without wash+ Plastic sack	51.2 b	0	39.33 a	8.67 a
IP+CW wash+PC without MAP	97.0 a	0	0 b	0 b
IP+CCa wash+PC with MAP	98.0 a	0	0 b	0 b
IP+CCa wash with WM+PC with MAP	97.6 a	0	0 b	0 b
Level of significance (%)	0.05	NS	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP=Traditional practices, IP=Improved practice, CW=Clean water, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP=Modified atmosphere packaging (1% perforated polyethylene sheet).

At wholesale level, the incidence of mechanical damage in brinjals in the form of compression and crack was found 39.33% and 8.67%, respectively when packed in the plastic sacks. On the other hand, no incidence of mechanical damage was found in brinjals that packed PC with MAP at wholesale level (Table 46). Plastic crates are rigid and highly recommended as packaging containers for tomato and other fresh vegetables since they provide adequate protection against compression damage (Esguerra *et al.*, 2016; Rapusas and Rolle, 2009).

**Recovery of sound brinjals at the retail outlets:** Integrated IP comprising washing of brinjal with CCa mixed water in washing house and using of plastic crates as packaging container with MAP, the recovery of sound and highly marketable brinjals amounted to 90.4 on day 1 which decreased slightly on day 2, reaching 88.6 and 72.6%, respectively (Table 47). Similar feature was observed for the brinjals which were washed through washing machine and packed in PC with MAP (Table 47). In contrast, the recovery of sound brinjals which handled with TP and packed in plastic sacks was 48.6, 35.3% and 28.5 on day 1 and day 2, respectively, which was significantly ( $P<0.05$ ) lower than IP. Among the four treatments, integrated IP including plastic crate with MAP showed significantly ( $P\leq 0.05$ ) the highest recovery of sound brinjal during 3-day retail display which was followed by plastic crate without MAP (Table 47).

Table 47. Proportion of sound brinjal at retail outlets.

Treatments	Sound brinjal at retail outlets (%)		
	Day 1	Day 2	Day 3
TP+Without wash+ Plastic sack	48.6 b	35.3 c	28.5 c
IP+CW wash+PC without MAP	87.6 a	75.4 b	61.5 b
IP+CCa wash+PC with MAP	90.4 a	88.6 a	72.6 a
IP+CCa wash with WM+PC with MAP	88.6 a	86.2 a	70.2 a
Level of significance (%)	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP=Traditional practices, IP=Improved practice, CW=Clean water, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP=Modified atmosphere packaging (1% perforated polyethylene sheet)

**Incidence of mechanically damaged brinjals at retail outlets:** Mechanical damages were counted altogether and found that significantly ( $P\leq 0.05$ ) the highest incidence of mechanically damaged brinjals amounted 42.6% for the fruits handled with TP that caused by bruising and/or compression effect during transportation and subsequent handling (Table 48). The incidence of mechanical damage in traditionally handled brinjals sharply increased over night, reaching 55.2% on day 2 and 61.5% on day 3 at retail outlets. On the other hand, significantly ( $P<0.05$ ) the lowest mechanically damaged brinjals were found in IP brinjals that was washed in calcinated calcium mixed water in washing house and packed in PC with MAP showing 9.2, 11.2 and 27.2% on days 1, day 2 and day 3, respectively (Table 48). The treatment of IP including PC packing with IP reduced the mechanical damage by 55.77% over traditional practices with plastic sack packing on Day 3 at retail shop. Results of another handling trial of brinjal also showed a reduction of compression damage from 52.7 to 32.0% and 37.4 to 23.3% for ‘Casino’ and ‘Black Ninja’ varieties, respectively when transported in plastic crates (PHTRC, 2004).

Table 48. Mechanically damaged brinjal (compressed + bruised) at retail display.

Treatments	Mechanically damaged brinjal at retail outlets (%)		
	Day 1	Day 2	Day 3
TP+Without wash+ Plastic sack	42.6 a	55.2 a	61.5 a
IP+CW wash+PC without MAP	12.1 b	23.2 b	39.3 b
IP+CCa wash+PC with MAP	9.2 c	11.2 c	27.2 d
IP+CCa wash with WM+PC with MAP	10.8 c	12.9 c	29.8 c
Level of significance (%)	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

TP=Traditional practices, IP=Improved practice, CW=Clean water, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP=Modified atmosphere packaging (1% perforated polyethylene sheet).

**Recovery of marketable brinjals at retail outlets:** The proportion of total marketable brinjals handled with IP and packed in PC with MAP remained 100% on day 1 and day 2 (Table 49). However, it decreased slightly on day 2 when PC without MAP was used as packaging container. In contrast, brinjals handled with TP and packed in plastic sack exhibited significantly ( $P \leq 0.05$ ) the lowest proportion of marketable fruits compared to those with integrated IP. The recovery of marketable brinjals followed TP and packed in plastic sack was 88.5% on day 1, which decreased rapidly, reaching 78.2% on day 2 and 69.5% on day 3 at retail outlets. Total marketable fruits consisted of sound brinjals and fruit exhibiting slight compression and abrasion. The incidence of slightly compressed brinjal was also higher in plastic sacks compared to those brinjals, which packed in PC.

Table 49. Total marketable brinjal at retail shops

Treatments	Total marketable brinjal at retail outlets (%)		
	Day 1	Day 2	Day 3
TP+Without wash+ Plastic sack	88.5 b (42.6)	78.2 b (55.2)	69.5 c (61.5)
IP+CW wash+PC without MAP	100 a (12.1)	95.3 a (23.2)	88.6 b (39.3)
IP+CCa wash+PC with MAP	100 a (9.2)	100 a (11.2)	97.2 a (27.2)
IP+CCa wash with WM+PC with MAP	100 a (10.8)	98.2 a (12.9)	95.5 a (29.8)
Level of significance (%)	0.05	0.05	0.05

Values in each column followed by the same letter (s) are not differed significantly.

Figures in the parenthesis are the mechanically damaged but marketable brinjal (%)

TP=Traditional practices, IP=Improved practice, CW=Clean water, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP=Modified atmosphere packaging (1% perforated polyethylene sheet)

### Quality Evaluation

Usually, the freshness of brinjal are chosen by looking its shape and size, colour, appearance, firmnes, and non-existence of quality defects such as peitiole and sepals withering, fruit withering and squeezing, and blemish or rotting creates negative impact to growers' choice. Considering the facts, these were determined or assessed and is shown below.

**Firmness:** Firmness of fruit is an important quality assessment criterion that influence on consumer's decision in buying a fresh commodity. Firmness of brinjal in different treatments is shown in Fig. 101. On the day arrival, the highest firmness (1.45 kg-f) was recorded from the fruits packed in plastic sack (Fig 110). It decreased gradually with extend of time and

down to 0.78 kg-f on 7days after harvesting. The retention of firmness was comparatively higher (0.94 kg-f) in the brinjals packed in plastic crate with MAP (Fig. 101).

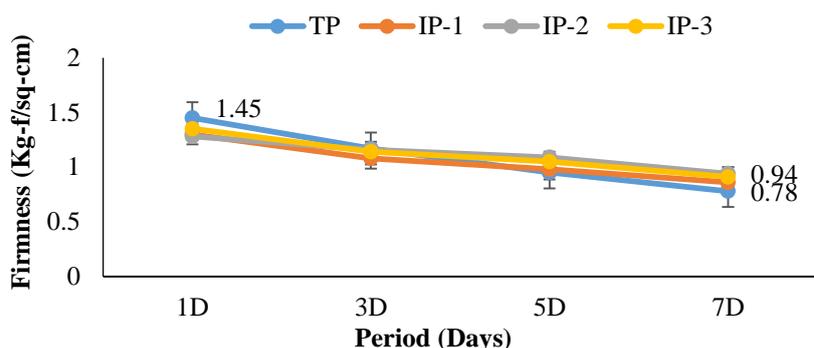


Fig. 110. Firmness of brinjal in different treatments during 7-days retail period

**Biochemical Traits:** TSS (%), titratable acidity (%) and vitamin C (mg/100g) content of brinjal fruits are presented in table 50. The TSS (%) and titratable acidity (%) increased and Vitamin C content (mg/100g) decreased with progression of time (Table 50). The retention of Vitamin C, however, found to be more in the brinjals in improved practices (Table 50). Total soluble solid, titratable acidity (%) and Vitamin C content of brinjal in improved and traditional postharvest practices during 6-days retail period

Treatments	TSS (%)			Titratable acidity (%)			Vitamin C (mg/100g)		
	1D	3D	6D	1D	3D	6D	1D	3D	6D
TP	5.64	5.76	7.12	0.38	0.38 a	0.46 a	12.4	7.4	4.8 b
IP-1	6.22	5.36	6.14	0.35	0.28 b	0.36 b	12.2	8.8	7.6 a
IP-2	6.20	6.06	6.10	0.37	0.30 b	0.44 a	11.6	9.6	5.6 a
IP-3	6.14	5.76	5.94	0.38	0.29 b	0.46 a	11.6	8	5.6 a
LS (%)	NS	NS	NS	NS	**	**	NS	NS	*

Values in each column followed by the same letter (s) are not differed significantly.

TP: Without wash+ Plastic sack packing; IP-1: Calcinated calcium (CCa) wash in washing house+Plastic crate (PC) packing without MAP; IP-2: CCa wash in washing house+PC with MAP; IP-3: CCa wash through washing machine (WM)+PC with MAP

**Petiole and sepals withering:** Withering of petiole and sepals reduced marketable value of brinjal. Petiole and sepals of the brinjals packed in plastic sacks were found be withered earlier than that of the fruits packed in PC with MAP (Fig. 111). This incidence was 4.67 % on 3 days and reached to 16.67% on 7 days in the brinjals in TP. It was 8.64% on 7 days for the brinjals in IP (Fig. 111).

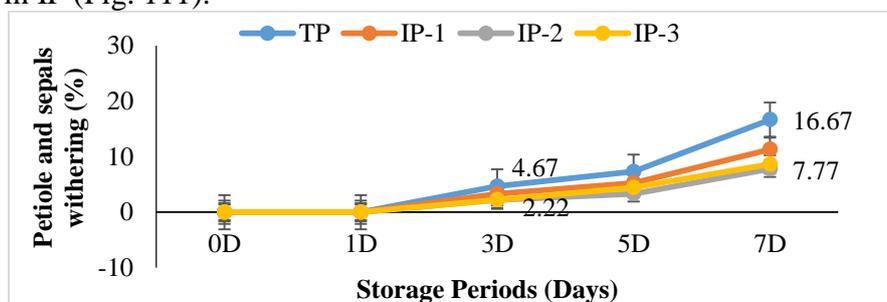


Fig. 111. Incidence of petiole and sepals withering of brinjal during 7-days period

**Fruit softening and squeezing:** Fruit withering and squeezing is another concerned to buy brinjals. Incidence of fruit withering and squeezing is shown in Fig. 112. It was found to be more in the brinjals in TP and less in the fruits in PC with MAP (Fig. 112). The highest

(23.33%) withered and shriveled fruits were recorded in the brinjals in TP on 7th day. It was less (7.44%) in the fruits packed in IP on same day.

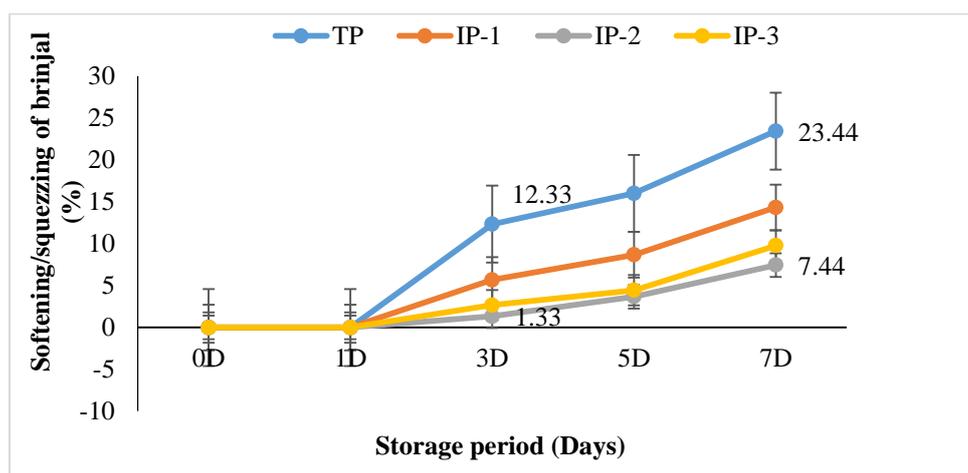


Fig. 112. Incidence of fruit withering and squeezing of brinjal during 7-days period

**Decay/Rotting:** Decay due to biotic or abiotic factor is one of the limitations in maintenance quality of fruits in postharvest chains. In this study, bulk brinjals packed in plastic sack was found to be infested higher in numbers than that of the fruits packed in plastic crate. The highest incidence (19.67%) of decay was observed in the brinjals on 7 day in TP. It was 2.67% for the brinjals washed in CCa and packed in PC with MAP (Fig. 113). Higher incidence of decay after 3 days in traditionally packed brinjals might be attributed mostly due to predisposing with mechanical damage during handling and transportation. Brinjals packed in IP had the less decay probably because of having less or almost nil mechanical damages. Also, CCa might be useful a bit in reducing decay and rotting in IP systems (Fig. 112 & 113. Pictorial view showing in relation to decay and rotting incidence during retail period).

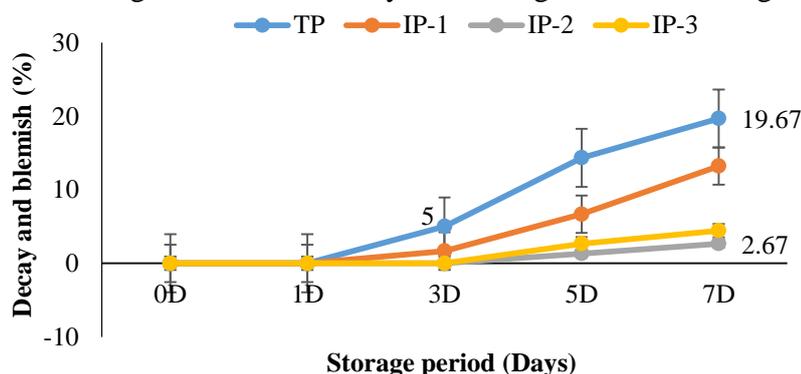


Fig. 113. Incidence of decay and rotting in the brinjals in 7-days postharvest period



Fig. 114. Pictorial view (clockwise) of showing brinjal handled with TP and IP: i. a & b. TP, ii. a. & b. IP including water wash and packing in PC lining with newsprint paper; left site: on the day of arrival from pack house to city market; right side: after 7 days of harvesting i.e. at retail day 6, for each of the mentioned treatment.



Fig. 115. Pictorial view (clockwise) of showing brinjal handled with IP: iii. a. & b. IP including CCa wash and packing in PC with MAP iv. a. & b. IP including CCa wash in washing machine and packing in PC with MAP; left site: on the day of arrival from pack house to city market; right side: after 7 days of harvesting i.e. at retail day 6, for each of the mentioned treatment.

## Storage Studies

**Marketability:** Marketability of brinjals in different integrated practices is shown in Fig. 116. It was observed that the marketability preference was dependent on retaining firmness and freshness of fruits along with less incidence of quality defects like squeezing or softening and decay or rotting of fruits and withering of petioles and sepals, accordingly the preference score remained acceptable up to 7 days (Fig. 116) for the brinjals those were washed with CCa (1%) mixed water and packed in PC with MAP. It lost marketability after five days of storage (Fig. 116) for the brinjals those were not washed and packed in plastic sacks i.e. in traditional management practices.

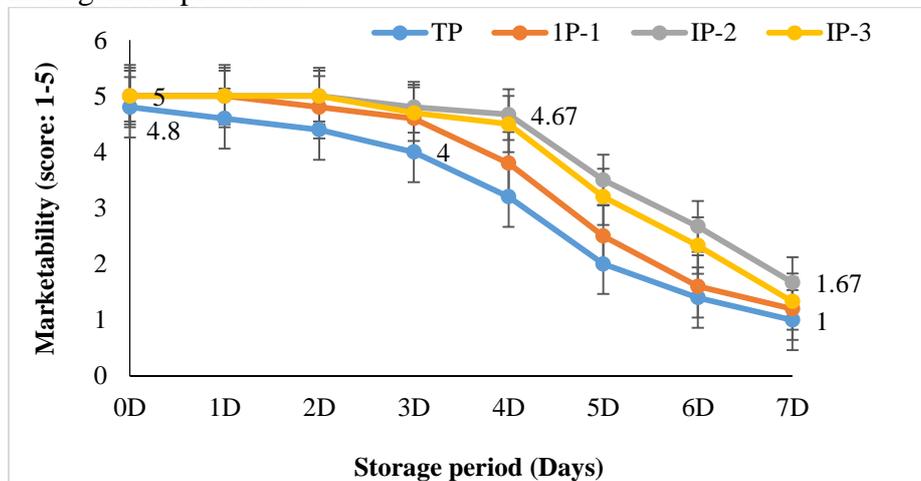


Fig. 116. Marketability of brinjal during 7-days postharvest period

**Marketable life:** The marketable life of brinjal in IP along with TP is shown in Fig. 117. Brinjals washed with CCa mixed water in washing house and packed in plastic crate with MAP had the highest marketable life (7.33 days) followed by those of washed in CCa mixed water through washing machine (2.67 days). The lowest marketable life (1.00 day only) was recorded for the fruits harvested at 20DAA, probably because of their rapid yellowing and splitting tendency. Fruits harvested at 10DAA were observed to be withered fast and became soft and harsh as they lost their marketable life within two days. Fruits harvested at 12 DAA retained their marketable life upto 2.33 days (Fig. 117).

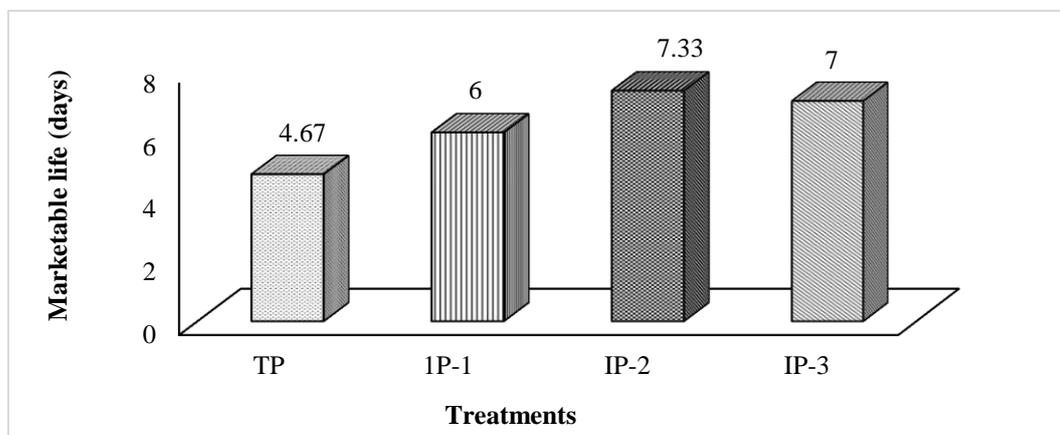


Fig.117. Marketable life of brinjal in traditional and integrated improved practices

## Postharvest losses

**Losses at Retail outlet:** Table 51 shows the proportion of unmarketable brinjals during the 3-day period at retail shops. There was no unmarketable brinjal fruits packed in plastic crate with MAP. However, only a slight increase in the proportion of unmarketable fruits with the use of plastic crates without MAP. In contrast, with the use of jute sacks, the proportion of unmarketable brinjals reached 21.8% on day 2 which was near about double that on day 1 (11.5) in retail shop. Unmarketable brinjals were considered as postharvest loss. At the retail level, the reduction in postharvest losses amounted to 100% till 2 day with CCa-water washing and plastic crate packaging with MAP. It reduced losses 90.8% on day 3 at retail outlet (Table 51).

Table 51. Unmarketable fruit and total losses of brinjal (%) during 2-days retail display

Treatments	Unmarketable brinjal fruit (%) at retail shops			Total loss (weight loss + damage)
	Day 1	Day 2	Day 3	
TP+Without wash+ Plastic sack	11.5 a	21.8 a	30.5 a	45.59 a
IP+CW wash+PC without MAP	0 b	4.7 b	11.4 b	17.56 b
IP+CCa wash+PC with MAP	0 b	0 c	2.8 c	7.41 c
IP+CCa wash with WM+PC with MAP	0 b	1.8 c	4.5 c	9.33 c
Probability (%)	**	*	*	*

TP=Traditional practices, IP=Improved practice, CW=Clean water, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP=Modified atmosphere packaging (1% perforated polyethylene sheet).

**Total losses in whole supply chain:** Fig. 118 shows the proportion of postharvest losses of brinjal at each stage of value chain. At wholesale level, there were no unmarketable fruits, which handled with IP including washing and plastic crate packing with or without MAP. In contrast, 8.67 % brinjals were found to be cracked when they were handled with TP with no washing and packing with plastic sac. Thus, the cumulative losses of brinjals in the entire value chain were calculated and showed that the highest total loss of 45.59% (cracks 8.67 % + transpiration/weight loss 6.42%+unmarketable 30.5%) was obtained in fruits packed in plastic sacks and lowest loss of 7.41% was recorded in brinjal washed with CCa (1%) in washing house and packed in plastic crate with MAP during transportation and subsequent handling and displaying retail shop for at 3-days period (Fig 118). Findings of this study are in agreement with Fernando (2006) and Rahman (2019). Fernando (2006) reported that the introduction of plastic crate as packaging container in the supply chain reduced postharvest losses of vegetables from 30% to 50% during handling and marketing. In their study, Rahman *et al.* (2019) also found similar results.

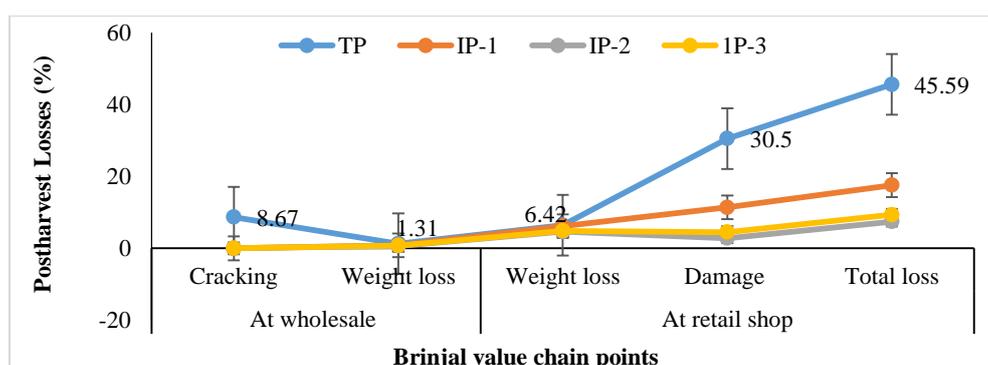


Fig. 118. Efficacy of improved practices in reducing postharvest losses of brinjal at different stages of value chain

Integrated treatments of improved practices reduced total postharvest losses of brinjal cv. ‘Jasori’ from 61.48% to 79.53% (Fig. 119) for a total postharvest period of 5 days. The highest loss reduction (84.96%) was calculated from IP including washing with 0.01% calcinated calcium and packing in plastic crate with MAP. High reduction of postharvest losses in the brinjals handled with IP probably because of lower incidence of physical damage happened in the brinjals during transportation from pack house site to city market and subsequently low incidence of decay due to having less injury. Also, calcinated calcium might play role in reducing disease infestation. This is in agreement with Rahman *et al.* (2019).

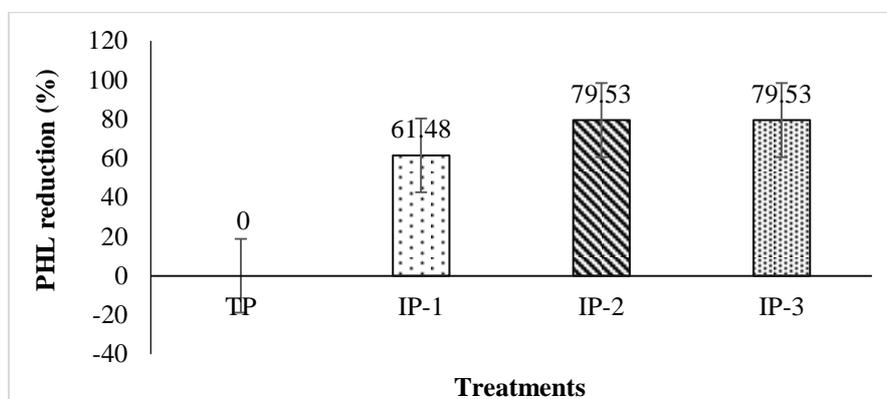


Fig. 119. Postharvest loss reduction of brinjal with integration of improved practices

#### Economic study:

**Partial budget analysis to estimate profitability of applying integrated practices:** A simple profitability tool such as partial budget analysis was used to analyze the expected changes in returns because of postharvest technology intervention like the use of plastic crates. Assuming that one trader can be handled 1200 kg of brinjal per week and that the brinjals are packed in plastic sacks during transportation from Bogura to Gazipur wholesale market by a commercial truck. From the results of the present study, the loss of eggplant due to highly mechanically damage amounted to 30.5%, which is equivalent to 366 kg of eggplant per week (Table 52). Partially mechanical damaged eggplant, on the other hand was 492 kg, which can be sold at lower price (BDT 30 kg<sup>-1</sup>). In contrast, applying calcinated calcium in the water in washing house and plastic crate packaging with MAP as packaging container, there was no cracking. However, 295 kg (24.6%) eggplant was found partially damage but marketable and thus, the complete loss of eggplant was only 34 kg (2.8%) due to transpiration and storage spoilage.

Table 52. Effect of integrated improved practices in reducing postharvest loss of brinjals during transportation and subsequent handling.

Treatments	Sound brinjal		Compressed/bruised brinjal		Unmarketable brinjal		Total Price
	Amount (kg)	Price (BDT)	Amount (kg)	Price (BDT)	Amount (kg)	Price (BDT)	
TP+Without wash+ Plastic sack	342	13680	492	14760	366	0	28440
IP+CW wash+PC without MAP	738	29520	325	9756	137	0	39276
IP+CCa wash+PC with MAP	871	34848	295	8856	34	0	43704
IP+CCa wash with WM+PC with MAP	842	33696	304	9108	54	0	42804

NB: Retail market price: Good quality brinjal= BDT 40 kg<sup>-1</sup>; partially damaged brinjal = BDT 30 kg<sup>-1</sup>. BDT= Bangladeshi taka; PC= Plastic crate; MAP= Modified atmosphere packaging (1% perforated); Figures in the parenthesis indicate the percentage recovery of total price.

TP=Traditional practices, IP=Improved practice, CW=Clean water, CCa=Calcinated calcium, WM=Washing machine, PC=Plastic crate; MAP=Modified atmosphere packaging (1% perforated polyethylene sheet).

**Added returns:** The retail prices of good quality and partially damaged brinjals were estimated to BDT 40 and 30 kg-1, respectively. Thus, the estimated gross income with the use of plastic sack would be 28440. With the use of calcinated calcium sanitizer in washing house and plastic crate packing with MAP, the loss was 34 kg, hence the estimated gross income would be BDT 43704. Therefore, the additional gross income per week as a result of using sanitizer in washing house and plastic crate packing with MAP would be amounted to BDT (43704 – 28440) = BDT 15264 (Table 52).

**Added cost:** Use of plastic crates entails depreciation cost of plastic crates and opportunity cost of capital invested in purchasing plastic crates. For 1200 kg of brinjals, 100 plastic crates are needed which cost BDT 32,000 @ BDT 320 crate-1. Plastic crates normally last for 10 years. So, the depreciation cost is BDT 3200 year-1 or BDT 61.54 week-1 at 10% depreciation cost. Salvage value is 0. The opportunity cost of capital is based on the assumption that the interest rate is 10% and is computed as follows:

$$I = \frac{[32,000 + (32,000 - 3200)]}{2.0} \times 0.1$$

$$= \text{BDT } 3040 \text{ year-1 or } 58.46 \text{ week-1}$$

For washing of 1000 kg brinjals, required amount of calcinated calcium (0.1%) would be 500g/500 liter of water, cost 1000.00 and one labour week-1 cost 550 BDT (one man's day cost of BDT 550 day-1). Total cost for washing practices would amount to BDT 1550.

The reduced cost in terms of labour for sorting brinjals due to mechanical damage with the use of plastic sack was BDT 1100 (2 man-day week-1 at BDT 550 day-1). With an additional gross income of BDT 15264 week-1 plus reduced labour cost of BDT 1100 week-1, one small trader who uses calcinated calcium sanitizer and plastic crate packaging with MAP will gain an additional weekly income of BDT 14,594.00 as shown in Table 53.

Table 53. Partial budget analysis for testing the profitability of applying IP for brinjal (with 100% reduction in loss at wholesale level).

A. Total gain (BDT)		B. Total loss (BDT)	
Added income:		Added cost:	
Additional gross income	15264.00	Depreciation	61.54
		Opportunity cost of capital	58.46
		Cost for sanitizer and labour	1550.00
Reduced cost			
Savings in labour for sorting	1100.00		
Total A	16364.00	Total B	1670.00
Additional weekly income = BDT (16264 – 1670.00) = BDT 14594.00			

Results of this study showed that brinjals could be washed properly and safely with 0.01% calcinated calcium either in washing house or through washing machine. Plastic crate lining with newsprint paper was the most suitable container in which brinjal could be packed and transported to distant market safely. Also, MAP will be beneficial in reducing weight loss, however, should be removed after arrival at wholesale market or as early as possible at destined outlets.

## **Implementing component-2: FMPE, BARI**

### **Expt. Improvement and fine tuning of washing machine for mango, banana and brinjal**

#### **Performance of leafy & fruit vegetable and fruit washing machine**

The vegetable washing machine was designed and fabricated with locally available MS materials at FMPE Division, BARI, Gazipur. The machine was tested with different vegetables and fruits in the laboratory. The performance results of the machine are presented in Table 54. The capacities of the machine were found to be 0.91-1.5 t/h for red amaranth, 1.5 t/h for brinjal, 0.80-1.0 for country bean, 0.8-2.0 t/h for Indian spinach. Zhengzhou Asian Machinery Company Limited, Henan, China fabricated similar vegetable washing machine having capacity of 1.5 t/h. Water use was 5.24 l/kg for red amaranth, 3.27 L/kg for brinjal, 3.5 L/kg for country bean, and 4.68 L/kg for Indian spinach. The capacities of machine were 1.0 t/h for banana and 1.5 ton /h for mango. Electric energy consumption for washing were 4 kWh/t for red amaranth, 1 kWh/t for brinjal, 1kWh/t for country bean, 1.3 kWh/t for Indian spinach and 1.25 kWh/t for mango and banana. Negligible injury of brinjal, red amaranth and Indian spinach was observed but 0.02 percentage of injury observed in country bean due to beans insert into conveyer net hole. By eye observation of washed vegetables and water transparency, dirt and inert material removed from vegetable surface successfully. It observed that washing quality of different vegetables were more freshness and cleanness comparing with the vegetables by traditional practice. The machine is suitable for washing of leafy and fruit vegetables.

Table 54. Performance of leafy & fruit vegetable and fruit washing machine for different vegetables and fruits

Vegetables	Quantity of water, litre/kg	Electric energy use, kWh/t	Labour requirement,	Injury, %	Speed of roller, rpm	Capacity t/h
Red amaranth	5.24	4.00	2	0.00	20 or 0.12m/s	0.91
Brinjal	3.27	1.00	4	0.00	20 or 0.12m/s	1.50
Bean short	3.60	1.00	4	0.02	20 or 0.12m/s	0.80
Bean long	3.43	1.00	4	0.02	20 or 0.12m/s	1.02
Indian Spinach	4.68	1.30	4	0.00	20 or 0.12m/s	2.00
Banana	3.27	1.25	2	0.02	20 or 0.12m/s	0.90
Mango	3.27	1.00	2	0.00	20 or 0.12m/s	1.50

#### **Profitability analyses**

##### **Washing cost of vegetable by the washing machine**

Price of the machine was estimated about 142000.00 Tk (Appendix-III). The washing cost, BCR, payback period of leafy & fruit vegetable and fruit washing machine is shown in Table 55. Profitability analysis revealed that the method of vegetable washing incurred fixed and variable costs. The lion share of cost was estimated for variable cost for the method. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity/fuel, R & M, materials and water charge. The washing cost of leafy & fruit vegetable and fruit washing machine was 0.171 Tk./kg. BCR and payback period of the machine were 3.4 and 21 days respectively.

Table 55. Economic analysis of the leafy & fruit vegetable and fruit washing machine

Cost item	Value
Machine price, Tk	142000
Fixed cost (FC)	
1. Capital consumption (CC), Tk./yr	25682.85
2. Shelter (T), Tk/yr	710
Sub-total, Tk./yr	26392.85
Sub-total, Tk./h	<b>13.20</b>
Variable cost (VC)	
Labour, Tk./h	125
Electricity, Tk./h	13.2
Fuel cost, Tk./h	0
Lubricant, Tk./h	2
R&M, Tk./h	2.49
Materials, Tk./h	1
Water cost, Tk/h	100
Sub-total	243.69
Total cost (FC+VC), Tk/h	<b>256.00</b>
Capacity of the machine, t/h	1.5
Washing cost (Total cost/capacity), Tk./t	<b>171</b>
Payback period, days	21
BCR	3.40

### Break-even point

Break-even-point of leafy & fruit vegetable and fruit washing machine is presented in Fig. 120. It observed that BEP of the leafy & fruit vegetable and fruit washing was 27 h per year. Therefore, vegetable washed by the machine could be profitable to traders when the annual use of the machine exceeds 27 hours.

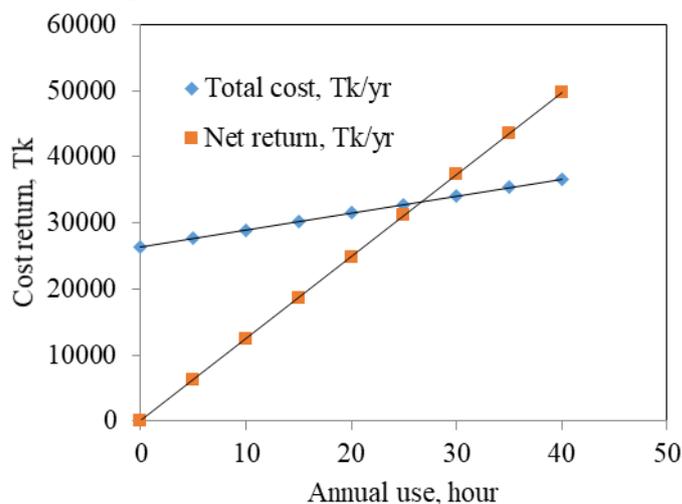


Fig. 120. Break-even point of leafy & fruit vegetable and fruit washing

### Farmer's reaction from field demonstration at Rajshahi and Bogura

Mango & vegetable grower and traders (male and female) presented in the field demonstration. They showed interest to buy the machines and use for treating of mango and washing of vegetables for getting higher prices.

### Expt. Improvement and fine tuning of washing machine for carrot

Performance of the carrot washing machine was evaluated with harvested fresh carrot at FMPE Division, BARI, Gazipur on 18 March 2020 (Table 56). About two tonnes of carrot was used for conducting the performance of the washing machine. The capacity of the washing machine was found to be 1190 kg per hour at the speed of 115-120 rpm whereas cleaning efficiency and washing efficiency of the machine were 95% and 98% respectively. The bruising carrot by the washing machine was one percent.

Table 56. Performance evaluation of carrot washing machine during 18 March 2020

Parameter	Results	Parameter	Results
Machine capacity, kg/h	1190	Machine bruising carrot, %	1.0
Cleaning efficiency, %	95	Speed of machine, rpm	115-120
Washing efficiency, %	98	Amount of carrot per batch, kg	121
		Washing time, minutes	5-6

### Development of drum type carrot washing machine

Self-propelled drum type carrot washing machine was fabricated with local iron materials. Overall dimension was 4750×1800×1980 mm. Performance test was evaluated with carrot at FMPE divisional workshop (Table 57). The machine was operated by diesel engine and motor was operated electricity. The drum was rotated at 8 rpm. The capacity, washing efficiency and cleaning efficiency were 5.55 t/h, 97.90% and 99.33% respectively. The machine was tested with harvested carrot at Mosurikhola 10 March 2021 (Table 58). The capacity, washing efficiency and cleaning efficiency were 5.40 t/h, 98.50% and 98.75% respectively.

Table 57. Performance test of the machine at FMPE (Lab test)

Sl. No.	Amount of carrot, kg	Required washing time, sec	Speed of drum, rpm	Loading time, min	Unloading time, min	Capacity, kg/h	Washing efficiency, %	Cleaning efficiency, %	Injury, %
1	273	180	8	3	12	5460.00	97.07	99.5	Nil
2	290	190	8	3	12	5494.74	98.62	99.0	Nil
3	300	190	8	3.5	12	5684.21	98.00	99.5	Nil
Mean	287.67	186.67	8.00	3.17	12.00	5546.32	97.90	99.33	

Table 58. Performance test results of the washing machine at farmer's field

Sl. No.	Amount of carrot, kg	Required washing time, sec	Speed of drum, rpm	Loading time, min	Unloading time, min	Capacity, kg/h	Washing efficiency, %	Cleaning efficiency, %	Injury, %
1	400	300	8	4	2	4800	98.00	98.5	Nil
2	700	420	8	8	3	6000	99.00	99.0	Nil
Mean	550	360	8	6	2.5	5400	98.5	98.75	

### Profitability analyses

Price of the machine was estimated about 300000.00 Tk (Appendix-IV). The washing cost, BCR, payback period of drum type carrot washing machines is shown in Table 59. Profitability analysis revealed that the method of vegetable washing incurred fixed and variable costs. The lion share of cost was estimated for variable cost for the method. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity/fuel, R & M, materials and water charge. The washing cost of carrot was 111 Tk./t. BCR and payback period of the machine were 1.7 and 14 days respectively.

Table 59. Economic analysis of the drum type carrot washing machine

Cost item	Value
Machine price, Tk	300000.00
Fixed cost (FC)	
1. Capital consumption (CC), Tk./yr	62762.00
2. Shelter (T), Tk/yr	1500.00
Sub-total, Tk./yr	6426.00
Sub-total, Tk./h	64.00
Variable cost (VC)	
Labour, Tk./h	250.00
Electricity, Tk./h	9.0
Fuel cost, Tk./h	123.00
Lubricant, Tk./h	2.0
R&M, Tk./h	10.00
Materials, Tk./h	2
Water cost, Tk/h	100
Sub-total	
Total cost (FC+VC), Tk/h	558.00
Capacity of the machine, t/h	5
Washing cost (Total cost/capacity), Tk./t	111.00
Payback period, days	14
BCR	1.7

**Expt. Effect of different packaging on the quality and shelf-life of banana for long distance transportation**

**Banana**

Variations of temperature and relative humidity inside packaging of CFB carton and wooden box and heap of bunches which stacked on the truck during transportation is presented in Fig.112. It was noted that traveling duration from Rajshahi to Gazipur was recorded to be 3.00pm to 8.00 am. It was observed that temperature inside the stacking of plastic crate and heap of bunches increased with the traveling. It might be occurred due to acceleration of respiration of fruits whereas rationally relative humidity was decreased. It was revealed that speed of ripening process of banana was accelerated for increasing temperature during the traveling period. Inside temperature (0.50°C) and relative humidity (2.40%) of bunch in heap was higher than those of hands in heap. It was might be due to compact of bunches with each other and there was no movement of aeration inside the bunch. It was also noted that temperature and relative humidity increased by 2.80 °C and 7.81% compared with initial temperature and relative humidity.

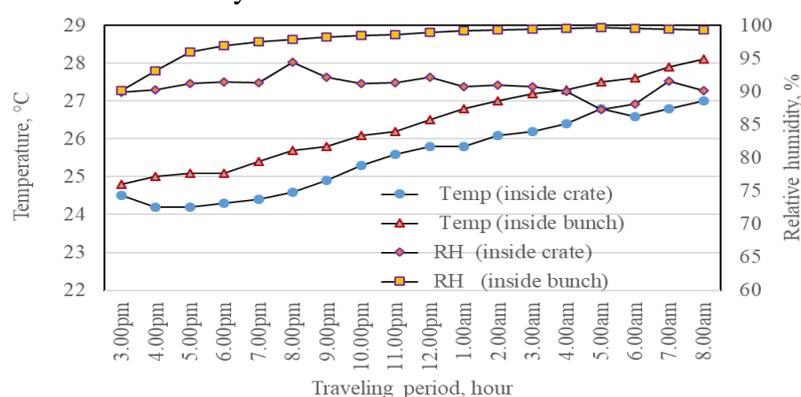


Fig. 121. Variations of temperature and relative humidity inside packaging and heap of bunches during traveling of loaded track

### Postharvest losses of banana for long transportation

Weight losses of different packages (CFB carton, Wooden box and Plastic crate), improved (hands in heaping) and traditional practice (bunch in heaping) during long transportation handling of banana is shown in Fig.122. It was observed that the highest weight loss (0.95%) was found in heap of market bunches in the track (traditional practice) compared to in heap of market hands (0.75%) and heaps of both the bunch (0.68%) and hands (0.22%) of orchard. It showed highly significant different with them. There was no significant difference between orchard bunch and market hands whilst had significant difference between orchard bunch and hands at 5% level. It is might be due to more handling of market bunch than orchard bunch. In respect packaging systems, it was also observed that the highest weight losses were found in without wrapping package (0.20%) whilst the lowest was in wrapping of cling paper (0.03%) for all packages. It was might be due to the cling wrapping paper slow the speed of evaporation rate. Highly significant difference among the wrapping system was observed. Among three packages, CFB carton showed the negligible weight loss.

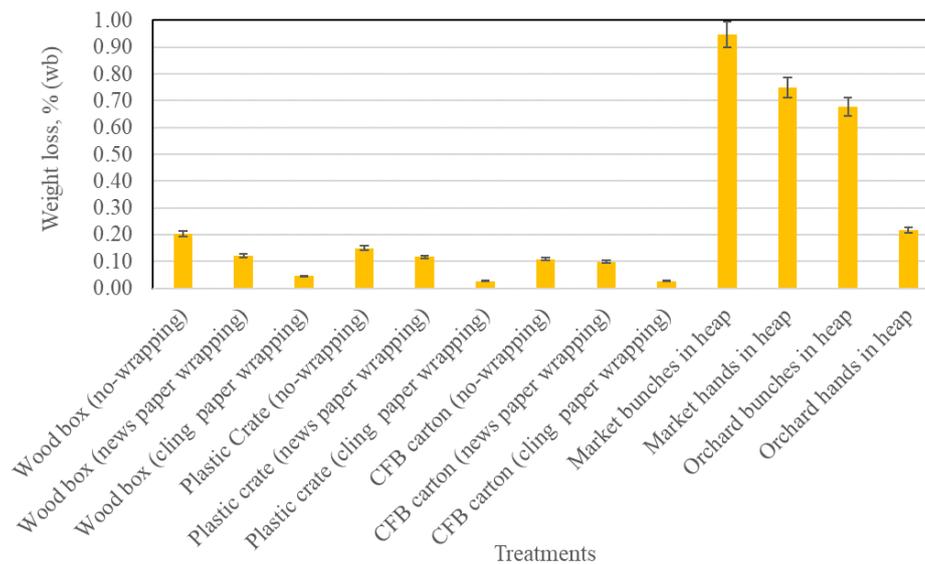


Fig. 122. Weight losses of different packages, improved and traditional practice during long transportation handling of banana

### Bruising losses of banana (Quality and Quantity)

Bruising losses of different packages, improved and traditional practice during long transportation handling of banana is shown in Fig.123. Bruising loss in treatment of market hands in heap was the highest (59%) followed by market bunch, orchard bunch and orchard hands in same practice whereas the lowest in treatment of orchard bunch. It was revealed that bruising losses of hands of orchard and market in heap was higher compared with bunch of orchard and market in same practice. They had highly significant difference. In respect of three packaging, no bruising losses in wrapping with news print paper and cling paper of all packages was observed. On the other hand, there was little losses was occurred in without wrapping packages those had significant difference. Bruising losses included surface rupture, injury, crack and damage and 80 percent surface rupture loss (47%), 20 percent injury, crack and damage losses (12%) out of 59% losses. Bruising losses were counted in numbers of surface rupture, injury, and crack and damage finger by total number of banana fingers. Similar study was done by Mishra et al., 2018 at Gujarat, India who found postharvest loss of banana at wholesaler level (7.23 percent), at producer's level (6.59 percent) and at retailer's level (4.41 percent). Being a high perishable fruit banana needs proper infrastructural facilities and backward and forward linkages to avoid PHL. Good

transportation facility like refrigerated trucks for transfer of produce to distant places and its quality distribution is another major area of great concern specially to boost up the export of fruit since the major share of marketing cost is spent on transportation. The development of cold chain network throughout the supply chain will help in reduction of postharvest loss (Anonymous, 2015). Due to lack of these facilities at every end the volume and quality of produce is greatly affected. Mebratie et al. 2015 found that the estimated postharvest losses of banana in the supply chain with the total loss found to be 26.5% (farm level: 4.5%, wholesale level: 7.1% and retail level: 14.9%). Mechanical damage followed by improper maturity and sun browning were identified as the main causes of banana loss at farm level while mechanical damage followed by failure to pulp softening and improper maturity were identified as the main causes to the loss at wholesale level. Mechanical injuries were therefore identified as the common causes resulting in increased postharvest losses of the fruits at all the stages of the supply chain.

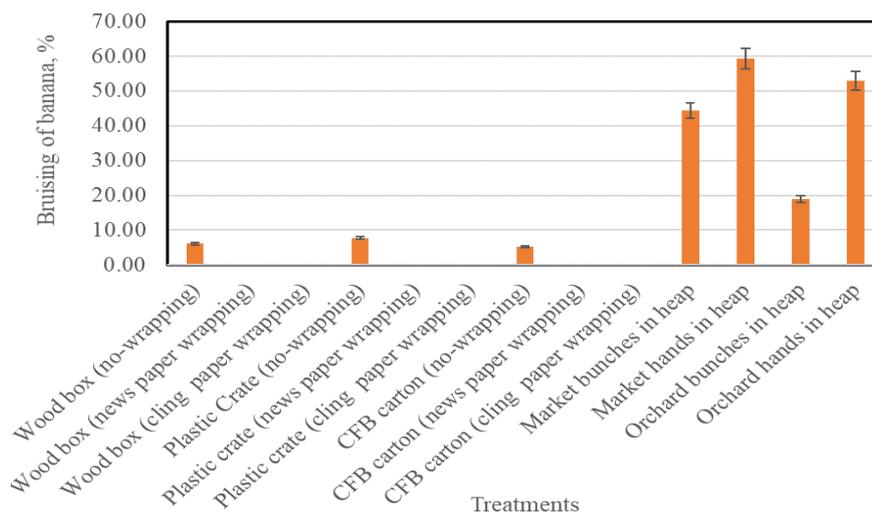


Fig. 123. Bruising losses of different packages, improved and traditional practice during long transportation handling of banana

### Firmness

Firmness of different packages, improved and traditional practice during long transportation handling of banana is illustrated in Fig.124. It was clear that firmness of matured harvested banana varied from 76 to 90 N. It might be varied due to variation of physiological maturity of different banana bunch. In traditional practice on bunch loaded in track in heaping collected from both the market and orchard and improved method hands kept in track heaping showed no significant difference in firmness. In packaging, traditional and improved method, firmness of banana decreased with long transportation. It might be occurred due to increase temperature inside the heaping of banana bunch and hands for acceleration of respiration of banana.

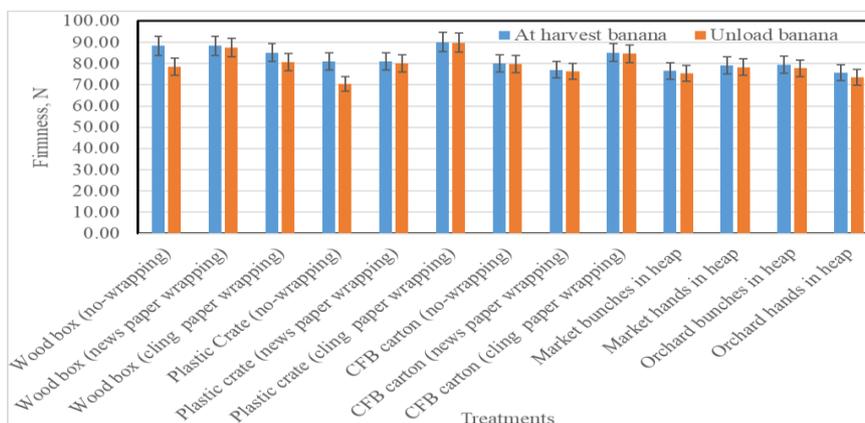


Fig. 124. Firmness of different packages, improved and traditional practice during long transportation handling of banana

### Colour parameters

Colour parameters of different packages, improved and traditional practice during long transportation handling of banana is presented in Fig.125.

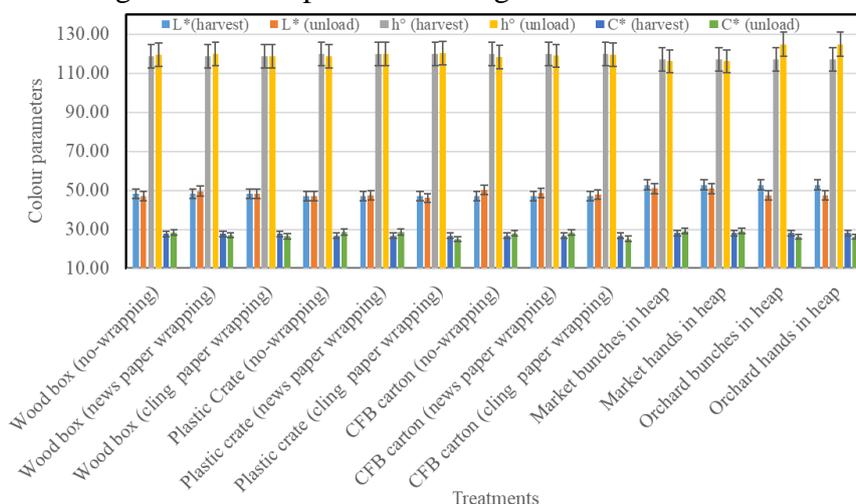


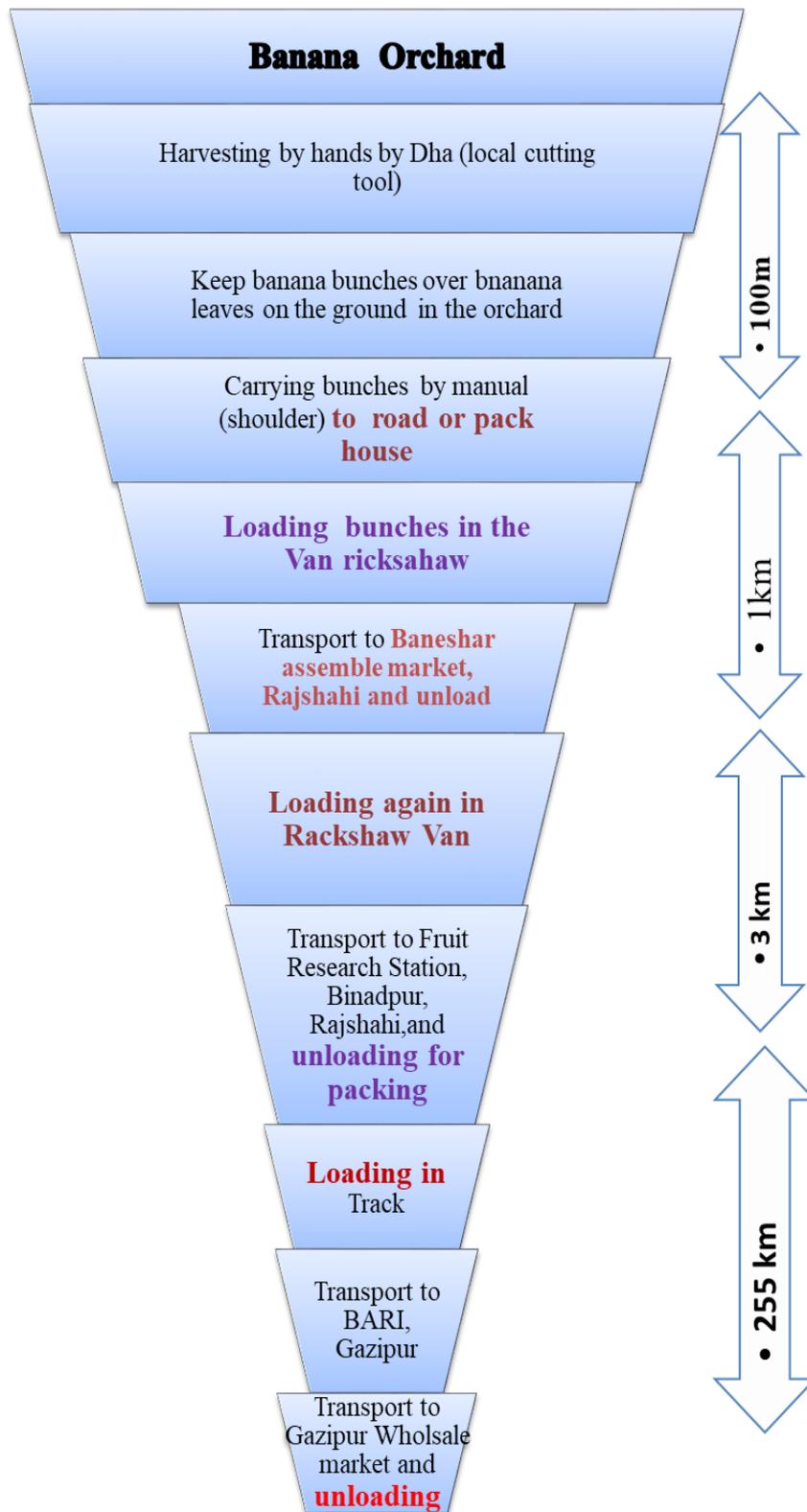
Fig. 125. Colour parameters of different packages, improved and traditional practice during long transportation handling of banana

It was observed that brightness ( $L^*$ ) of harvested matured banana at zero day in Rajshahi and 8 hours after harvesting in Gazipur was found to be 47-52.82 and 46-51.00 and their brightness had no significantly changed within the traveling period. The hue angle of banana varied from 117-120 at harvest and 116-124 at unloading. It indicated that the peel colour of banana was deeply green. There was no significant difference among the treatments in respect hue angle, chroma and brightness.

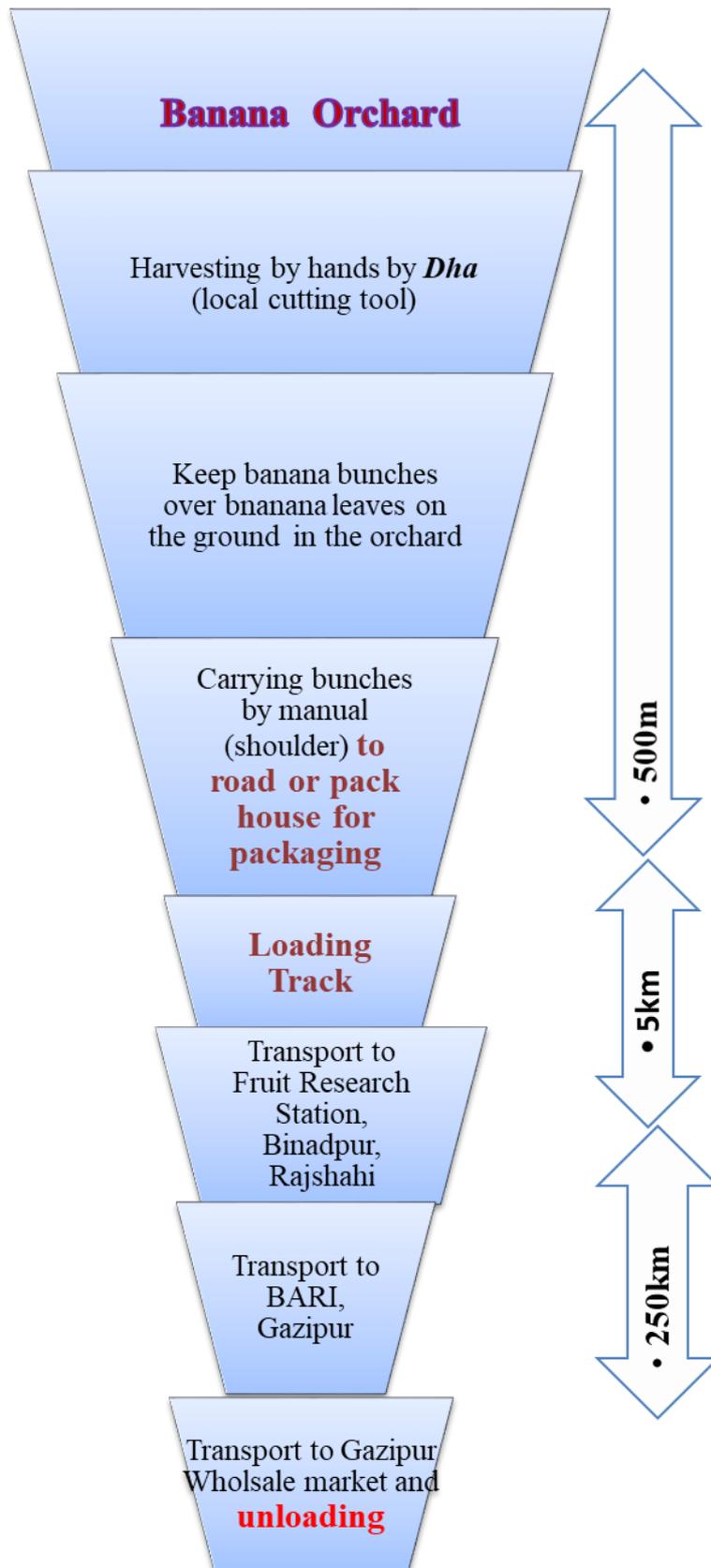
### Development of supply chain protocol

Two protocols of supply chain for banana transportation from orchard to Banessar assemble market to Binadpur, Rajshahi to Gazipur wholesale market; and directly orchard, Shibpur, Rajshahi to Gazipur wholesale market were developed. The protocols flow chart is mentioned bellow:

**Protocol of banana supply chain (orchard to assemble market to wholesale market)**



**Protocol of banana supply chain (orchard to wholesale market)**



### Expt. Adoption of a hydraulic lifter for bagging of mango

Performance test of the lifter are illustrated in table 60. It was observed that up/down speed of the lifter was found to be 0.04 m/s and 0.24 m/s during without load whereas speeds decreased about half of the unloading speed when load is applied on the platform of the lifter from 65 kg (self-weight of one man) to 195 kg (self-weight of three men). The lifting speed is found similar to rated speed from the company but landing speed is similar.

Table 60. Performance test of the hydraulic lifter

Sl. No.	Items	Data
1	Lifting time without load, second	151
	Lifting height without load, m	10
	Landing time without load, second	41
	Speed of lifting and landing, m/s	<b>0.07 and 0.24</b>
2	Lifting time with load one man (65 kg), second	231
	Lifting height with load one man (65 kg), m	9
	Landing time with load one man (65 kg), second	60
	Speed of lifting and landing, m/s	<b>0.04 and 0.15</b>
3	Lifting time with load two man (130 kg), second	214
	Lifting height with load two man (130 kg), m	9
	Landing time with load one man (65 kg), second	55
	Speed of lifting and landing, m/s	<b>0.04 and 0.16</b>
4	Lifting time with load three man (195 kg), second	208
	Lifting height with load three man (195 kg), m	9
	Landing time with load one man (195 kg), second	55
	Speed of lifting and landing, m/s	<b>0.04 and 0.16</b>

### Performance test of the hydraulic lifter

The performance of the hydraulic lifter was evaluated for bagging of mango fruits at Horticultural Research Centre mango orchard, Gazipur on 26 April 2020 is shown in table 61. Speed of lifter for up and down was recorded to be 4.5 and 16 m/min. Twenty one second or more was required for bagging of one mango fruit. It is varied on height of branch and density of branches of tree.

Table 61. Field test of lifter at HRC mango orchard on 26 April 2020

Trial	Tree height, m	Tree age, yr	Mango age, days	Bagging time, min	Number of bagging	Height of bagging of mango, m	Labour required, no.	Speed of lifter, up/down, m/min
1	8	40	35	7	30	6	2	4.5/16
2				2	10	6.5	2	

The performance of the hydraulic lifter was evaluated for bagging of mango fruits at FMPE workshop premise on 28-29 April 2020 is shown in table 62. Speed of lifter for up and down was recorded to be 4.5 and 16 m/min. About twelve second and twenty were required for bagging of one mango fruit. Time is less due to mango fruits were together near the operators. Time is more due to mango fruits were scattered near the operators. It is varied on height of branch and density of mango.

Table 62. Field test of lifter at FMPE workshop premise on 28-29 April 2020

Trial no.	Tree height, m	Tree age, yr	Mango age, days	Bagging time, min	Number of bagging	Time required for bagging of each mango fruit, second	Height of bagging of mango, m	Labour required, no.	Speed of lifter, up/down, m/min
1	12	45	45	20	100	12.00	9.45	2	4.5/16
2				15	46	19.57	10	2	
3				16	76	12.63	8	2	

### Modificatin of the lifter

On the basis of problems, the lifter was modified into self-propelled lifter using diesel engine and lifter was operated by generator instead of electricity (Fig.126).



Fig. 126. Hydraulic lifter modified into self-propelled lifter

The performance of the hydraulic lifter was evaluated at Fruit Research Station, Binodpur, Rajshahi on 15 March 2021. Speed of lifter for up and down was recorded to be 4.7 and 15 m/min.

### Expt. Determination of combined effects of temperature and exposure time on treating mango in hot water

#### Mango

#### Physiological weight loss (PWL)

Effect of physiological weight loss on the storage period of treated and untreated mango is presented in Fig.127 It obtained that PWL of both the treated and untreated mango gradually increased with the storage period and reached a maximum PWL (12.48% wb) at the last edible stage, which might be due to evaporation, transpiration, dehydration and respiration.

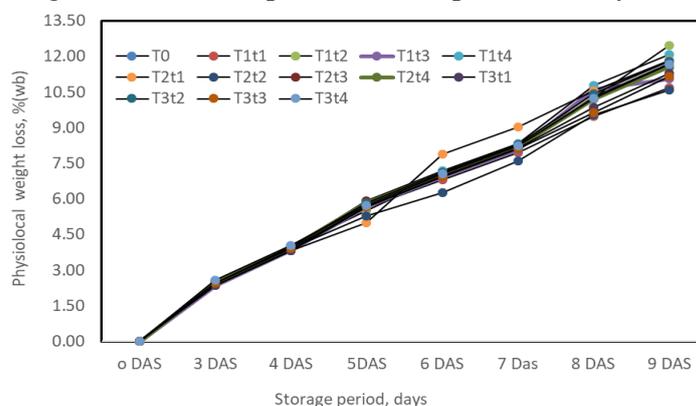


Fig. 127. Effect of physiological weight loss on the storage period of treated and untreated

Note: T<sub>0</sub>=non treated (control), T<sub>1t1</sub>=treated at 50 for 3 min, T<sub>1t2</sub>=treated at 50 for 5 min, T<sub>1t3</sub>=treated at 50 for 7 min, T<sub>1t4</sub>=treated at 50 for 9 min, T<sub>2t1</sub>=treated at 55 for 3 min, T<sub>2t2</sub>=treated at 55 for 5 min, T<sub>2t3</sub>=treated at 55 for 7 min, T<sub>2t4</sub>=treated at 55 for 9 min, T<sub>3t1</sub>=treated at 57 for 3 min, T<sub>3t2</sub>=treated at 57 for 5 min, T<sub>3t3</sub>=treated at 57 for 7 min, T<sub>3t4</sub>=treated at 50 for 9 min.

The minimum PWL (10.59% wb) of mango was recorded in treatment of 50 °C for 5 minutes and maximum at 55 °C for 5 minutes. Not significant variation was observed among the treatments combination at 5% level (SPSS 17.0). Results of this study are in agreement with the findings on four mango varieties –Gopalbhog, Khirshapat, Langra and Fazli of researcher who reported that weight losses of this varieties under treated at 51-55 °C for 5 minutes were 26.33, 26.13, 15.34 and 10.66% after 9 days of storage (Azad, 2001). It occurred due to evaporate the moisture from surface and respiration of the cell.

### Brightness of mango (L\*)

Effect of brightness on the storage period of treated and untreated mango is presented in Fig.128. It was observed that colour parameter L\* value of treated and untreated mango increased with the storage period. It revealed that initial brightness of treated mango surface was lower instantly than that of untreated mango at 0 days. It is might be occurred due to reduce the glossy of mango peel surface for heating effect. At the end of the 12 days storage, the treatment combination of T<sub>1</sub> (50 °C) for different exposure periods (t<sub>1</sub>=3, t<sub>2</sub>=5, t<sub>3</sub>=7 and t<sub>4</sub>=9 minutes), T<sub>1t4</sub> (50°C for 9 min) showed the highest brightness followed by T<sub>1t1</sub>, T<sub>1t2</sub> and T<sub>1t3</sub> but there was no significant difference among them except T<sub>1t1</sub>. Now considering the combination of T<sub>2</sub> (55 °C) for said exposure time, the highest brightness of mango peel surface was in treatment combination of T<sub>2t1</sub> (55°C for 3 min) followed by T<sub>2t2</sub>, T<sub>2t3</sub> and T<sub>2t4</sub> but not significant differences among them was observed. On the other hand, in treatment combination of T<sub>3</sub> (57 °C) for same exposure period, the highest brightness of mango surface was observed in treatment combination of T<sub>3t1</sub> (57°C for 3 min) followed by T<sub>3t2</sub>, T<sub>3t3</sub> and T<sub>3t4</sub> but it was significant difference among them. It was noted that treated mango with the combinations of T<sub>3t2</sub>, T<sub>3t3</sub> and T<sub>3t4</sub> showed negative impact on mango physical quality those combinations did not suit for treating of BARI Aam-3.

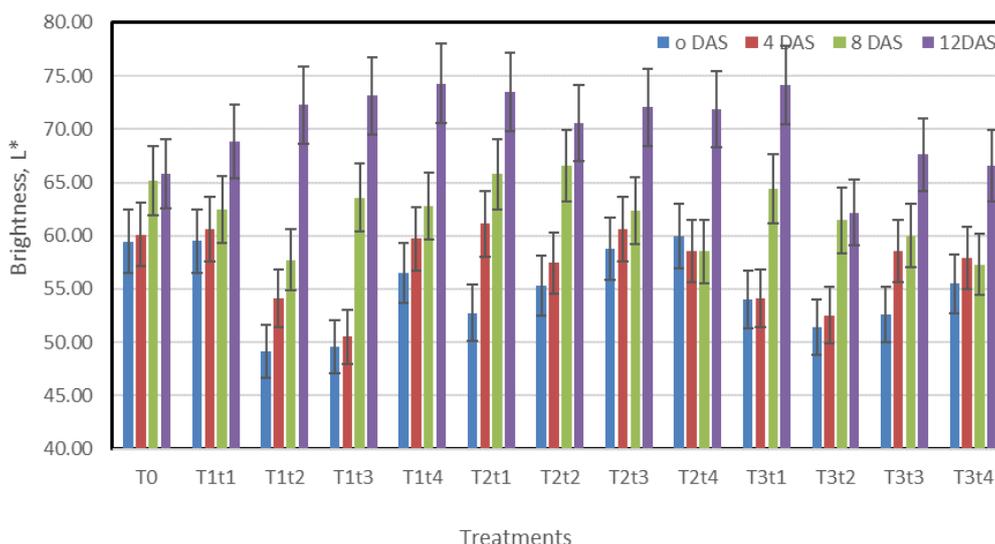


Fig. 128. Variations of brightness (L\*) on the storage period of treated and untreated mango

Note: T<sub>0</sub>=non treated (control), T<sub>1t1</sub>=treated at 50 for 3 min, T<sub>1t2</sub>=treated at 50 for 5 min, T<sub>1t3</sub>=treated at 50 for 7 min, T<sub>1t4</sub>=treated at 50 for 9 min, T<sub>2t1</sub>=treated at 55 for 3 min, T<sub>2t2</sub>=treated at 55 for 5 min, T<sub>2t3</sub>=treated at 55 for 7 min, T<sub>2t4</sub>=treated at 55 for 9 min, T<sub>3t1</sub>=treated at 57 for 3 min, T<sub>3t2</sub>=treated at 57 for 5 min, T<sub>3t3</sub>=treated at 57 for 7 min, T<sub>3t4</sub>=treated at 50 for 9 min.

Variations of hue angle on storage period of treated and untreated mangoes is shown in Fig. 129. It was observed that hue angle of fresh harvested treated and untreated mango varied from 115-127° at 0 day of storage that indicated all mangoes peel colour were green. The hue angle of treated and untreated mangoes decreased with the storage period of 12 days. After storage of 12 days, hue angle of treated and untreated mangoes varied from 75 to 89°. It indicated that all ripe mangoes colour was light yellow to lime. The hue angle was found in all treatments of treated ripe mangoes except T<sub>1</sub>t<sub>1</sub> treatment were higher than that of untreated ripe mangoes. The higher hue angle value expressed that the mango is not completely ripe. These results are very close to the findings of the Rahman et al. (2019) who reported that brightness (L\*) increased and hue angle of Khirsapat decreased with the storage period of 4 days.

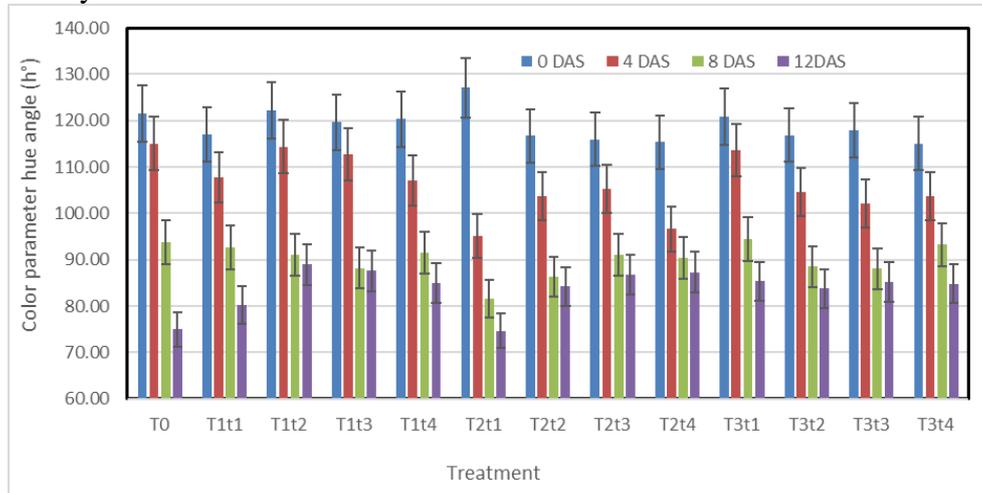


Fig. 129. Variations of hue angle on storage period of treated and untreated mangoes

Variations of chroma on storage period of treated and untreated mangoes is shown in Fig. 130. It was observed that chroma of fresh harvested treated and untreated mango varied from 19-34 at 0 day that indicated all mangoes were moderate vividness of green colour. It was also observed that chroma of treated and untreated mangoes increased with the storage period of 12 days (Fig.131).

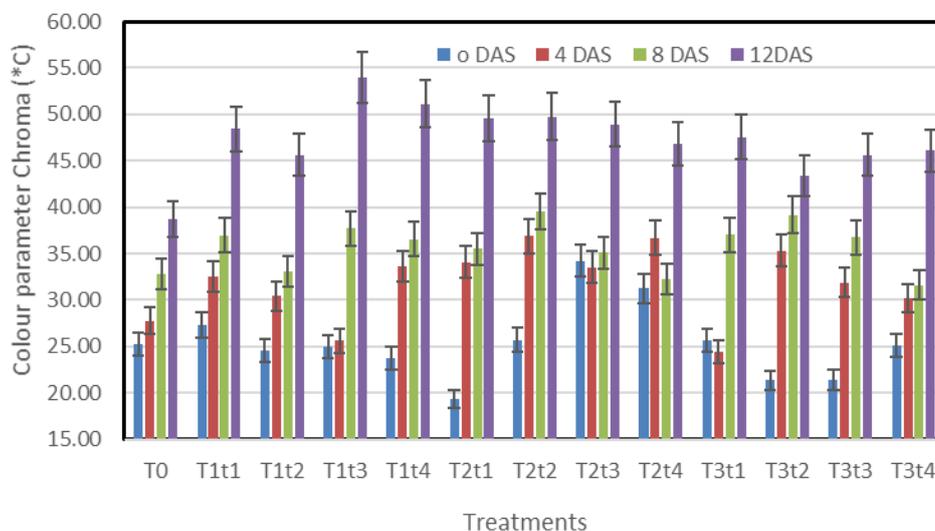


Fig. 130. Variations of chroma on storage period of treated and untreated mangoes



Treated mango at 55°C for 5 minute



Untreated mango

Fig. 131. Observation quality of treated ( $T_{2t_2}$ ) and untreated ( $T_0$ ) mango colour

After storage of 12 days, chroma of treated and untreated mangoes varied from 39-54. It indicated that all ripe mangoes were most vividness of lime colour. The chroma was found in all treatment of treated ripe mangoes were higher than that of untreated ripe mangoes (Fig. 130). Treatment combinations of  $T_{1t_3}$ ,  $T_{1t_4}$ ,  $T_{2t_1}$ ,  $T_{2t_2}$ ,  $T_{2t_3}$ ,  $T_{2t_4}$ ,  $T_{3t_1}$  showed better performance for treating mango of BARI Aam-3.

### Firmness

Variations of firmness on storage period of treated and untreated mangoes is shown in Fig. 132. The initial firmness of fresh harvested treated and untreated mango varied from 42-55 Newton (N). The firmness of all mangoes followed a decline trend during ripening at twelve days' storage period. At the end of twelve-days, not significant treatments combinations of  $T_{1t_4}$ ,  $T_{2t_2}$  and  $T_{2t_4}$  showed harder (7.31-7.72N) compared to untreated mango (6.47N) (Table 63). Similar findings were found by the researchers for Khirsapat variety (Rahman, et al., 2019 and Alam, et al., 2019).

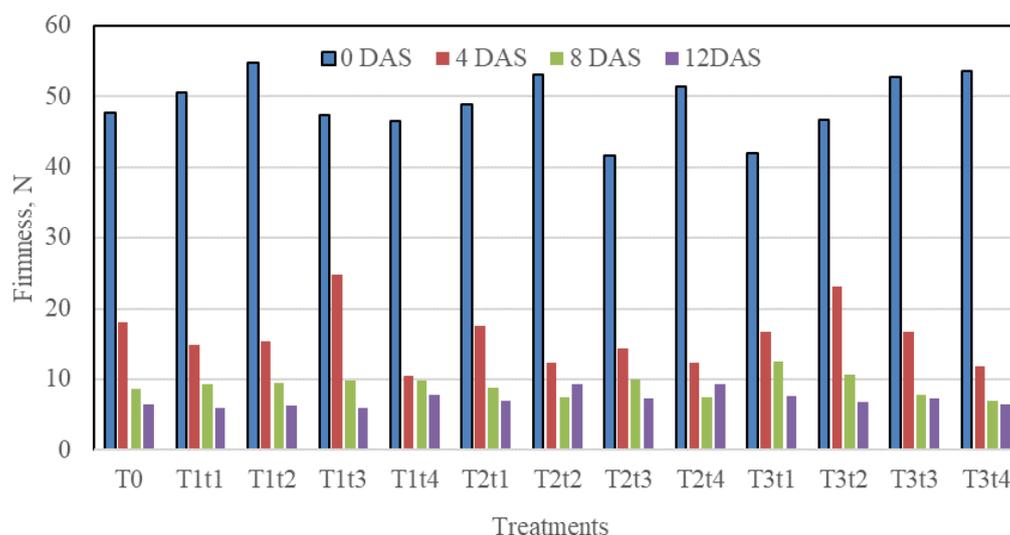


Fig. 132. Variations of firmness on storage period of treated and untreated mangoes

Table 63. Statistical analysis of firmness of untreated and treated mango

Treatments	0 day	4 days	8 days	12 days
$T_0$	47.68de	26.24ab	7.89bcd	6.44ab
$T_{1t_1}$	50.60bcd	20.76cd	8.88bc	6.03b
$T_{1t_2}$	54.82a	21.79bc	9.47bc	6.55ab
$T_{1t_3}$	47.35de	26.40ab	9.79bc	5.85b

Treatments	0 day	4 days	8 days	12 days
T <sub>1</sub> t <sub>4</sub>	46.58e	13.77 efg	9.78bc	7.72a
T <sub>2</sub> t <sub>1</sub>	48.92cbd	14.29efg	7.63cd	7.00ab
T <sub>2</sub> t <sub>2</sub>	53.04ab	15.69defg	8.65bcd	7.60ab
T <sub>2</sub> t <sub>3</sub>	41.68f	11.18g	8.40bcd	7.29ab
T <sub>2</sub> t <sub>4</sub>	51.43bc	12.26g	7.42cd	7.31ab
T <sub>3</sub> t <sub>1</sub>	42.02f	18.41cdef	12.57a	6.57ab
T <sub>3</sub> t <sub>2</sub>	46.66e	27.76a	10.38ab	6.80ab
T <sub>3</sub> t <sub>3</sub>	52.63ab	19.01cde	8.03bcd	7.26ab
T <sub>3</sub> t <sub>4</sub>	53.53ab	13.42fg	6.88d	6.47ab

### °Brix

°Brix of untreated and treated mango during storage period is presented in Fig. 133. Initial °Brix of fresh harvested treated and untreated mango was found to be 11-12. It increased with the acceleration of ripening and storage period. At the end of the storage (12 days), the highest (24.2°Brix) and lowest (20.23°Brix) °brix were found in treatment of T<sub>0</sub> (untreated) and T<sub>2</sub>t<sub>4</sub> (55°C for 5 minutes). It was revealed that °Brix of treated mango always lower than that of untreated mango at the end of 12 days of storage period. It indicated that treated mango did not reach to full ripe whilst the untreated mango was become full ripe. Similar results were reported by (Azad, 2001; Rahman, et al., 2019 and Alam, et al., 2019) for Fazli, Langra, Khirsapat varieties of mango.

### Organoleptic test of ripe mango

Peel color, flesh, taste and flavor/aroma assessment of ripe mango (BARI Aam-3) are shown in Fig.134. It was observed that untreated mango (T<sub>0</sub>) and treated of T<sub>3</sub>t<sub>4</sub> and T<sub>2</sub>t<sub>4</sub> mango peel colour (score greater than or equal 3) were moderately good but other treated mangoes colour (score greater than 2) were much good. Very much good flesh of treated mangoes was found in treatments of T<sub>1</sub>t<sub>2</sub>, T<sub>1</sub>t<sub>4</sub>, T<sub>2</sub>t<sub>1</sub>, T<sub>2</sub>t<sub>2</sub> and T<sub>3</sub>t<sub>1</sub>. It was also noted that the lowest taste value of treated mango was found at treatment of T<sub>2</sub>t<sub>2</sub>. Good flavor was found in treatment of T<sub>1</sub>t<sub>2</sub> and T<sub>2</sub>t<sub>2</sub>. Similar trend was found for taste. Considering the overall acceptability, the lower value of the treated mangoes was observed in T<sub>1</sub>t<sub>2</sub> (treated mango at 50°C for 5 minutes), T<sub>2</sub>t<sub>2</sub> (treated mango at 55°C for 5 minutes) and T<sub>3</sub>t<sub>1</sub> (treated mango at 57°C for 3 minutes).

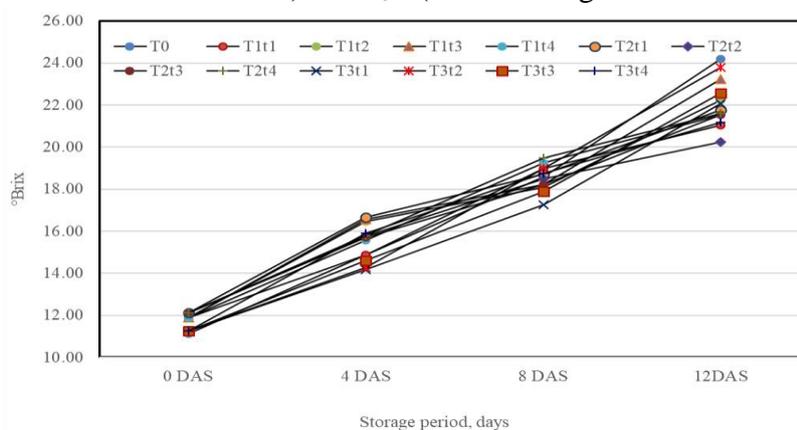


Fig. 133. Variations of brix on storage period of treated and untreated mangoes

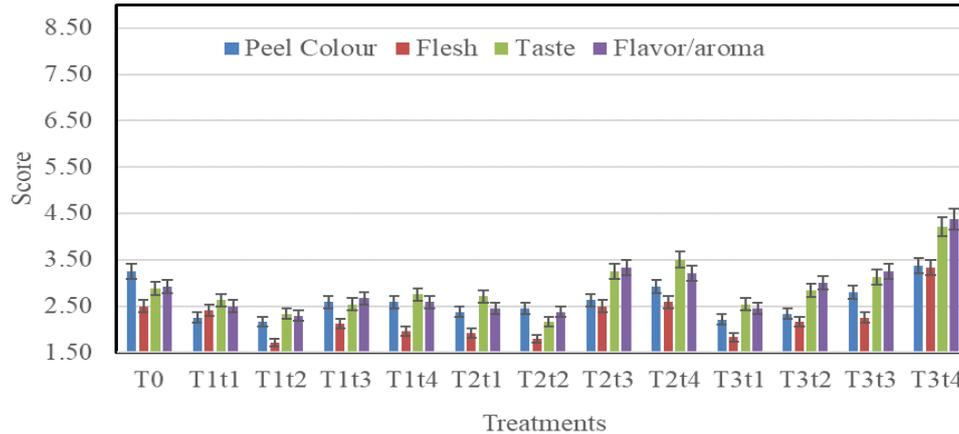


Fig. 134. Peel color, flesh, taste and flavor/aroma assessment of ripe mango (BARI Aam-3)

Fruits were exposed to a panel of 10 assessors using a 1-9 scale (1=like extremely, 2= like very much, 3= like moderately, 4= like lightly, 5= neither like nor dislike, 6= dislike slightly, 7= dislike moderately, 8= dislike very much and 9= dislike extremely) for general appearance.

On the other hand, the higher values of the peel color, flesh, taste and flavor/aroma were found in treatments of T<sub>2t3</sub>, T<sub>2t4</sub> and T<sub>3t2</sub>, T<sub>3t3</sub>, and T<sub>3t4</sub>. It noted that the treatments of T<sub>2t3</sub>, T<sub>2t4</sub> and T<sub>3t2</sub>, T<sub>3t3</sub>, and T<sub>3t4</sub> were not good for edible but T<sub>1t1</sub>, T<sub>1t2</sub>, T<sub>1t3</sub>, T<sub>1t4</sub>, T<sub>2t2</sub> and T<sub>3t1</sub> were good for edible. It was concluded that T<sub>1t2</sub> (treated mango at 50°C for 5 minutes), T<sub>2t2</sub> (treated mango at 55°C for 5 minutes) and T<sub>3t1</sub> (treated mango at 57°C for 3 minutes) were better accepted for edible. Among them, T<sub>2t2</sub> is the best treatment for BARI Aam-3.

### Shelf-life

Variations of shelf-life of treated and untreated mango is shown in Fig.135. Shelf-life of treated mango was higher compare to untreated mango. Treatment combinations of T<sub>1t4</sub> (at 50°C for 9 minutes) exhibited the highest shelf-life followed by T<sub>1t1</sub> (at 50°C for 3 minutes), T<sub>1t2</sub> (at 50°C for 5 minutes) and T<sub>1t3</sub> (at 50°C for 7 minutes). Treatment combinations of 55°C (T<sub>2</sub>) for 5, 7 and 9 showed higher shelf-life of mango. Treatment combinations of 57°C (T<sub>3</sub>) for 3, 7 and 9 showed higher shelf-life of mango. The shelf-life of the varieties of BARI Aam-3 treated with hot water treatment increased by 33% over untreated fruits. The highest shelf-life (12 days) of mango was found in combination of T<sub>2</sub> (55°C) and t<sub>2</sub> (5 minutes) which was similar to T<sub>2</sub> (55°C) and t<sub>3</sub> (7 minute), and the lowest shelf-life of mango (8 days) was in T<sub>0</sub> (ambient condition). Hot water treatment perhaps retarded the physiological and biochemical activities and finally led to the longest shelf-lif. Similar results were reported by (Azad, 2001; Rahman, et al., 2019 and Alam, et al., 2019).

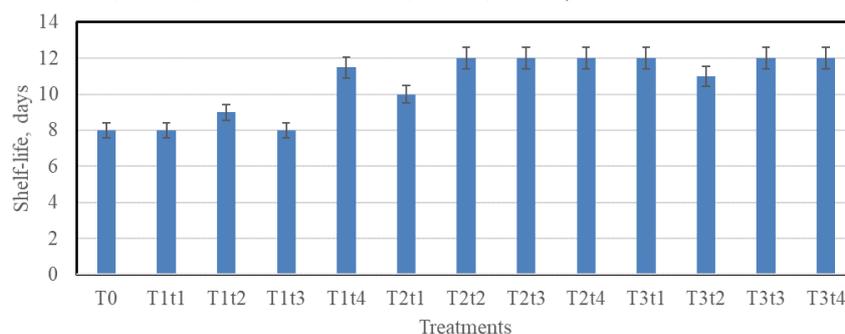


Fig. 135. Variations of shelf-life of treated and untreated mango

### Disease severity of mango during storage

The main diseases observed on mango fruits through the experimental period were *Anthracnose* which is caused by a fungus (*Colletotrichum gloeosporioides*). Hot water treatment is accepted as an effective disease control technology, particularly anthracnose. At day 10 of storage, any symptom of anthracnose infestation was not observed almost all hot water treated fruits. At the end of day 11, all of the treatments showed a number of symptoms with a little variation between each treatment. Disease severity of different treatments of ripe mango was recorded at 11 the days of storage in Fig. 136. It was observed that the highest disease severity (7.95) was found in treatment T<sub>0</sub> (untreated mangoes) followed by treatments of treated mangoes that was significantly higher than other treatments (Table 64 and Fig. 137). It was noted that there was no disease severity occurred in treatments of T<sub>2t4</sub>, T<sub>3t1</sub>, T<sub>3t3</sub> and T<sub>3t4</sub>. Negligible disease severity was observed in treatment of T<sub>2t2</sub>, T<sub>2t3</sub> and T<sub>3t2</sub> but there were no significant differences among the treatments of T<sub>2t1</sub>, T<sub>2t2</sub>, T<sub>2t3</sub>, T<sub>2t4</sub>, T<sub>3t1</sub>, T<sub>3t2</sub>, T<sub>3t3</sub> and T<sub>3t4</sub>. There was a good combination of temperature and exposure time for BARI Aam-3 in treatment of 55°C for 5,7 and 9 minutes and also found other good combination of temperature and exposure time for BARI Aam-3 in treatment of 57°C for 3,7 and 9 minutes. Disease severity of treated mango was reduced by 79% over untreated fruits. This indicated that hot water treatment is the most favorable treatment for controlling anthracnose, the similar observations were observed by Rahman, et al., 2019 and Chaplin *et al.* 1991 who found that hot water treatment is effective against fungal infection in fruits.

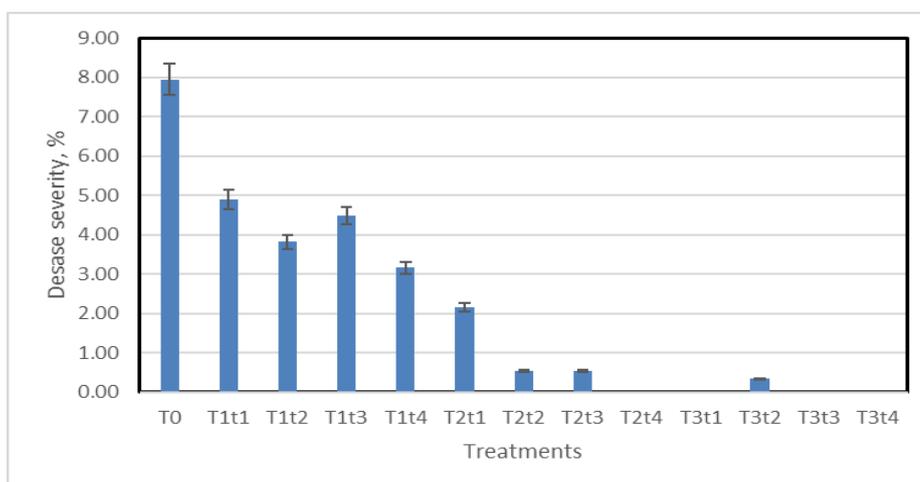


Fig. 136. Variations of disease severity of treated and untreated mango

Table 64. Statistical analysis of disease severity of untreated and treated mango

Treatment	Disease severity, %	Treatment	Disease severity, %
T <sub>0</sub>	7.95a (2.72)	T <sub>2t3</sub>	0.54c (0.96)
T <sub>1t1</sub>	4.89ab(2.28)	T <sub>2t4</sub>	0.0c (0.71)
T <sub>1t2</sub>	3.81ab(2.07)	T <sub>3t1</sub>	0.0c(0.71)
T <sub>1t3</sub>	4.48ab(2.22)	T <sub>3t2</sub>	0.33c (0.88)
T <sub>1t4</sub>	3.15ab(1.89)	T <sub>3t3</sub>	0.0c (0.71)
T <sub>2t1</sub>	2.15bc(1.47)	T <sub>3t4</sub>	0.0c (0.71)
T <sub>2t2</sub>	0.55c (0.96)		

Note: T<sub>0</sub>=non treated (control), T<sub>1t1</sub>=treated at 50 for 3 min, T<sub>1t2</sub>=treated at 50 for 5 min, T<sub>1t3</sub>=treated at 50 for 7 min, T<sub>1t4</sub>=treated at 50 for 9 min, T<sub>2t1</sub>=treated at 55 for 3 min, T<sub>2t2</sub>=treated at 55 for 5 min, T<sub>2t3</sub>=treated at 55 for 7 min, T<sub>2t4</sub>=treated at 55 for 9 min, T<sub>3t1</sub>=treated at 57 for 3 min, T<sub>3t2</sub>=treated at 57 for 5 min, T<sub>3t3</sub>=treated at 57 for 7 min, T<sub>3t4</sub>=treated at 57 for 9 min.

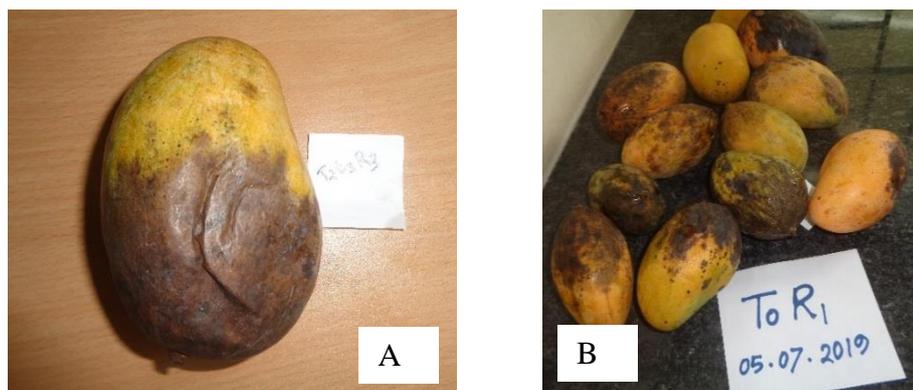


Fig. 137. Observation of stem end rot and anthracnose disease of treated (A) and untreated mango (B) during storage period

### Expt. Effects of cold storage temperature and humidity for different packaging on shelf-life and quality of carrot

The unwashed and washed (with water and CCA) carrots were stored in jute sack at a commercial cold storage. It was observed that TAB of unwashed carrot packed in jute sack increased with storage period up to 3 months later it slightly decreased with the storage period. In case of washed carrot packed in jute sack, TAB increased upto two months storage and then decreased. In case of CCA washed carrot packed in jute sack TAB increased in 1 month and later it decreased. The lowest value of TAB and TCC was found in CCA washed carrot packed in jute sack up to 4 month of storage than those of washed with water and unwashed carrot. The lowest of Y&M was found in CCA washed carrot increased in 4 months of storage. It revealed that CCA washed carrot packed in jute sack was better in respect of TAB, TCC and Y&M up to 3 month storage (Fig.138).

The total aerobic bacterial count were recorded as 5.64 log CFU/g in unwashed carrot samples in 0 month of storage, and these values decrease little during 1 month of storage and then increased significantly (6.67 log CFU/g) at 4 months of storage. Total coliform count (TCC) was recorded as 4.87 log CFU/g in unwashed samples at 0 month storage, and remain constant throughout 4 months storage period. The substantial number of *E. coli* count 3.67 log CFU/g was recorded in unwashed samples at 0 month storage, however, no *E. coli* was observed in 1 months, but presence of *E. coli* was observed in 2 months storage carrot sample. *Salmonella* was not present in any of the carrot samples in this study.

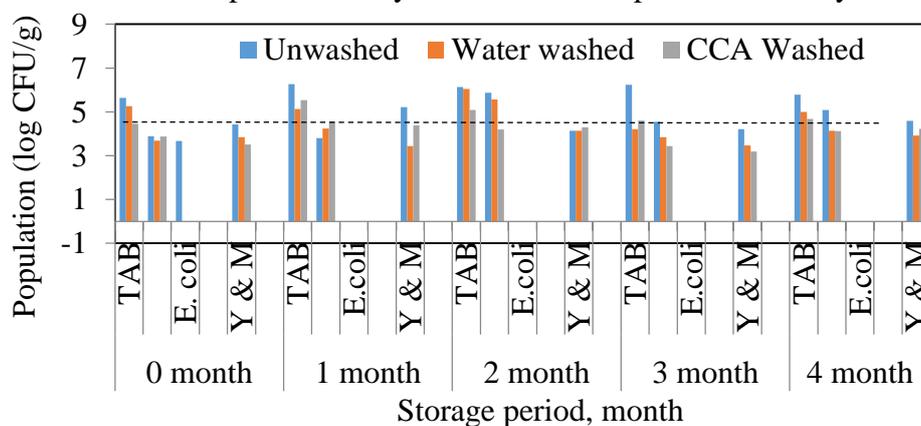


Fig.138. Effect of storage period on microbial load of washed and unwashed carrot packed in jute sack

The unwashed and washed (with water and CCA) carrots were stored in jute sack with polyethylene lining at a commercial cold storage. It was observed that TAB, TCC and of Y&M of both the washed and unwashed carrot packed in jute sack increased with storage period up to 2 month but slightly decreased in 3 month of storage but later those were increased. They were good up to 3 month of storage. In respect of microbial load, the best performance was found in water washed carrot packed in jute sack with polythene lining (Fig.139).

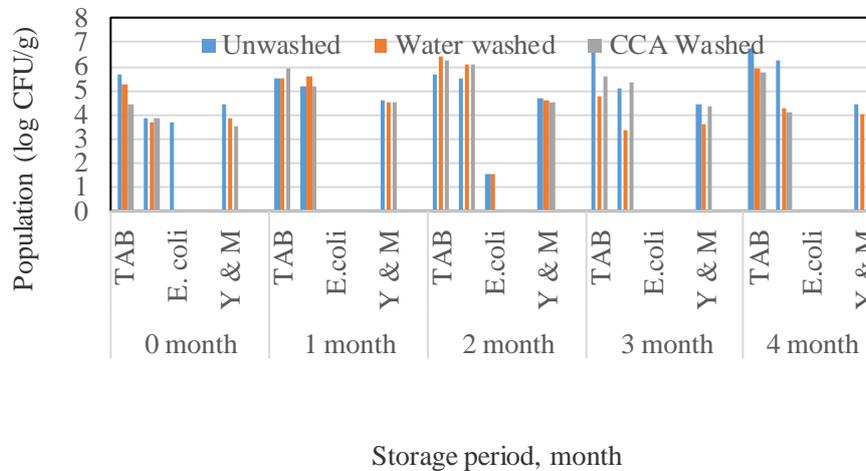


Fig.139. Effect of storage period on microbial load of washed and unwashed carrot packed in jute sack with polyethylene lining

The unwashed and washed (with water and CCA) carrots were stored in plastic crate with polyethylene lining at a commercial cold storage. It was observed that TAB of unwashed carrot packed in plastic crate with polyethylene lining increased with storage period up to 4 month. The lower TAB and TCC were observed in washed carrot with water and CCA than that of unwashed carrot. The lowest of Y&M was found in CCA washed carrot in 4 month of storage. It revealed that CCA washed carrot was better in respect of TAB, TCC and Y&M up to 3 month storage (Fig.140).

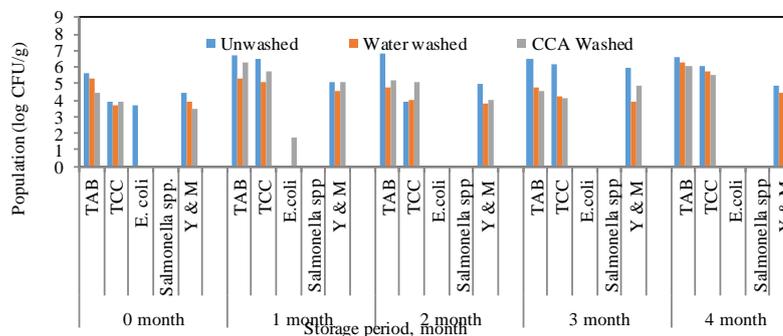


Fig.140. Effect of storage period on microbial load of washed and unwashed carrots packed in plastic crate with polyethylene lining

The unwashed and washed (with water and CCA) carrots were stored in CFB with polyethylene lining at a commercial cold storage. In respect of TAB, TCC and Y & M, CCA washed carrot was the best quality than that of washed carrot with water during the storage period (Fig.141).

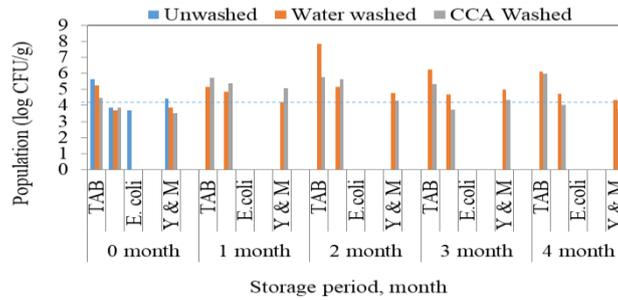


Fig.141. Effect of storage period on microbial load of washed and unwashed carrots packed in CFB with polyethylene lining

The unwashed and washed (with water and CCA) carrots were stored in polyethylene bag at a commercial cold storage. In respect of TAB, TCC and Y & M, CCA washed carrot was the best quality than that of washed carrot with water and unwashed carrot up to 3 month (Fig.142).

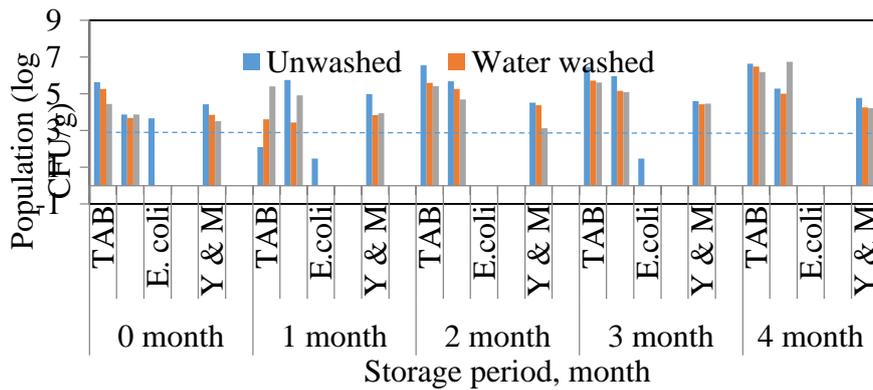


Fig.142. Effect of storage period on microbial load of washed and unwashed carrots packed in polyethylene bag

The unwashed and washed (with water and CCA) carrots were stored in perforated polyethylene bag at a commercial cold storage. In respect of TAB, TCC and Y & M, CCA washed carrot was the best quality than that of washed carrot with water and unwashed carrot up to 3 month (Fig.143).

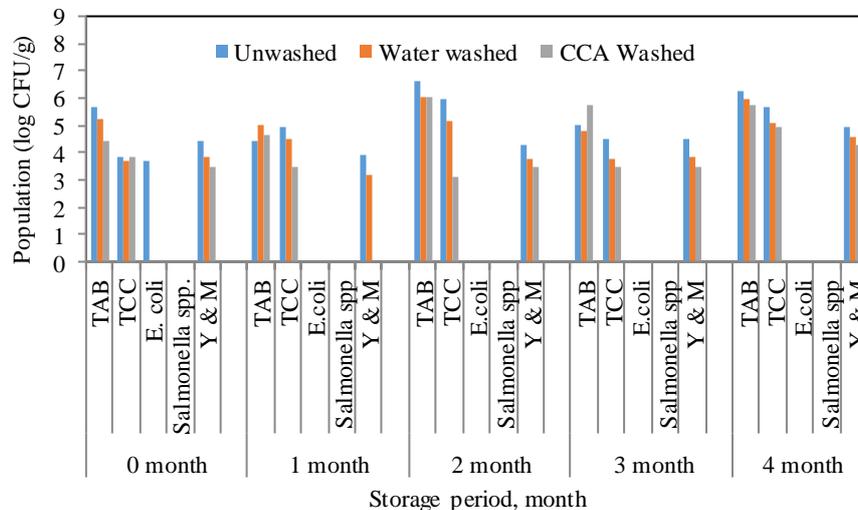


Fig.143. Effect of storage period on microbial load of washed and unwashed carrots packed in perforated polyethylene bag

### Microbial loads of harvested fresh washed and unwashed carrots during March 2019

The aerobic bacterial count (TABC) and Total coliform count (TCC) were recorded as 5.6 log CFU/g, and 3.8 log CFU/g in unwashed samples at 0 month storage, however, no *E. coli* nor were any salmonella detected in the samples analyzed. Yeast and mold count was recorded as 4.7 CFU/g at 0 month storage. When carrot was washed with NaOCl followed by water wash, 1.3 log CFU/g of APC count and approximately 1.0 log CFU/g reduction of TCC counts, and 1.5 log CFU/g of Y & M counts were observed. On the other hand, higher reduction of TABC, and TCC counts was observed with CCA washed carrot compared to NaOCl washed carrot. Similar reduction of yeast and mold counts were observed in CCA or NaOCl washed carrot (Fig. 144).

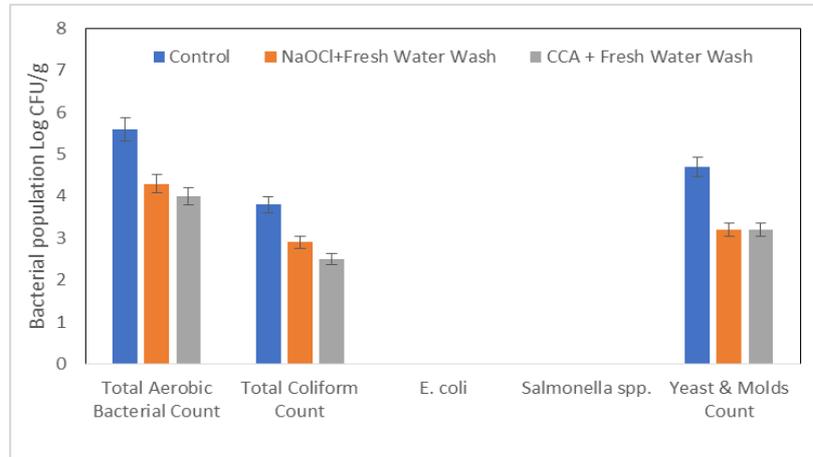


Fig. 144. Microbial loads of harvested fresh washed and unwashed carrots

### Firmness

Carrot firmness of all treatments generally increased and decreased over cold storage period at 1-2° C and 99% RH (Fig.145). It revealed that firmness may be varied due to fluctuation of temperature and humidity in the cold storage and variation of physiological maturity.

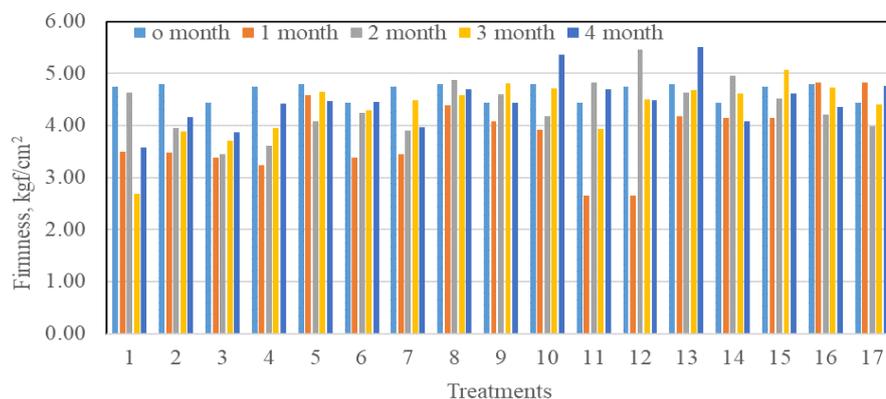


Fig. 145. Variation of treatment of carrot on firmness with the storage period in commercial cold storage

Firmness of harvested washed and unwashed carrots on 10 March 2019 is shown in Fig. 146. It was observed that firmness of harvested matured carrot in both the washed and unwashed were collected from lot of harvested carrots was little different but there was no significant difference among the treatment at 5% level.

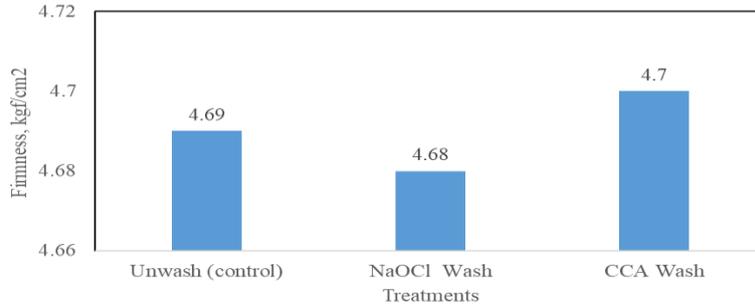


Fig. 146. Variation of treatment of carrot on firmness with the storage period in commercial cold storage

### External colour

External colour changes of carrot were monitored by measuring hue angle ( $h^\circ$ ) over the storage of 4 months (Fig. 147). Little colour variation of washed and unwashed carrot of different packages were observed. Hue angle of carrots for all treatment was close to  $60^\circ$ , so it was concluded that all surface colour of washed carrots were yellow. Unwashed carrot packed in jute sack with polythene lining and only polyethylene bag of harvested carrot, washed with water, CCA was more yellow than other treatments. Unwashed carrot contained lime-yellow colour for hue angle less than  $60^\circ$ .

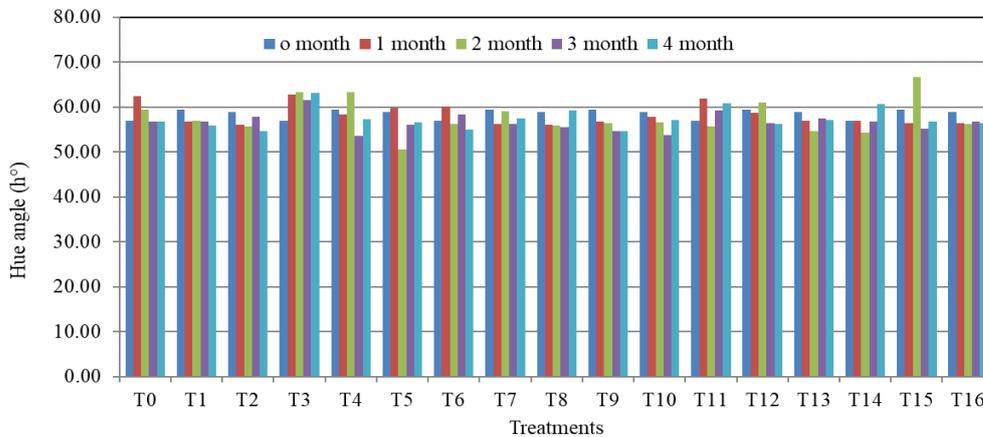


Fig. 147. Variation of treatment of carrot on hue angle with the storage period in commercial cold storage during 2018

$T_0$  = unwashed jute sack (conventional practice),  $T_1$  = washed in water into jute sack,  $T_2$  = washed in water + CCA into jute sack,  $T_3$  = Unwashed polyethylene bag covered with jute sack,  $T_4$  = Washed in water and polyethylene bag covered with jute sack,  $T_5$  = Washed in water + CCA and polyethylene bag covered with jute sack,  $T_6$  = Unwashed and plastic crate covered with polyethylene,  $T_7$  = Washed in water and plastic crate covered with polyethylene,  $T_8$  = Washed in water + CCA plastic crate covered with polyethylene,  $T_9$  = Washed in water and polyethylene bag packed in CFB carton,  $T_{10}$  = Washed in water + CCA and polyethylene bag packed in CFB carton,  $T_{11}$  = Unwashed in water and only polyethylene bag,  $T_{12}$  = Washed in water and only polyethylene bag,  $T_{13}$  = Washed in water + CCA and kept them into only polyethylene bag,  $T_{14}$  = Unwashed and perforated polyethylene bag (0.2%),  $T_{15}$  = Washed in water and o perforated polyethylene bag (0.2%),  $T_{16}$  = Washed in water + CCA and perforated polyethylene bag (0.2%).

Variation of external colour of unwashed and washed carrot were observed by measuring different colour parameters during starting the experiment on 10 March 2019 (Fig. 148). Value of colour parameter  $a^*$  is positive that means washed and unwashed carrot external colour were red. But the highest red colour of washed carrot by NaOCl was found followed

by washed by CCA and unwashed. Value of colour parameter  $b^*$  is positive that means washed and unwashed carrot external colour were yellow. But the highest yellow colour of washed carrot by CCA was found followed by washed by NaOCl and unwashed. Higher colour parameter  $L^*$  was found in washed carrot by CCA and NaOCl than that of unwashed carrot. So, it revealed that more brightness was observed in washed carrot than that of unwashed carrot. The higher hue angle value ( $>60^\circ$ ) was found in unwashed carrot than that of washed carrot.

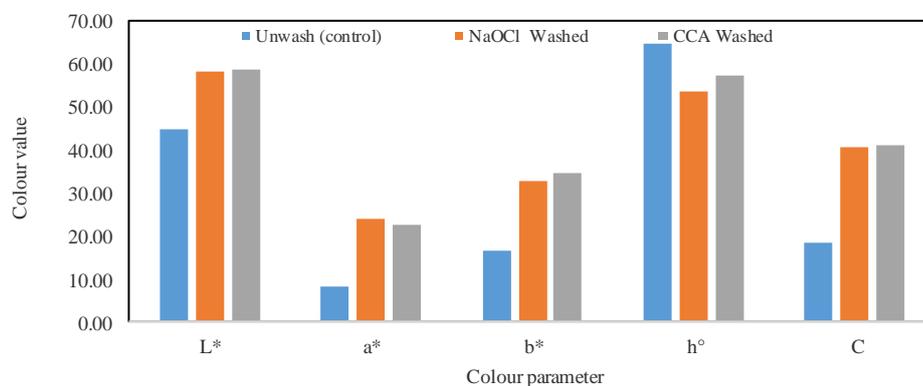


Fig. 148. Variation of treatment of carrot on colour parameters at starting the experiment

The unwashed carrot surface colour was yellow-lime but hue angle value of washed carrot was about  $60^\circ$  that means fully yellow colour. It revealed that better yellow colour was found in washed carrot by CCA than washed of NaOCl. The higher colour parameter of  $C^*$  was found in washed carrot than that of unwashed carrot. So, it was concluded that washed carrot colour was intense yellow than that of unwashed carrot. Among the washed treatments (NaOCl and CAA), CCA washed carrot was better than that of NaOCl washed carrot. Similar results were found in previous study. In respect of  $L^*$ ,  $a^*$ ,  $b^*$  and C, carrot washed by sanitizer showed significantly higher followed control (unwashed) at 5% level. In case of  $h^\circ$ , unwashed carrot was found highly significant followed by washed carrot by sanitizer at 5% level (Table 65).

Table 65. Statistical analysis of colour parameter of harvested washed and unwashed carrots

Treatment	Parameters				
	$L^*$	$a^*$	$b^*$	$h^\circ$	C
Unwashed (control) carrot	44.48b	7.89b	16.20b	64.44a	18.04b
Washed by NaOCl carrot	58.00a	22.30a	32.69a	53.57b	40.53a
Washed by CCA carrot	58.54a	23.82a	34.53a	57.00b	41.11a

### Weight loss of carrot in cold storage

Effect of storage period on weight of washed and unwashed carrots of different treatments stored in commercial cold storage at 4 month is shown in Fig.149. It was observed that the maximum weight loss was found in  $T_0$  (unwashed carrot packed in jute sack) than that of other treatments. It was also observed that the lower weight losses of washed carrot with water and CCA packed in jute sack, unwashed and washed carrots packed in jute sack with polyethylene lining were found. On the other hand, negligible weight losses of other treatments were found due to carrot packed with polythene lining.

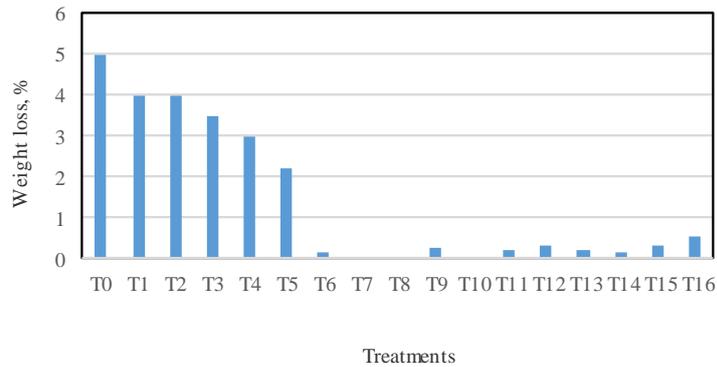


Fig.149. Effect of storage period on weight loss of washed and unwashed carrots of treatments stored in commercial cold storage at 4 month

### Rotting of stored carrot

Effect of storage period on washed and unwashed carrots of different treatments stored at 60, 66 and 120 days of storage is presented in Fig.150. It was observed that there was no rotting or spot of carrots at 60 days of storage at 0-1° C and 98-100% Rh. It was also observed that rotting of carrot occurred from 66 days of storage at same storage condition.

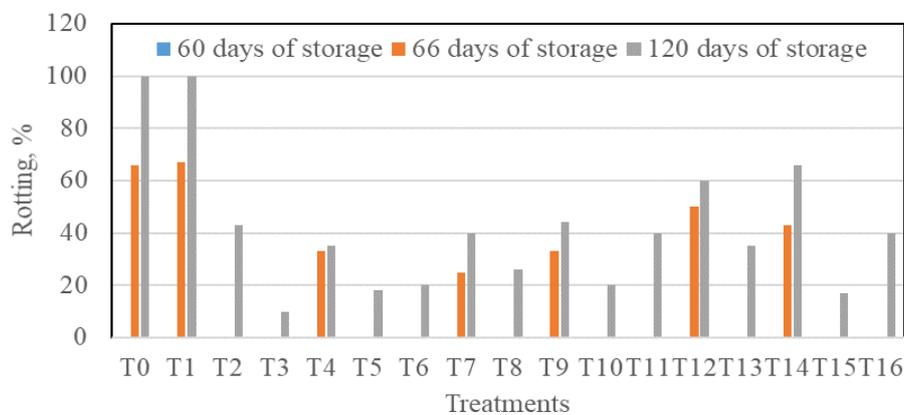


Fig.150. Effect of storage period on rotting of washed and unwashed carrots of treatments stored in commercial cold storage at 4 month

In 66 days of storage period, the maximum rotting was found in treatments of T<sub>0</sub> & T<sub>1</sub>; and no rotting was in T<sub>2</sub>, T<sub>3</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>8</sub>, T<sub>10</sub>, T<sub>11</sub>, T<sub>13</sub>, T<sub>15</sub> and T<sub>16</sub>. At 120 days of storage of carrot, 100% carrot was rotting in treatment of T<sub>0</sub> & T<sub>1</sub> and at minimum (10 -20%) rotting was observed in T<sub>3</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>8</sub>, T<sub>10</sub>, and T<sub>15</sub>. It revealed that minimum rotting was occurred due to polyethylene lining and CCA washed. The lowest rotting was found in T<sub>3</sub> (Unwashed packed in jute sack with polyethylene lining). Rotting of stored carrot was measured at 66 days of storage by collection of sample about 1 kg of treatment. At last, rotting of stored carrot was calculated at 4 month of storage.

### Chemical parameters of washed and unwashed carrots

Chemical parameters of harvested fresh unwashed and washed carrots with sanitizer during 11 March 2019 are shown in Table 66. Total phenolic content ranged from 0.052- 0.064 mg GAE/g of dry weight of the sample. The CCA washed carrot showed higher total phenolic content than that of NaOCl washed carrots. It was also evident that irrespective of washing

materials the total phenolic content reduces. The total carotenoid content of the non-washed and washed carrot samples before cold storage were significantly ( $P < 0.05$ ) different on day 0, ranging from 142.12-158.57 mg/100g fresh weight (FW). The ascorbic acid (vitamin C) content of non-washed and washed carrot before cold storage ranged from 4.48–5.05 mg/100g FW and was significantly ( $P < 0.05$ ) lower for non-sanitized carrot. The total soluble solids (TSS) ranged from 8.7–9.3 %. Carrots are regarded to be typically low in acid (Vora, 2001). Commercially the TA value is equally as important as TSS with regards to quality scoring. The TA (citric acid) values ranged from 0.07–0.11% on day 0. In all the chemical parameter analyzed, non-washed carrot showed higher values compared with washed carrots. On the other hand, CCA washed samples showed significantly higher than that of NaOCl washed carrots.

Table 66. Chemical parameters of harvested fresh washed and unwashed carrots

Test parameters	Treatments	Results
Total Phenolic (mg GAE/g)	Unwashed carrots (control)	0.064
	Chlorine water (3.8 ml/2 litre) washed	0.052
	CCA (1g/10 litre) water washed	0.059
Total carotenoids (mg/100g)	Unwashed carrots (control)	158.57 ± 6.26
	Chlorine water (3.8 ml/2 litre) washed	142.12 ± 4.73
	CCA (1g/10 litre) water washed	150.21 ± 2.33
Vitamin C (mg/100g)	Unwashed carrots (control)	5.05 ± 0.02
	Chlorine water (3.8 ml/2 litre) washed	4.48 ± 0.01
	CCA (1g/10 litre) water washed	4.95 ± 0.01
Titratable acidity (%)	Unwashed carrots (control)	0.11
	Chlorine water (3.8 ml/2 litre) washed	0.07
	CCA (1g/10 litre) water washed	0.09
TSS Brix (%)	Unwashed carrots (control)	9.3 ± 0.01
	Chlorine water (3.8 ml/2 litre) washed	8.7± 0.01
	CCA (1g/10 litre) water washed	9.1± 0.01

**Physiological weight and decay losses:** The weight and decay losses of unwashed and washed carrot packed in different packages stored in commercial cold store is shown in Fig.151. It was observed that weight and decay losses of unwashed and washed carrot packed in jute sack were higher than that of washed and unwashed carrot packed in plastic crate and CFB carton on 6 months of cold storage. But there was no significant differences among unwashed and washed with CCA and NaOCl packed in jute sack (Table 67). It was revealed that weight loss of unwashed carrot in jute sack was lower than those of washed carrot in jute sack due to mud on the unwashed carrot surface that is functioned as wax material. The lowest weight losses of unwashed and washed carrot packed in CFB carton was found followed to jute sack and plastic crate. The highest decay loss of washed carrot was observed in CCA washed packed in jute sack. The lowest decay loss of washed (with CCA and NaOCl) carrots packed in plastic crate was found followed by jute sack and CFB carton packages. In respect of decay loss, there were no significant differences among washed with CCA carrot packed in plastic crate and CFB carton with polythene lining and washed with NaOCl packed in plastic crate with polyethylene lining (Table 67). It was also noted that unwashed carrot packed in CFB and plastic crate were comparatively better than those of unwashed and washed carrot packed in jute sack regarding on decay and weight loss. In respect of decay and weight loss, it was concluded that CCA and NaOCl washed carrot

packed in plastic crate and CCA washed packed in CFB carton were significantly the best package for storing of 5-6 months in commercial cold store. Using these packages, weight loss was reduced by 82-100% compared with conventional practice (carrot with mud packed into jute sack) and decay reduced by 90-96% compared with conventional practice (carrot with mud packed into jute sack). Similar study was conducted by Yanmaz et al. (1999) for packaging in perforated PE bags decreased weight loss in carrots during storage period. Weight loss was also affected by storage temperature. While weight loss determined as 1-5% after six months in 0°C. Weight loss attributable to changes in the tissue water content was the most important factor affecting postharvest life of carrots according to relevant studies. Geeson (1985) also reported increased weight loss and softening of tissue with an increased storage temperature; weight loss was 0.4-0.8% during a 9-month storage period at 0°C with no softening, but increased to 1.5 to 2.0% during 4 to 5 month storage period at accompanied by softening at 5°C.

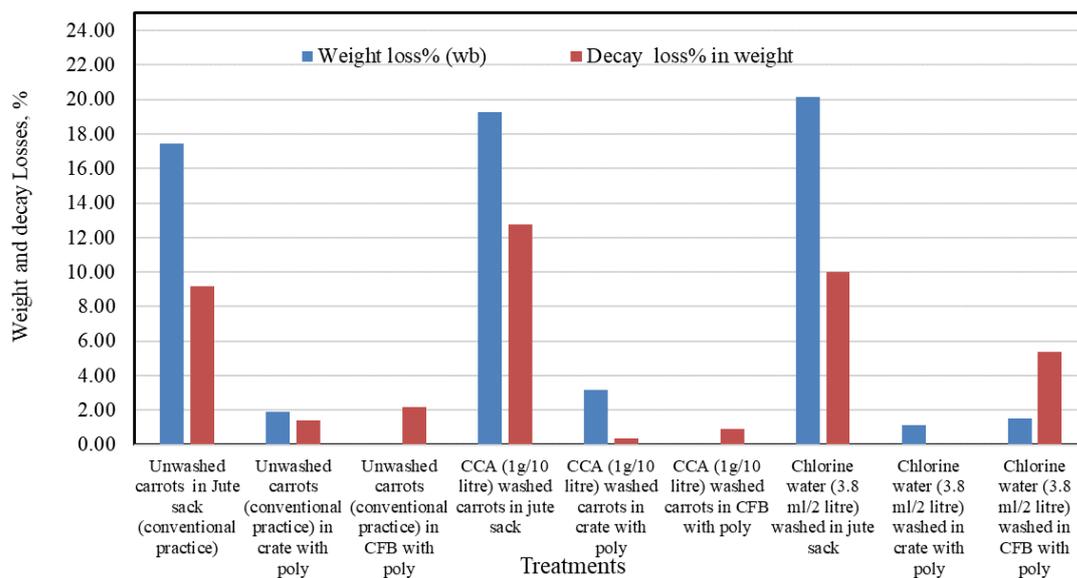


Fig. 151. Weight and decay losses of stored (cold storage) washed and unwashed carrot packed in different packages

Table 67. Statistical comparison of weight and decay among the treatments

Treatment	Weight loss, % (wb)	Decay loss, % in weight
Unwashed carrots in jute sack (conventional practice)	17.43a(4.17)	9.17a (3.08)
Unwashed carrots (conventional practice) in crate with poly	1.90ab(1.55)	1.43ab(1.38)
Unwashed carrots (conventional practice) in CFB with poly	0.00 c (0.71)	2.20ab(1.63)
CCA (1g/10 litre) washed carrots in jute sack	19.26a (4.38)	12.75a(3.57)
CCA (1g/10 litre) washed carrots in crate with poly	3.18b (1.91)	0.367c(0.89)
CCA (1g/10 litre) washed carrots in CFB with poly	00.00c (0.71)	0.90c (1.07)
Chlorine water (3.8 ml/2 litre) washed in jute sack	20.14a (4.49)	9.98a (3.18)
Chlorine water (3.8 ml/2 litre) washed in crate with poly	1.13b(1.26)	0.00c(0.71)
Chlorine water (3.8 ml/2 litre) washed in CFB with poly	1.50b (1.37)	5.40 b(2.14)

### Colour parameters of washed and unwashed carrot:

Brightness of unwashed and washed carrot packed in jute sack, plastic crate and CFB carton during cold storage period is presented in Fig.152. It was observed that colour parameter L\* value of carrot increased with the storage period. Brightness of harvested fresh washed carrot was higher than that of unwashed carrots at zero month. At the end of 6 months, unwashed carrot in different packages showed insignificantly the highest brightness. On the other hand, L\* value of washed carrot with CCA and NaOCl in jute sack higher than unwashed carrot in jute sack those were insignificant with same sanitizer of plastic crate and CFB carton. Both the CCA and NaOCl washed carrot packed into all package was significantly higher brightness than unwashed carrot in same package upto 5 months. In respect of package, both the package of CFB carton and plastic crate washed with sanitizer showed more brightness. It was obvious that non-chlorine sanitizer (CCA) is preferred than chlorine sanitizer (NaOCl) for washing of carrot. For this reason, CCA washed carrot packed into CFB carton and plastic crate would be used for long time storing. Similar finding was reported by Özdemir et al.,(2018).

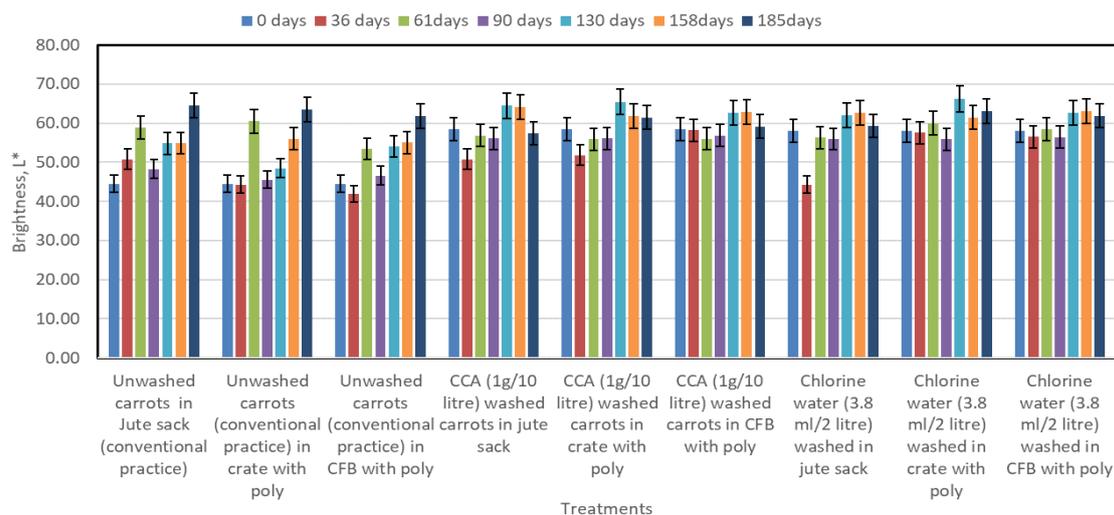


Fig. 152. Brightness of unwashed and washed carrot packed in jute sack, plastic crate and CFB carton during cold storage period

Hue angle of washed with CCA and NaOCl and unwashed carrot packed in jute sack, plastic crate and CFB carton is shown in Fig. 153. Hue angle ( $h^\circ$ ) of fresh harvested unwashed carrot in all packages was higher than  $60^\circ$  at 0 month storage. It increased to  $85^\circ$  at the end of 6 months storage. It indicated that unwashed carrot was yellowish lime colour. It was not attractive colour for marketing. It was observed that hue angle of fresh harvested washed carrot in all packages was less than  $60^\circ$  at 0 month storage. It increased to  $67^\circ$  with storage period (at the end of 6 months storage). It was obvious that washed carrot was reddish yellow colour.

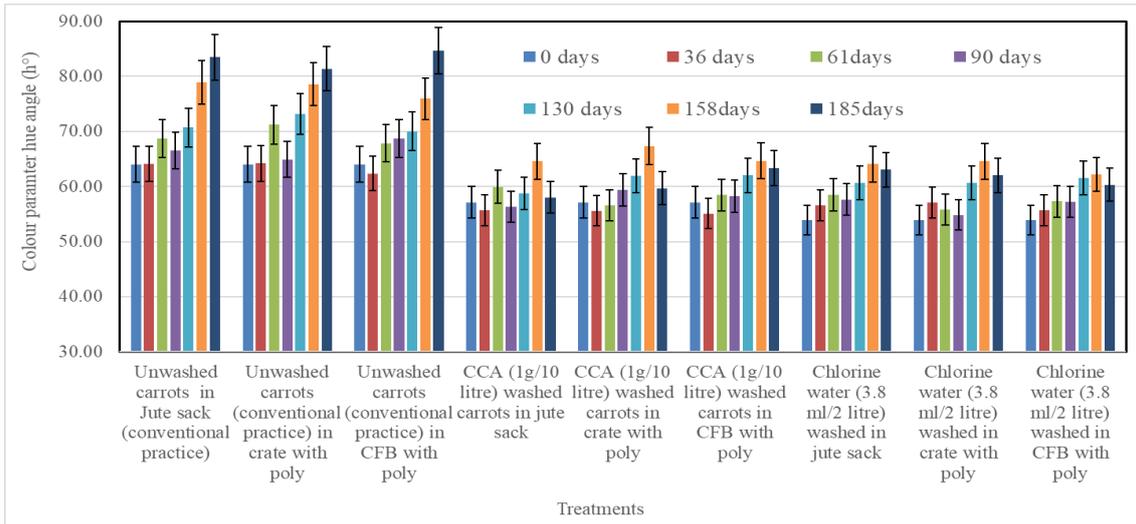


Fig. 153. Hue angle of washed with CCA and NaOCl and unwashed carrot packed in jute sack, plastic crate and CFB carton

It is noted that washed carrot with both the sanitizers packed in plastic crate and CFB carton was reddish yellow colour than that of washed carrot in jute sack. On the other hand, washed carrot with NaOCl packed in CFB was more reddish yellow colour than that of CCA washed packed in CFB carton. Now it was known to all that chlorine sanitizer use is discouraged. So, plastic crate and CFB carton along with non-sanitizer (CCA) would be used for washing of carrot. Similar findings were reported by the investigators that carrot color  $h^{\circ}$  value of the carrots reduced in the MAP storage (Genç, 2018a, b; Karaca et al. 2008).

Chroma of washed with CCA and NaOCl and unwashed carrot packed in jute sack, plastic crate and CFB carton is shown in Fig. 154. It was observed that chroma value of unwashed carrot packed in jute sack, CFB carton and plastic crate lower than that of washed carrot packed same packages with polyethylene lining. The lower chroma value represented vividness of colour is lower intense. The chroma value of washed carrot packed in all packaged with polyethylene lining was double than those of unwashed carrot in all packages without lining. The higher value of chroma expressed higher vividness of colour.

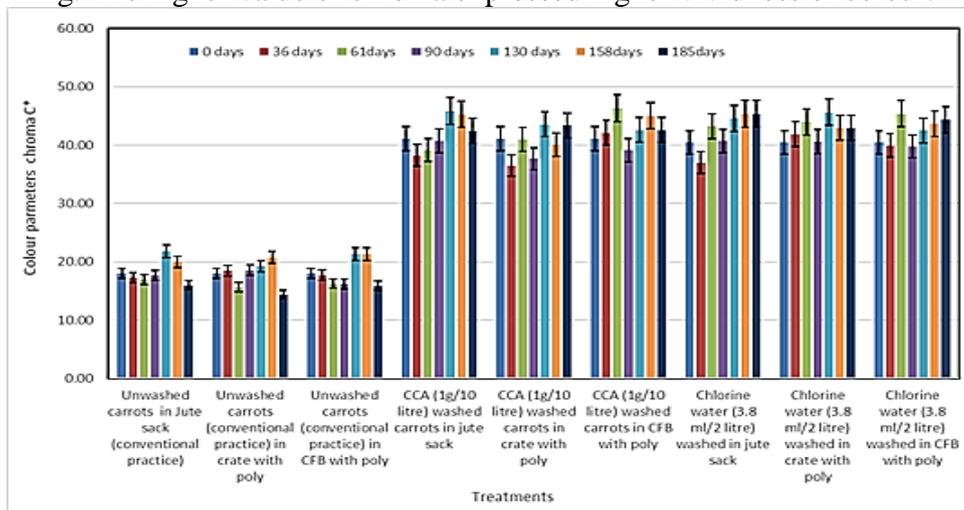


Fig. 154. Chroma of washed with CCA and NaOCl and unwashed carrot packed in jute sack, plastic crate and CFB carton

## Firmness

Variation of firmness on storage period of washed and unwashed carrot packed in jute sack, plastic crate and CFB carton is shown in Fig.155. Firmness of fresh harvested carrot was ranged from 43 to 49 Newton. Firmness of washed and unwashed carrot varied during storage period and similar trend was observed for all treatments. It revealed that firmness increased or decreased due to varied of temperature and humidity in the cold storage inside and to variation of physiological maturity of carrot. At 4 and 5 month storage period, firmness of all treatments increasing trend except NaOCl washed carrot packed in CFB carton with polyethylene. On the other hand, higher firmness was observed in washed carrot packed in both the CFB carton and plastic crate than that of unwashed carrot packed in jute sack, plastic crate and CFB carton during storage period of 4 to 5 months. Similar results on carrot firmness were found in many studies ((Genç, et. al 2018a,b; Kasım, 2001a,). As the storage period of the carrots got longer, the carrot firmness, which initially averaged 99.67 N showed some increases and decreases; at the end of the 5th month, it decreased to 82.89 N. However, the variations between treatments were found as statistically insignificant at carrot firmness during storage time (Özdemir et al.,2018). Contrary, unlike our findings, Klaiber et al. (2004) observed an increase in the firmness of storage resulting from the dehydration and the onset of lignification during storage.

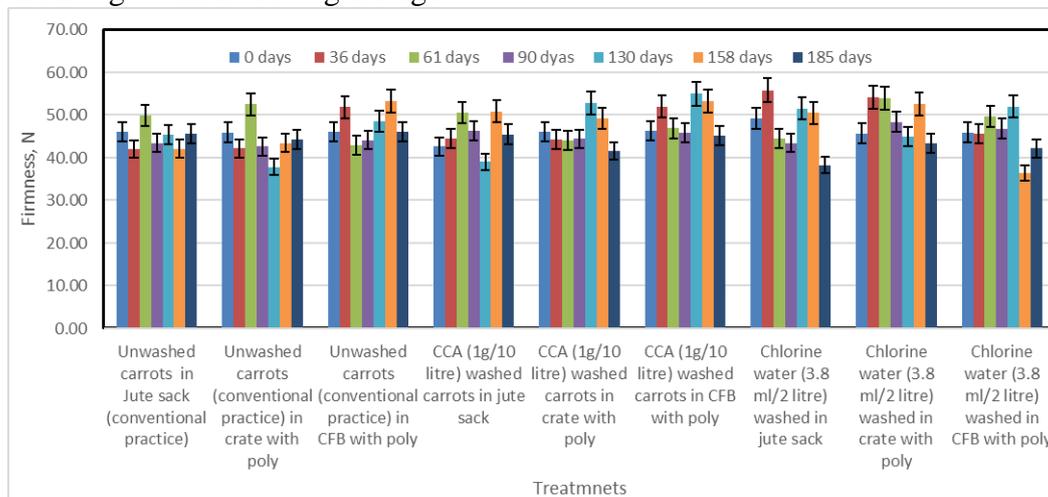


Fig. 155. Variation of firmness on storage period of washed and unwashed carrot packed in jute sack, plastic crate and CFB carton

## Microbial load analysis

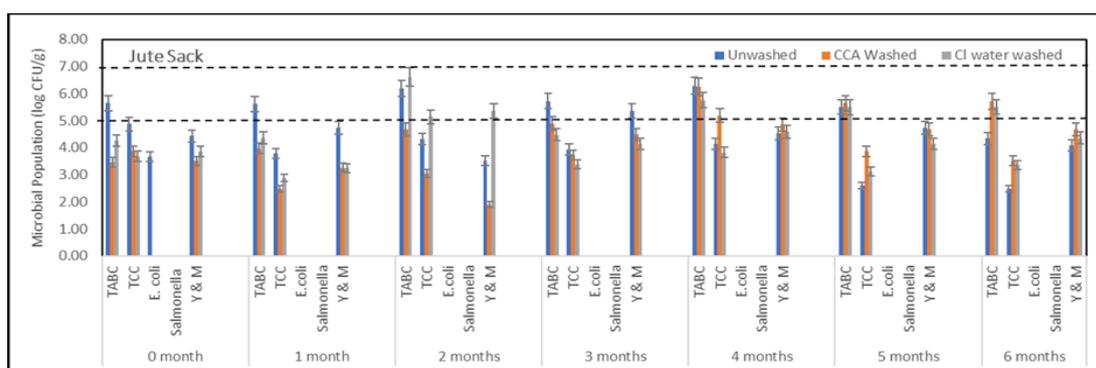
According to the ICMSF 2002, Total aerobic bacterial count 5.0 log CFU/g is the lower threshold limit of freshness of cold stored (0-2°C; 98% RH) fresh produce and 7.0 log CFU/g is the thresholds limit of spoilage of cold stored fresh produce. Therefore, these values were applied in the graph to judge the microbiological quality of carrot stored for 6 months in a commercial cold store.

This study results showed that washed carrot showed better microbial quality than that of unwashed carrot throughout the six months storage period in commercial cold storage. Total bacterial count in unwashed carrot packed in Jute sack, CFB carton and plastic crate, and stored under commercial cold storage, cross the lower threshold limit from 1 month and increase gradually or remain constant throughout the 6 months storage period, on the contrary, unwashed carrot in jute sack packages showed better microbial quality than other two packaging conditions (Fig. 156 A). Nevertheless, irrespective of packaging conditions, non-significant differences in microbial quality of washed carrot stored six months in a commercial cold storage was observed. However, CCA washed carrot showed lower TABC &

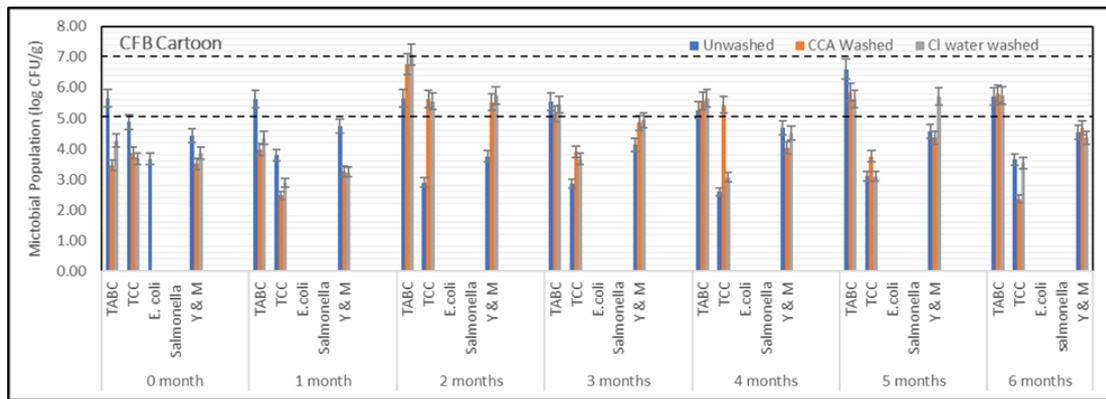
TCC count, which is below the lower threshold limit after six months of storage. In addition, CCA washed carrot packed in plastic crate and CFB carton stored under commercial storage conditions, showed better microbiological quality than chlorine washed carrot under similar packaging and storage conditions (Fig.156 B, C). On the other hand, chlorine washed and unwashed carrot cross the lower threshold limit after six months of storage in jute sack and CFB carton under commercial storage conditions. Overall, irrespective of packaging conditions, none of the washed carrot stored in a commercial cold storage for six months was found cross the upper threshold limit and thus acceptable in microbial quality. However, among the packaging and washing treatment, CCA washed carrot packaged in plastic crate and stored in commercial cold storage showed better quality than chlorine washed and non-washed carrot stored under similar packaging and storage conditions (Fig.156 C). The most prominent storage decays are bacteria soft rot (induced by *Pectobacterium carotovora* or *Pseudomonas marginalis*), gray mold rot (*Botrytis cinerea*), rhizopus soft rot (*Rhizopus* spp.), watery soft rot (*Sclerotinia sclerotiorum*), and sour rot (*Geotrichum candidum*) (Snowden 1992). Ozone is a fungistatic against *Botrytis* and *Sclerotinia*, but tissue damage and color loss occur after treatment (Liew and Prange 1994). Good sanitation during packing and storage at 0 °C minimizes postharvest diseases.

Appropriate postharvest handling practices are important to minimize postharvest losses and to maintain the quality of vegetables. Potential postharvest handling activities include packaging, pre-treatment, pre-cooling, washing and sorting. The function of packaging is to protect the produce from mechanical injury and contamination during marketing. It also prevents moisture loss, and facilitates in chemical treatment and ethylene absorption (Kader and Rolle, 2004). Long distance transportation of fresh produces with poor packaging conditions were the major sources of wastage. Transport of fresh vegetables using plastic crates in cold environment minimizes the loss (Ananya and Pornthipa 2017).

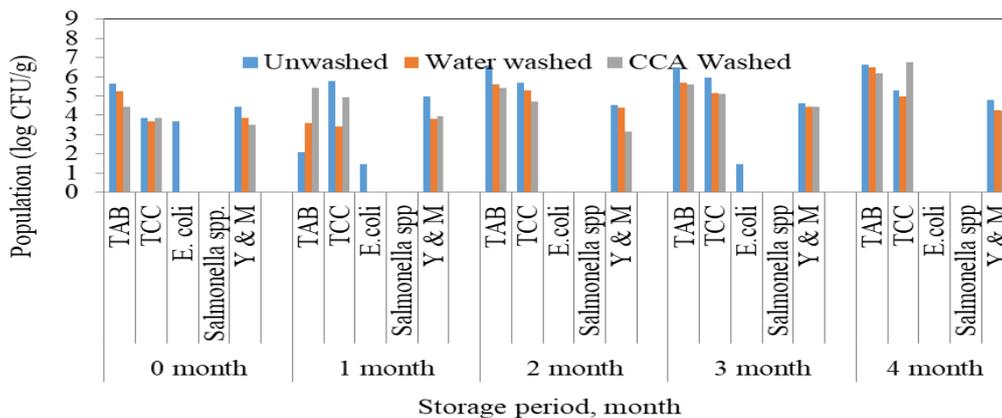
Washing and sanitization are now considered as standard post-harvest operation and various sanitizing agents including, acidified NaOCl (Inatsu et al., 2005; Nei et al., 2010) Ca(OCl)<sub>2</sub>, acidified Ca(OCl)<sub>2</sub> (Kim et al. 2005; Inatsu et al., 2010; Elano et al., 2011), Na<sub>3</sub>PO<sub>4</sub>, Tsunami™ (Beuchat et al., 2004), H<sub>2</sub>O<sub>2</sub> (Ukuku et al.,2004), gaseous acetic acid (Nei et al., 2010), organic acid (Ukuku et al., 2015), ozone, ozonated water & ozone nano bubble (Inatsu et al., 2011), acidified electrolyzed water (Bari et al., 2003; Rahman et al., 2010), peroxyacetic acid (Beuchat et al., 2004), Combination of EDTA and organic acid, (Bari et al., 2005) etc., were used for washing fruits and vegetables in reducing the risk of microbial contamination, helping in the prevention of postharvest diseases and foodborne illness. However, most of these sanitizers, were either expensive or non-user friendly or involves some risk. Furthermore, ozone, electrolyzed water, mild-heat treatment (Yasmin et al., 2008; Ingram & Millner, 2007) with organic acid, heated shell powder or calcinated calcium (Bari et al., 1999) and other natural sanitizers alone or in combinations have been applied to various fresh vegetables and are acceptable for both organic and non-organic fresh produce.



A) Jute Sack packages



B) CFB carton



C) Plastic Crate

Fig. 156. Microbiological quality of washed and un-washed carrot packed in A) jute sack, B) CFB carton and C) plastic crate, and stored in a commercial cold storage (0.1-4.3°C; 94% RH) for 6 months.

Variation of temperature and relative humidity inside the cold storage is shown in Fig.157. The maximum, minimum and average temperature and relative humidity inside cold store were found to be 4.30, 0.1 and 1.14°C; and 93.90, 76.30 and 89.62% respectively. It is noted that this temperature and humidity are suitable for long time (5-6 month) storing of carrot. Gor'kovenko (1992) has pointedly recommended a 1-2° C storage temperature and 80-85% relative humidity as the optimal conditions for carrot storage.

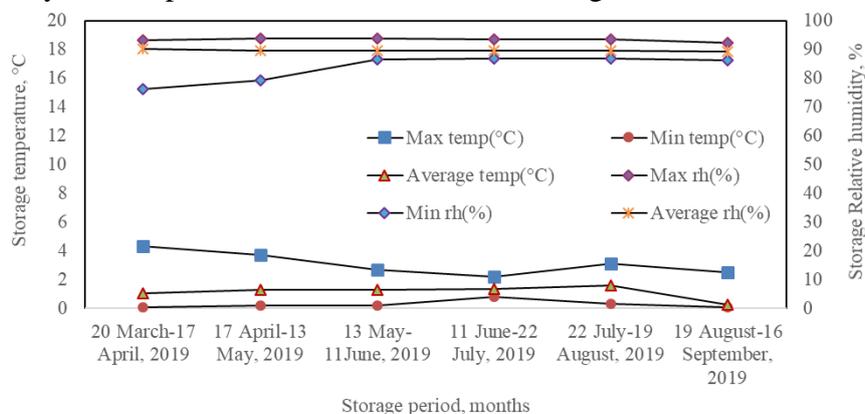


Fig. 157. Variation of temperature and relative humidity on storage period of washed and unwashed carrot packed in jute sack, plastic crate and CFB carton

In carrots storage, clean stores should be used in the storage, the temperature should be kept close to 0°C and the relative humidity should not be more than 95% (Tülek, S., Dolar, F.S., 2011). Gross et al. (2016) mentioned carrot storage conditions in their hand book that carrots would be harvested top trimmed and packed in 0.5 to 2.25 kg perforated plastic “Cello-pack” bags. Prompt washing and hydrocooling to under 5°C are essential to maintain carrot freshness and crispness. Typically, carrots pass through several wash and flume steps that remove field heat and are then hydrocooled in chlorinated water before packing. Mature topped carrots is stored for 7 to 9 mo at 0°C with 98 to 100% RH. So, topped carrots are often stored for 5 to 6 month at 0 to 5°C with 90 to 95% RH in commercial storage.

### Observation of sprouting

Table 68 shows the sprouting of stored carrot occurred during storage period. Sprouting of carrot is observed to increase in all packages over the six months storage period. It was occurred in unwashed carrot packed in jute sack, CFB carton and plastic crate and washed carrot in jute sack from 3 months storage period. At the end of 6 months, 100% carrot was sprouted in both the CFB carton and plastic crate except jute sack (50-60%) (Fig. 158). It is seem to be fungus but really it is sprouting on carrot. Less sprouting was observed for unwashed and washed carrot packed into jute sack. It was reported by different investigators that root and sprout ratios increased during storage. It was reported that the storage temperature should be between 0.1 and 4.30°C in order to minimize the sprout rate during storage (Genç, et. al 2018a,b; Kasım, 2001a, b). In all treatments, sprouting were observed, but unlike our findings, in a study conducted by Terzioğlu (2000), carrots were not rooted and sprouted in all treatments during cold storage for 5 months. Özdemir et al. (2018) determined that using MAPTW (modified atmosphere packaging and washing with tap water) + SMBS treatment, ‘Nanco F1’ type carrots could be stored for 4 months and using MAPTW treatment, they could be stored for 5 months at 0°C and 85-90% relative humidity without losing much of the quality for local and distant markets. As the storage period of ‘Nanco F1’ variety carrots was prolonged, the ratios of rooting and sprouting increased from 2nd month and reached to average 64.17% and 20.42% respectively at the end of 5th month. Similar worked conducted by Yanmaz et al. (1999). They reported that sprouting and weight loss of Nandor F1 variety carrot were found to increase by 66.53% and 4.91% for 20 kg packages as storage period respectively.



Fig. 158. Observation of sprouting of stored carrot

Table 68. Sprouting of stored carrot during storage period

Treatments	Observation of sprouting, %					
	Storage duration, Months					
	1	2	3	4	5	6
Unwashed carrots in jute sack (conventional practice)	0	0	10	20	40	60
Unwashed carrots in crate with poly	0	0	03	10	50	100
Unwashed carrots in CFB with poly	0	0	03	10	50	100
CCA (1g/10 litre) washed carrots in jute sack	0	0	10	20	30	50
CCA (1g/10 litre) washed carrots in crate with poly	0	0	0	10	25	100

Treatments	Observation of sprouting, %					
	Storage duration, Months					
	1	2	3	4	5	6
CCA (1g/10 litre) washed carrots in CFB with poly	0	0	0	10	25	100
Chlorine water (3.8 ml/2 litre) washed in jute sack	0	0	5	10	30	50
Chlorine water (3.8 ml/2 litre) washed in crate with poly	0	0	0	10	30	100
Chlorine water (3.8 ml/2 litre) washed in CFB with poly	0	0	0	10	25	100

### Carrot storage during 2020

Colour parameters, firmness, specific gravity and dry matter of harvested fresh carrot are shown in Table 69. It was observed that brightness of washed carrot was higher than that of unwashed carrot. The highest brightness was found in treatment of washed carrot with NaOCl followed by others that was significantly higher. On the other hand, there was no significant difference between unwashed and washed in CCA carrot. Reddish colour (positive a\*) of washed and unwashed carrot was observed but they had significant differences. The highest reddish colour was observed in treatment of CCA washed carrot whereas the lowest reddish colour was unwashed carrot. All treatments showed yellowish colour (positive b\*) but the highest yellowish color was observed in both the CCA and NaOCl washed carrot and the lowest yellowish color was in unwashed carrot. It was revealed that yellowish color of washed carrot was significantly higher compared to unwashed carrot. In respect of hue angle (h°), there was significant differences among them whereas the highest hue angle was found in unwashed carrot and the lowest was in CCA washed carrot. The lowest saturation of colour (C\*) was found in unwashed carrot that was significantly different followed washed carrot. Both the CCA and NaOCl washed carrot had no significant differences in respect of chroma (C\*). The vividness of colour of washed carrot was double than that of unwashed carrot. In respect of hue and chroma, the combinations of reddish (a\*) and yellowish (b\*) colour represented orange-yellow for unwashed carrot and yellowish-orange for both the washed carrot. In respect of firmness of carrot, there was no significant differences among the treatments. The dry matter content of fresh harvested carrot was found to be 11.83 to 14.87% (wb). The highest dry matter content was found in NaOCl washed carrot followed by unwashed carrot and CCA washed carrot. Both the washed treatments similar but they were significantly difference from unwashed carrot. It was also found that specific gravity of harvested fresh carrot was 1.013 g/cc. It indicated that carrot was fully matured.

Table 69. Maturity parameters of harvested fresh carrot

Treatment	L*	a*	b*	h°	C*	Kinds of colour	Firmness, N	Dry matter content, % (wb)	Specific gravity, g/cc
Unwashed carrots	48.05b	5.50c	20.59b	52.99a	25.78b	Orange-yellow	111.96a	11.83b	1.013
CCA washed carrot	48.26b	28.97a	33.88a	49.43c	44.59a	yellowish-orange	115.05a	12.45b	
NaOCl washed carrot	50.99a	26.54b	33.30a	51.33b	42.59a	yellowish-orange	106.43a	14.87a	

### Dry matter contents of stored carrots

Dry matter contents of stored carrots packed in jute sack, CFB carton and plastic crate for 5 months storage is shown in Fig.159. It was observed that dry matter of unwashed carrots packed in different packages increased with the storage period followed by washed carrots with CCA and NaOCl. On the other hand, unwashed carrot packed in jute sack was higher

than that of other packages of washed and unwashed carrots. Dry matter contents of washed carrot with CCA and NaOCl packed in CFB carton and plastic crate insignificantly decreased with the storage period.

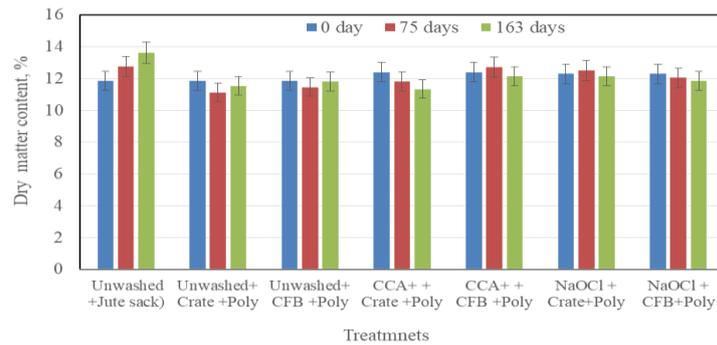


Fig. 159. Changes of dry matter contents of washed and unwashed in different packages with storage period of 5 months

Changes of brightness of washed and unwashed in different packages with storage period of 5 months is shown in Fig. 160. It was found that brightness of peel of unwashed carrots was lower in 75 days storage but later it was insignificantly increased whereas brightness of washed carrot was significantly increased with storage periods compared to unwashed carrot in same packages. It was also observed that brightness of CCA washed carrot peel was higher followed by unwashed and washed in NaOCl.

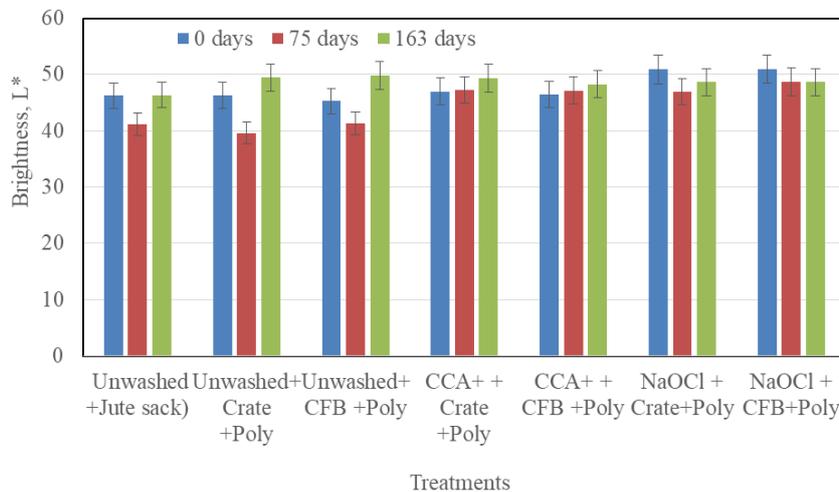


Fig. 160. Changes of brightness of washed and unwashed in different packages with storage period of 5 months

Changes of hue angle and chroma of washed and unwashed in different packages with storage period of 5 months is shown in Fig.161 and 162 respectively. It was observed that hue angle of unwashed carrot insignificantly increased with storage period whereas insignificantly decreased in washed carrots in the both sanitizers (CCA and NaOCl).

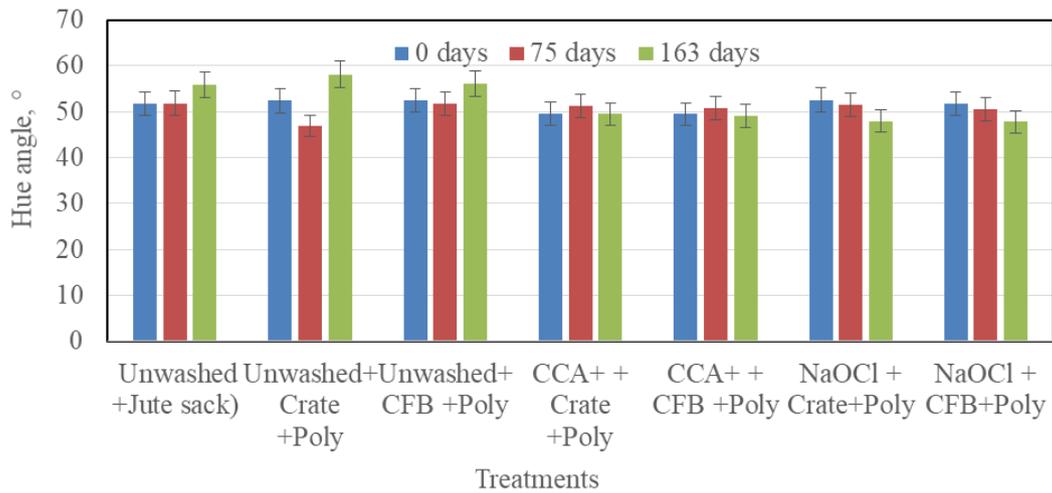


Fig. 161. Changes of hue angle of washed and unwashed in different packages with storage period of 5 months

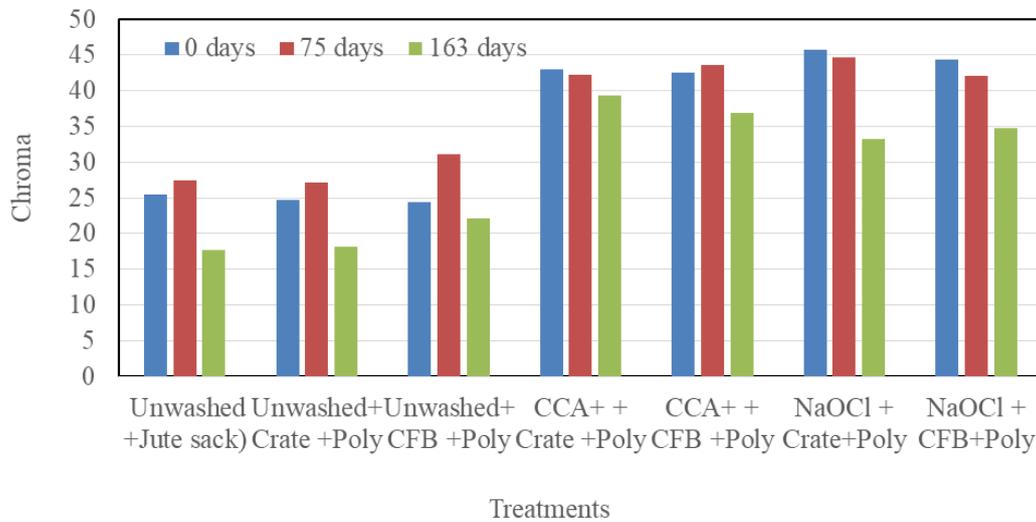


Fig. 162. Changes of chroma of washed and unwashed in different packages with storage period of 5 months

Higher chroma was found in washed carrots compared to unwashed carrots. Colour intensity was deep in washed carrots. Chroma of washed and unwashed carrots decreased with the storage periods. The colour of unwashed and washed carrots was yellow and orange yellow respectively. CCA and NaOCl washed carrot packed in CFB carton showed better in colour followed by others.

Changes of decay of washed and unwashed in different packages with storage period of 5 months is presented in Fig.163. After storing of 5 months, the significantly lowest decay was observed in unwashed carrot packed in CFB carton followed by unwashed carrot packed in jute sack and plastic crate and washed in all packages. The second lowest was found in unwashed carrot packed in plastic crate. The CCA washed carrot packed in CFB carton showed the third lowest in respect of decay followed by washed carrot packed in plastic crate.

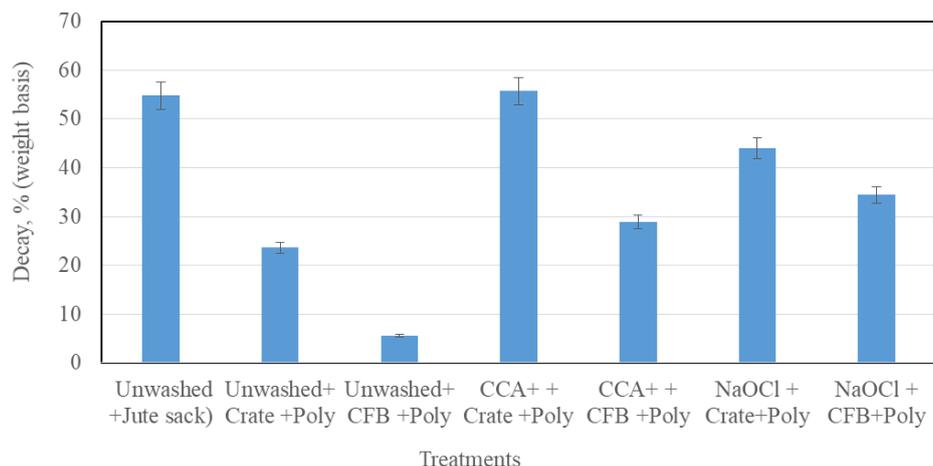


Fig. 163. Changes of decay of washed and unwashed in packages with storage period of 5 months

Changes of sprouting of washed and unwashed in different packages with storage period of 5 months is presented in Fig. 164. After storing of 5 months, all carrots of washed and unwashed packed in jute sack, CFB carton and plastic crate were sprouted. It indicated that the significantly lowest sprouting was observed in top of the unwashed carrot packed in jute sack whereas sprouting on the peel surface of unwashed and washed carrot both packed in CFB carton and plastic crate. The lowest sprouting on peel was observed in unwashed and washed with CCA packed in plastic crate followed by other washed and unwashed carrot packed in same packages.

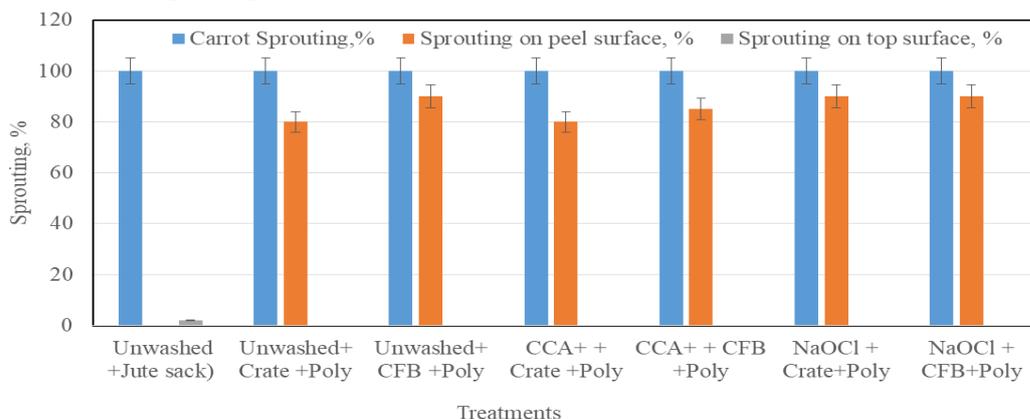


Fig. 164. Changes of sprouting of washed and unwashed in different packages with storage period of 5 months

### Evaluation of market price of carrot

Variation of purchasing and selling prices of harvested and stored carrot is shown in Fig. 165. It was found that purchase price of harvested carrot during 21 March 2018 was 15 Tk./kg. The market selling price of stored carrots gradually increased up to May 2018 and later it decreased. It revealed that market selling price of stored carrot always higher than that of harvested carrots. The cold storage charge of carrots was 10 Tk./kg for 4-6 month of storage.

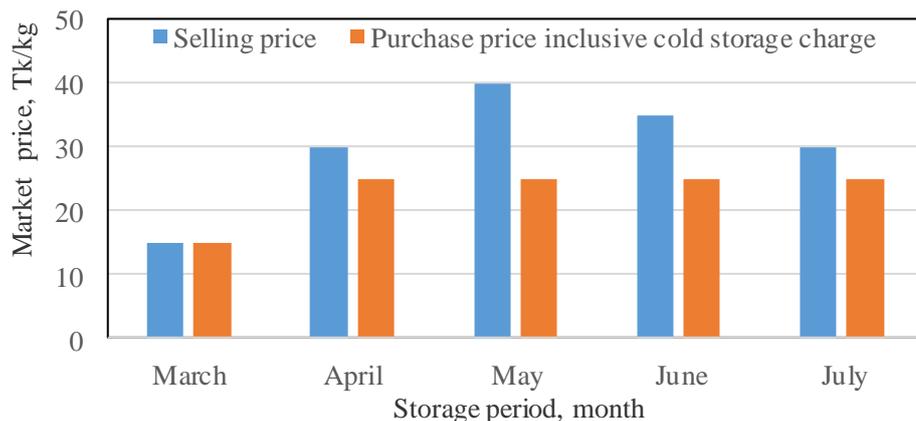


Fig. 165. Variation of market price of carrots during storage period

The purchase price of the carrots inclusive storage charge was 25 Tk./kg for whole the storage period. It was also observed that selling price was higher than that of purchase price inclusive storage charge. The maximum profit was found to be 15 Tk./kg and minimum was 10 Tk./kg.

#### Calculation of benefit cost ratio

Calculation of benefit cost of stored carrot in commercial cold storage during 4 months is presented in Table 70. Profit of the stored carrots packed in jute sack with polyethylene lining was found to be 7 Tk per kg and benefit cost ratio was 1.26.

Table 70. Calculation of benefit cost of stored carrot in commercial cold storage during 4 months

Sl. No.	Item	Price, Tk./kg
1	Purchase price of harvested carrot	15
2	Average selling price of stored carrot for 4 month storage	34
3	Cold storage charge during storage periods (1-4 months)	10
4	Total price of stored carrot for jute sack (1+3+7a+7b+8+10))	27.15
5	Profit(2-4)	7
6	BCR(2/4) over total price	1.26
7	Packaging cost	
a	Price of Jute sack of 80 kg (70 Tk),	0.90
b	Price of polyethylene bag of 80 kg (20 Tk)	0.25
c	CFB carton of 10 kg (20 Tk)	2.0
d	Plastic crate of 15 kg (300 Tk)	0.10
8	Sorting, grading and packaging cost	0.50
9	Washing cost of harvested carrot	0.40
10	Washing cost of stored carrot	0.50

At first storage variety of carrot is to be selected and harvested matured carrot (maturity index: hue angle:57-64°, Firmness: 46N and °Brix:8) at early in the morning or afternoon. Donot harvest carrot after immediate rainfall on the carrot field. and donot harvested carrot in the sunshine. As soon as possible, keep harvested carrot in the shad place or bagging and transported in the shdy place or packhouse. Within one days harvested carrot should be sorted (discared over size, injury,under size, spot, crack) graded (uniform size), cleaned,

washed, dried and packed in package with lining polyethylene sheet (0.05mm thickness) and immediately stored in inside the cold storage at 1-2°C for 90-95% relative humidity. Before packing, sorting and grading must be maintained. Before entering inside the cold storage, packed carrot should be kept in pre-cooling room at 15-20°C. In jute sack should be turnover 3-4 times during the storage period. Cleaning efficiency and washing efficiency should be maintained at 96% and 98% respectively. Protocol of carrot storage value chain is illustrated in Fig.166.

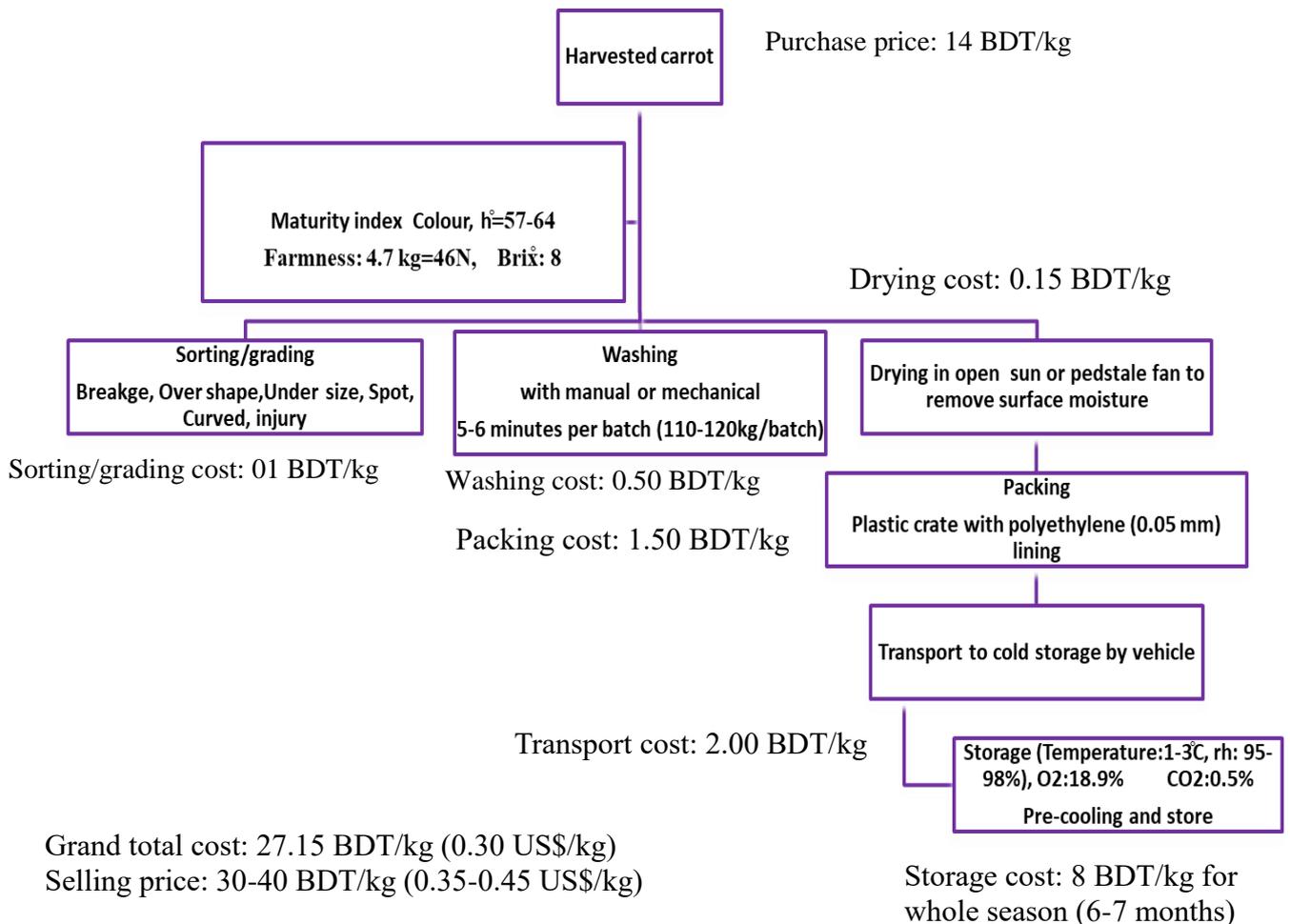


Fig.166. Protocol of carrot storage value chain

### Implementing component-3: CARS, DU

#### Study-1:

**Survey in the value Chain:** Postharvest Technology Section (PHTS) of HRC, BARI took initiative of conducting survey; Dhaka University assisted in collecting information on quality and safety related practices followed by value chain actors for the target crops. Findings of survey were reported in the part of implementing component-1 by PHTS; hence, would not be mentioned in the respective section of implementing component-3.

**Study-2:** Study on the efficacy of non-chlorine sanitizer, natural salt and/or in combination of both against the microbes on mango, banana, Brinjal, carrot and Cauliflower

One experiment was conducted on carrot under the study # 2 outlined in PP. Findings of this experiment would be a basis in assessing of efficacy of sanitizers. It might be applicable to other crops viz. mango, brinjal and carrot excluding cauliflower. The results of the experiment on carrot are stated below:

**Expt. 1.** Study on the efficacy of using sanitizer in preservation of carrots in cold storage

**First trial:** Microbiological quality of carrots washed with sanitizers and stored in polyethylene bag in jute sack at a commercial cold storage for six months were to observe. The initial data showed that higher level of APC (6.48 log CFU/g), TCC (5.62 log CFU/g), and Yeast & mold (4.53 log CFU/g) count was observed compared to jute sack storage study. Irrespective of storage condition or washing treatments, non-significant increase or decrease in APC, TCC, and Yeast & mold count was observed throughout the 2 months storage periods. However, little increase and decrease was observed upto 4 months of storage. Although, Salmonella was not detected in any of the carrot samples but E. coli was detected in 2 or 3 months samples, irrespective of wash or unwashed. However, due to the development of fungus at the 5th month of storage on all the carrot samples, we did not proceed further. This might be due to the temperature abuse of the ASKEO MSP cold storage, but details were not provided to us.

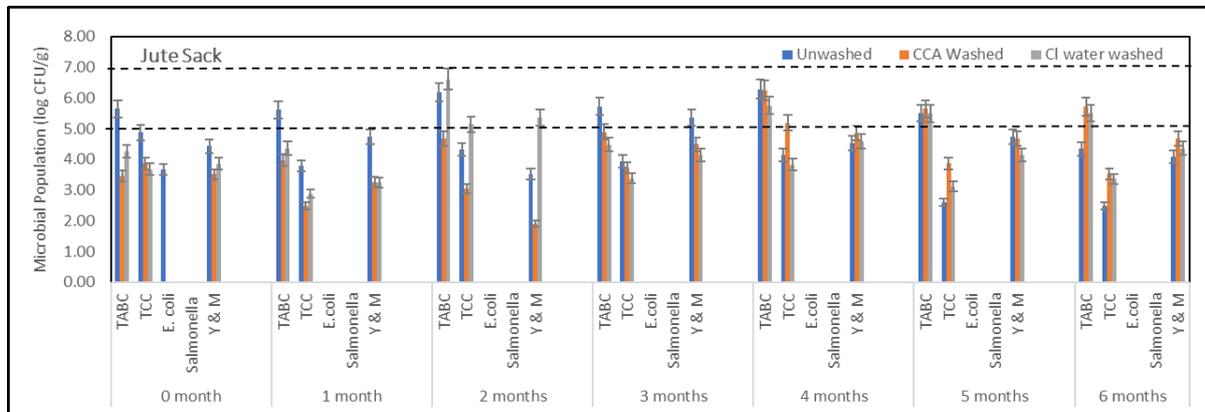
**Second trial:** According to the ICMSF 2002, Total aerobic bacterial count 5.0 log CFU/g is the lower threshold limit of freshness of cold stored (0-2<sup>0</sup>C; 98% RH) fresh produce and 7.0 log CFU/g is the thresholds limit of spoilage of cold stored fresh produce. Therefore, these values were applied in the graph to judge the microbiological quality of carrot stored for 6 months in a commercial cold store and presented in Figure 161.

This study results showed that washed carrot showed better microbial quality than that of unwashed carrot throughout the six months storage period in commercial cold storage. Irrespective of washing methods and packaging condition, both TABC and TCC counts were increased significantly during 1 & 2 months of storage and decrease thereafter and remain constant throughout the 6-month storage at cold store. On the other hand, Yeast & Mold count was recorded as 4.43 CFU/g, in unwashed carrot samples in 0 month of storage and significantly reduced (more than 2.5 log CFU/g) within 2 months of storage and thereafter increased little or remain constant throughout the 6-months storage period (Fig 167A). Furthermore, Total bacterial count in unwashed carrot packaged in Jute sack, CFB cartoon and plastic crate, and stored under commercial cold storage, cross the lower threshold limit from 1 month and increases gradually or remains constant throughout the 6 months storage period, on the contrary, unwashed carrot in jute sack packages showed better microbial quality than other two packaging conditions.

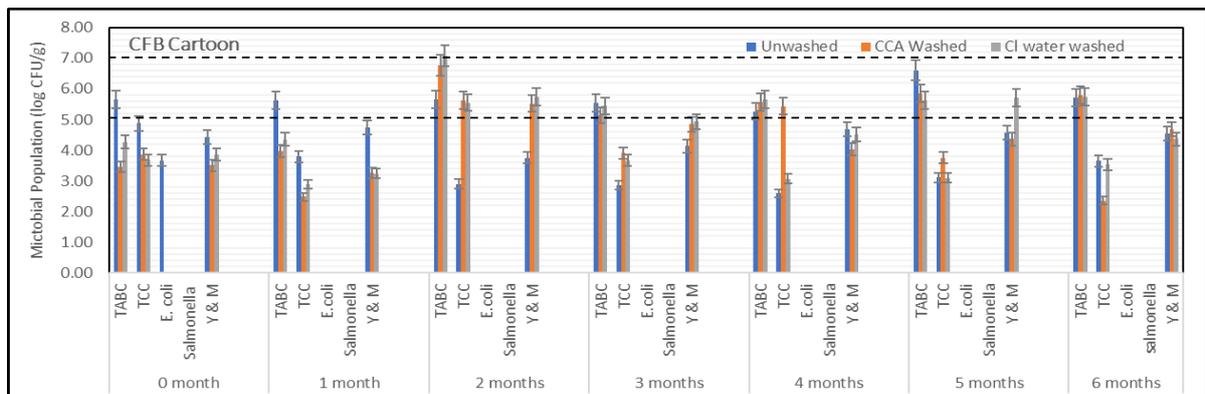
As TABC count and Y & M count indicate the quality of samples, and presence of higher TABC and Y & M indicating the lower quality of carrots and storage of this low-quality carrot will not be able to store for longer time. On the other hand, TCC counts indicate the hygienic condition of the samples processing or packaging area, thus presence of higher number of TCC population indicating the poor hygiene practices of carrot handlers. However, washing the carrot with sanitizers were able to reduce 1.5 log CFU/g of TCC and thereafter increased little or remain constant throughout the 5-months storage period (Fig-167B). However, irrespective of packaging conditions, non-significant differences in microbial quality of washed carrot stored six months in a commercial cold storage were observed.

However, CCA washed carrot showed lower TABC & TCC count, which is below the lower threshold limit after six months of storage.

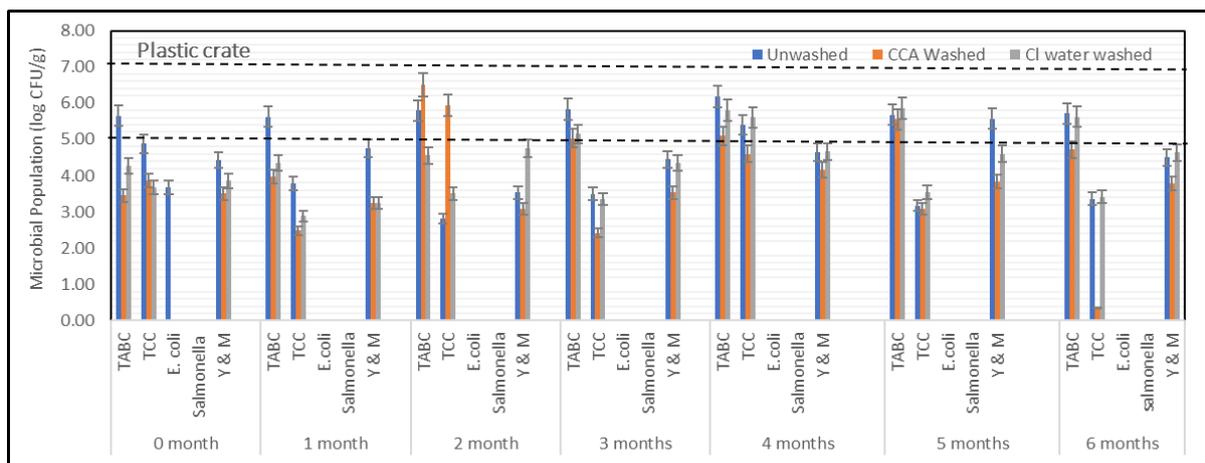
Irrespective of packaging condition washed carrot showed better quality than that of non-washed carrot. However, plastic crate packaging showed less damage and better visualized carrot compared to jute sack and CFB cartoon packages. Thus, the microbiological study along with visual observation showed that the freshness of stored carrots in plastic crate, CFB cartoon and Jute sack were within the acceptable level (Fig-167C). Thus, washing the carrot with sanitizers and then storage at a commercial cold storage (0°C; 95% RH) could be the best way to preserve fresh carrot with extended shelf life.



A) Jute Sack packages



B) CFB Cartoon



C) Plastic Crate

Fig-167: Microbiological quality of washed and un-washed carrot packed in A) jute sack, B) CFB Cartoon and C) plastic crate, and stored in a commercial cold storage (0-2<sup>0</sup>C; 98% RH) for 6 months.

Nevertheless, CCA washed carrot packed in plastic crate and stored under commercial storage conditions, showed better microbiological quality than chlorine washed carrot under similar packaging and storage conditions. On the other hand, chlorine washed and non-washed carrot cross the lower threshold limits after six months of storage in jute sack and CFB cartoon under commercial storage conditions. Overall, irrespective of packaging conditions, none of the washed carrot stored in a commercial cold storage for six months was found cross the upper threshold limit and thus acceptable in microbial quality. However, among the packaging and washing treatment, CCA washed carrot packaged in plastic crate and stored in commercial cold storage showed better quality than chlorine washed and non-washed carrot stored under similar packaging and storage conditions.

**Study #3:** Evaluation of microbial load and pesticide residues of banana, mango, cauliflower and brinjal using in intervened postharvest technologies in the value chain

Four experiments were conducted under study#3, outlined in PP. The crops were as mango, banana, cauliflower and brinjal. These investigations were done by collecting the sample of each treatment from the conducted experiment of PHTS with exception of including two more treatment combinations of banana and the findings on microbial loads in four crops handled with traditional and improved practices were as below.

**Expt. No. 1.** Evaluation of microbial load in mango as affected by traditional and improved practices integrated in the value chain

**Result Analysis:** The control sample containing higher presence of TABC, TCC and *S. aureus*, but no pathogenic bacteria including *E. coli*, *Bacillus cereus*, *Salmonella* spp, *Shigella* spp, *Vibrio cholera* and yeast & mold including *A. niger*, was recorded in control sample. In addition, none of the pathogenic bacteria and yeast & mold was recorded in the mango samples (900 Kg) studied. Bagging has been widely practiced in mango orchard to inhibit fruit fly, major causes of spoilage. Although bagging was able to inhibit fruit-fly successfully, however, was unable to reduce the bacterial and yeast & mold contamination on the mango surfaces. This might be due to the contamination occurred during post-harvest handling or processing. Irrespective of bagging or non-bagging, hot water treatment at 50<sup>0</sup>C for 5 min was able to kill yeast & mold and reduce resident bacterial populations to 1.0-1.5 log cfu/g. Irrespective of treatment conditions hot water + sanitizer treatment showed better microbial reduction than that of hot water treatment alone. Furthermore, hot water + sanitizer treatment of both bagging and non-bagging mangoes followed by transportation in refrigerated van showed best in terms of microbial quality.

Table 71. Microbial population count (log CFU/g)

Treatments	Microbial population (log CFU/g)								
	TABC	TCC	E. coli	Bacillus cereus	Salmonella spp.	Shigella spp.	S. aureus	Vibrio cholerae	Aspergillus niger
<b>Non-Cooling Traditional Transport System</b>									
Control (TP)	5.14 ± 0.09	3.65 ± 0.07	<10	<10	<10	<10	4.38 ± 0.03	<10	<10
IP-1	5.44 ± 0.06	<10	<10	<10	<10	<10	2.39 ± 0.12	<10	<10

Treatments	Microbial population (log CFU/g)								
	TABC	TCC	E. coli	Bacillus cereus	Salmonella spp,	Shigella spp,	S. aureus	Vibrio cholerae	Aspergillus niger
IP-1A	4.28 ± 0.03	2.10 ± 0.03	<10	<10	<10	<10	2.72 ± 0.03	<10	2.30 ± 0.0
IP-2	3.97 ± 0.02	<10	<10	<10	<10	<10	2.62 ± 0.03	<10	<10
IP-2A	4.81 ± 0.05	<10	<10	<10	<10	<10	<10	<10	<10
IP-2B	4.33 ± 0.04	<10	<10	<10	<10	<10	<10	<10	<10
<b>Cooling Transport System</b>									
IP-3	4.49 ± 0.02	<10	<10	<10	<10	<10	3.63 ± 0.01	<10	70
IP-3A	4.46 ± 0.02	<10	<10	<10	<10	<10	3.39 ± 0.12	<10	<10
IP-3B	4.31 ± 0.01	<10	<10	<10	<10	<10	<10	<10	20

\*<10= below detection limit

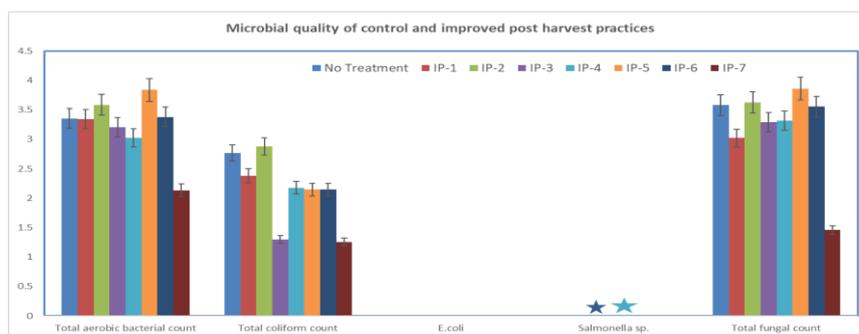
TP= Traditional management practices; IP= Improved management practices;

IP-1: NBG+NDS+NHW+PC+T, IP-2: BG+DS+HS+PC+T, IP-2A: BG+DS+HWT+PC+T. IP-2B:BG+DS+HS+PC+T,IP-3: NBG+DS+NHW+PC+RV, IP-3A: BG+DS+HWT+PC+RV, IP-3B: BG+DS+HS+PC+RV; NBG=Non-bagged, BG=Bagged (pre-harvest), NDL=No de-latexing or de-sapping, NW= No washing, NHW=No hot water treatment, HW=Hot water treatment, PC=Plastic crate, T=Truck, RV=Reefer van (transport vehicle)

**Expt. No. 2.** Evaluation of microbial load and sanitizer residue in banana as affected by traditional and improved practices integrated in the value chain

The treatment of this experiment was almost similar to the experiment of banana conducted by implementing component-1; however, some additional treatments were included in the experiment as mentioned in methodology section.

**Results Analysis:** Although *E. coli* was not detected in any of the sample analyzed, however, *Salmonella* was evident in some banana samples. Total bacterial count, total coliform count and total fungal count was found significantly lower in non chlorine sanitizer treated banana compared to non treated samples as shown in the figures. While comparing traditional practices with improved practices, the IP-7 which use CCa wash in washing machine then dried naturally using table fan and put in the plastic crate and transported by non-refrigerated truck showed better microbiological quality than any other improved treatment done in this study.



Where, \*= *Salmonella* detected after enrichment

No treatment = TNWNDHT =Traditional- No Washing-No De-Handing-No Packaging-Transported by Truck

IP-1= DHWWTPTCT =De-handing-Water Wash in Tank-Plastic Crate Packaging-Transported by Truck

IP-2=DHAWTWMPT =De-handing-Alum Water Wash in Tank-Without MAP-Packed in Plastic Crate -Transported by Truck

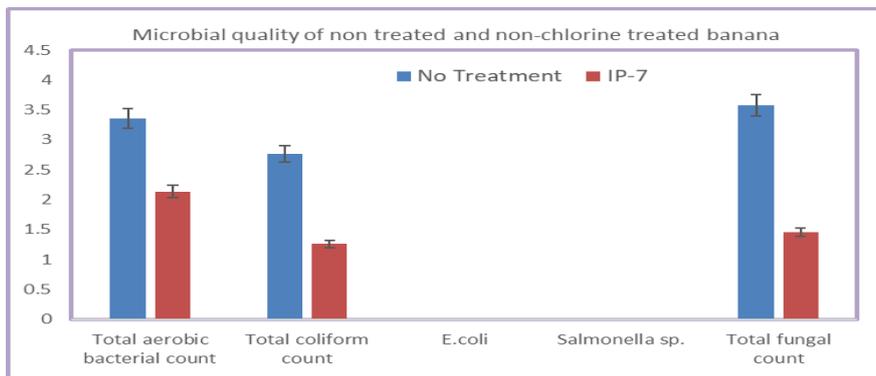
IP-3= DHAWTMPT =De-handing-Alum Water Wash in Tank-With MAP- Plastic Crate Packaging-Transported by Truck

IP-4=BDHAWTMPT=Pre-harvest Bagging-De-handing-Alum Water Wash in Tank-With MAP-Plastic Crate Packaging-Transported by Truck

IP-5=DHAWMMPT=De-handing-Alum Water Wash in Washing Machine-Without MAP-Packed in Plastic Crate Packaging-Transported by Truck

IP-6=DHAWMMPT=De-handing-Alum Water Wash in Washing Machine-Without MAP-Packed in Plastic Crate Packaging-Transported by Truck

IP-7=DHCWMMPT=De-handing-CCa Water Wash in Washing Machine-Without MAP-Packed in Plastic Crate Packaging-Transported by Truck

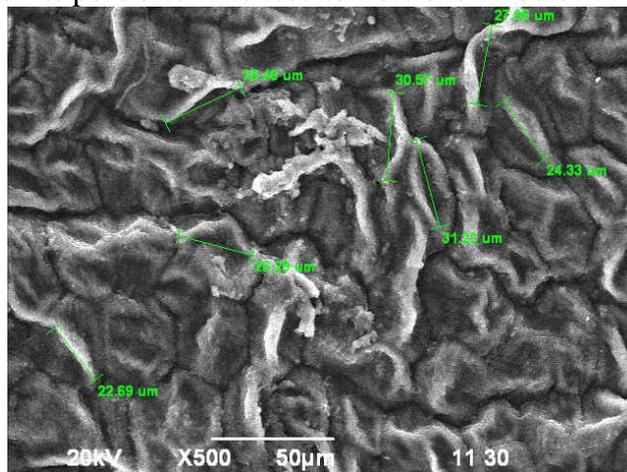


Where,

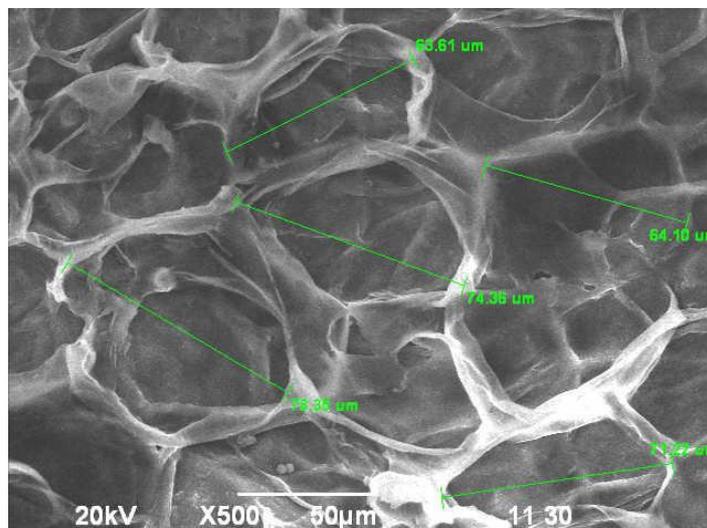
No treatment = TNWNDHT =Traditional- No Washing-No De-Handing-No Packaging-Transported by Truck

IP-7=DHCWMMPT=De-handing-CCa Water Wash in Washing Machine-Without MAP-Packed in Plastic Crate Packaging-Transported by Truck

In addition, whether the sanitizing agents used over the banana is entering into inside the banana or not, to evaluate this, both outer and inner banana peel was observed under scan electron microscopy for its pore size. The results were shown below:



**The Scan electron microscopic image of outer banana peel.** The banana peel was sliced as thin as possible and dried to observe under the SEM. The SEM result revealed that, the banana tissue cell of peel has the porosity of around 24  $\mu\text{m}$  to 31  $\mu\text{m}$ . If the treatment compound has the porosity was less than the peel's one, then the compound has the chance to enter into the banana.



**The Scan electron microscopic image of inner banana peel.** The banana peel was sliced as thin as possible and dried to observe under the SEM. The SEM result revealed that, the banana tissue cell of peel has the porosity of around 63  $\mu\text{m}$  to 78  $\mu\text{m}$ . If the treatment compound has the porosity was less than the peel's one, then the compound has the chance.

**Expt. No. 3.** Evaluation of microbial load in cauliflower as affected by traditional and improved practices integrated in the value chain

**Result Analysis:** Irrespective of treated and non treated, the control cauliflower with traditional-covering crate with newsprint paper and net bag packaging & transported by truck from bogura showed average APC, TPC & yeast and mould count, however, neither Salmonella nor any *E. coli* was present throughout the study. On the other hand, improved packaging with MAP inside the plastic cauliflower showed slightly lower bacterial and fungal count. Non significant differences of different improved practices were evident in the experiments.

Table 72. Microbiological quality of traditional and improved practices cauliflowers

Types of microorganisms	Control Cauliflower (TP)	IP-1 Cauliflower	IP2 Cauliflower	IP3 Cauliflower
Microbial population (Log CFU/g)				
Total aerobic bacterial count	5.92 ± 0.23	5.91 ± 0.22	4.78 ± 0.22	4.32 ± 0.13
Total coliform count	4.23 ± 0.55	3.94 ± 0.45	3.44 ± 0.25	2.54 ± 0.15
<i>E. coli</i>	0	0	0	0
<i>Salmonella</i> sp.	0	0	0	0
Yeast & Mould count	5.05 ± 0.21	4.99 ± 0.12	4.41 ± 0.10	3.85 ± 0.32

TP=TP+NPP+SNB, IP-1: IP+PPB+SNB, IP-2: IP+NPP+PC without MAP, IP-3: IP+PPB (MAP)+PC, IP-4: IP+PC with PPS (MAP)

TP= Traditional practices, IP= Improved practice, NPP=Newsprint paper, SNB=Synthetic netted bag, PPB=Perforated (1%) polyethylene bag, PC=Plastic crate; MAP=Modified atmosphere packaging, PPS=Perforated (1%) Polyethylene sheet.

**Expt. No. 4.** Evaluation of microbial load in brinjal as affected by traditional and improved practices integrated in the value chain

**Results Analysis:**

In the control samples higher presence of APC, TCC and *Salmonella* spp was detected and after enrichment fecal coliform, *E. coli* and *Salmonella* spp were recorded in control samples (Table 73). When the brinjal samples were washed with 0.01% CCa solution all the pathogens were found eliminated and the resident bacterial count was reduced by max 2.0 log CFU/g from the brinjal surfaces. In addition, irrespective of holding containers CCa washed brinjal showed better microbiological quality and safety compared to traditional sample (Table 74).

Table 73. Microbiological quality and safety of Brinjal value chain

Microorganisms	Control (Top)		Control (Bottom)		Control (Middle)		Control (Side)	
	Before enrichment	After enrichment						
Total aerobic bacterial count	1.2×10 <sup>5</sup>	NA	5.1×10 <sup>4</sup>	NA	1.8×10 <sup>4</sup>	NA	5.2×10 <sup>4</sup>	NA
Total coliform count	2.3×10 <sup>4</sup>	Present	1.7×10 <sup>3</sup>	Present	6.5×10 <sup>3</sup>	Present	1.2×10 <sup>3</sup>	Present
Total fecal coliform count	BDL	Absent	BDL	Absent	BDL	Absent	BDL	Absent
<i>Escherichia coli</i>	BDL	Present	BDL	Absent	BDL	Absent	BDL	Present
<i>Salmonella</i> spp.	4.8×10 <sup>3</sup>	Present	BDL	BDL	BDL	Absent	7×10 <sup>2</sup>	Present
Total yeast & mold		NA		NA		NA		NA

Control= Traditional practices= TRD: TP+Without wash+ Plastic sack

Table 74. Microbiological quality and safety of Brinjal value chain based on covering materials

Microorganisms	CCA+ MAP.		CCA+ Paper		Water+ Plastic Crate	
	Before enrichment	After enrichment	Before enrichment	After enrichment	Before enrichment	After enrichment
Total aerobic abacterial count	5.1×10 <sup>4</sup>	NA	4.8×10 <sup>4</sup>	NA	1.8×10 <sup>3</sup>	NA
Total coliform count	5.2×10 <sup>3</sup>	Present	3.2×10 <sup>3</sup>	Present	BDL	Present
Total fecal coliform count	BDL	Absent	BDL	Absent	BDL	Absent
<i>Escherichia coli</i>	BDL	Absent	BDL	Absent	BDL	Present
<i>Salmonella</i> spp.	BDL	Absent	BDL	Absent	BDL	Present
Total yeast & mold		NA		NA		NA

CCA+MAP=IP-3: IP+CCa wash+PC with MAP

CCA+Paper=IP-2: IP+CCa wash+PC without MAP

Water+Plastic crate=IP-1: IP+Clean water wash+PC without MAP

**Study#4.** Evaluation of microbial quality, safety and pesticide residue level to validate and introduce BARI developed postharvest technologies at the vegetables field.

To evaluate the microbial quality and safety including with a view to set a basis in assessing or validating of using sanitizing agent including with integrated technologies, an experiment was conducted with brinjal collected from open market and the results of using three sanitizers viz. distilled water, 0.01% calcinated calcium (WP) and 1% H<sub>2</sub>O<sub>2</sub> on microbial load in different days after washing along with storage condition are presented in Table 75, 76 and 77, respectively. From Expt. no. 4 under study#3 and experiment conducted under study#4, it was evident that microbial loads became less in the brinjals in integrated handling practices including of using sanitizer i.e. 0.01% calcinated calcium (Table 73). However, washing with same sanitizer could not restrict microbial population in collected market brinjals during the storage period of seven days (Table 75, 76, 77, 78 and 79). From these results of two Expts. (Expt. no. 4 under study#3 and experiment conducted under study#4), it could be noted that, integrated technologies were found to be effective in maintaining quality and safety of fresh brinjals, might be applicable to other crops that would be fit for applying of integrated postharvest handling practices used in this project.

Table 75. Sanitized with distilled water

Storage condition	Microorganisms	Log CFU/ gm			
		Before wash	After wash	4 <sup>th</sup> day	7 <sup>th</sup> day
Room temperature	TABC	6.09 ± 0.14	5.35 ± 0.15	5.78 ± 0.69 <sup>1</sup>	7.44 ± 0.23 <sup>2</sup>
	TCC	5.38 ± 0.09	5.06 ± 0.60	5.67 ± 0.18	6.78 ± 0.19
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	5.11 ± 0.56	6.09 ± 0.54	6.54 ± 0.18
Refrigerator	TABC	6.09 ± 0.14	5.35 ± 0.15	6.26 ± 0.15	5.99 ± 0.62 <sup>3</sup>
	TCC	5.38 ± 0.09	5.06 ± 0.60	5.87 ± 0.54	5.62 ± 0.23
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	5.11 ± 0.56	6.24 ± 0.24	5.97 ± 0.60

<sup>1</sup>Fungus were visible on the pedicle

<sup>2</sup>Visible fungus, eggplant rotten

<sup>3</sup>Eggplant shrunken but not rotten

Table 76. Sanitized with 0.01% SP (calcinated calcium)

Storage condition	Microorganisms	Log CFU/ gm			
		Before wash	After wash	4 <sup>th</sup> day	7 <sup>th</sup> day
Room temperature	TABC	6.09 ± 0.14	4.69 ± 0.21	5.04 ± 0.14	7.39 ± 0.20 <sup>1</sup>
	TCC	5.38 ± 0.09	3.72 ± 0.11	4.11 ± 0.01	5.57 ± 0.36
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	3.85 ± 0.32	5.13 ± 0.14	7.24 ± 0.54
Refrigerator	TABC	6.09 ± 0.14	4.69 ± 0.21	4.88 ± 0.41	6.42 ± 0.16 <sup>2</sup>
	TCC	5.38 ± 0.09	3.72 ± 0.11	3.57 ± 0.22	5.41 ± 0.22
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	3.85 ± 0.32	4.42 ± 0.30	6.23 ± 0.04

<sup>1</sup>Visible fungus and maggots were found in the rotten eggplant

<sup>2</sup>Eggplant shrunken but not rotten

Table 77. Sanitized with 1% H<sub>2</sub>O<sub>2</sub>

Storage condition	Microorganisms	Log CFU/ gm			
		Before wash	After wash	4 <sup>th</sup> day	7 <sup>th</sup> day
Room temperature	TABC	6.09 ± 0.14	3.45 ± 0.54	5.34 ± 0.28	6.90 ± 0.17 <sup>1</sup>
	TCC	5.38 ± 0.09	3.26 ± 0.24	5.61 ± 0.61	6.95 ± 0.06
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	3.65 ± 0.33	5.41 ± 0.43	7.31 ± 0.73
Refrigerator	TABC	6.09 ± 0.14	3.45 ± 0.54	5.25 ± 0.38	5.56 ± 0.02 <sup>2</sup>
	TCC	5.38 ± 0.09	3.26 ± 0.24	5.20 ± 0.42	5.51 ± 0.05
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	3.65 ± 0.33	5.12 ± 0.30	5.57 ± 0.06

<sup>1</sup>Still fresh, <sup>2</sup>Quite shrunkenTable 78. Sanitized with 0.5% H<sub>2</sub>O<sub>2</sub>

Storage condition	Microorganisms	Log CFU/ gm			
		Before wash	After wash	4 <sup>th</sup> day	7 <sup>th</sup> day
Room temperature	TABC	6.09 ± 0.14	3.93 ± 0.42	5.00 ± 0.01 <sup>1</sup>	7.02 ± 0.11
	TCC	5.38 ± 0.09	3.86 ± 0.34	4.80 ± 0.07	6.94 ± 0.11
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	3.89 ± 0.41	5.12 ± 0.43	6.99 ± 0.10
Refrigerator	TABC	6.09 ± 0.14	3.93 ± 0.42	5.40 ± 0.24	6.05 ± 0.14 <sup>2</sup>
	TCC	5.38 ± 0.09	3.86 ± 0.34	4.03 ± 0.45	5.00 ± 0.00
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	3.89 ± 0.41	5.12 ± 0.16	5.24 ± 0.34

<sup>1</sup>Visible fungus, eggplant rotten<sup>2</sup>Eggplant shrunken but not rottenTable 79. Sanitized with 150 ppm Cl<sub>2</sub>

Storage condition	Microorganisms	Log CFU/ gm			
		Before wash	After wash	4 <sup>th</sup> day	7 <sup>th</sup> day
Room temperature	TABC	6.09 ± 0.14	4.56 ± 0.43	6.36 ± 0.21	6.70 ± 0.88 <sup>1</sup>
	TCC	5.38 ± 0.09	4.45 ± 0.34	5.33 ± 0.37	6.31 ± 0.16
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	4.46 ± 0.29	5.43 ± 0.17	6.68 ± 0.17
Refrigerator	TABC	6.09 ± 0.14	4.56 ± 0.43	6.50 ± 0.09	5.54 ± 0.21 <sup>2</sup>
	TCC	5.38 ± 0.09	4.45 ± 0.34	4.80 ± 0.17	5.15 ± 0.21
	<i>E. coli</i>	<1.0	<1.0	<1.0	<1.0
	Fungi	5.89 ± 0.49	4.46 ± 0.29	5.21 ± 0.15	5.30 ± 0.43

<sup>1</sup>Visible fungus, eggplant rotten<sup>2</sup>Eggplant shrunken but not rotten

## 12. Research highlight (title, background, objectives, methodology, key findings, and keywords)

### Implementing component-1: PHTS, HRC, BARI

#### Study#1: Baseline survey of the value chain of selected fruits and vegetables

**Background:** A supply chain is simply a transfer of a commodity from one stakeholder to another in a chained manner. On the other hand, value chain entails value addition at different stages of transfer. The value chain describes the activities required to bring a product from its conception to the final consumer (Ensign, 2011). There is enormous scope of intervening of

improved postharvest technologies and best practices developed and identified by scientist in different organizations. To intervene improved technologies, first value chain status, value actors involved in the chain, their management practices should be known. Also marketing channels should be found out. To gather this information, base line survey should be done. A baseline survey allows the researcher to understand the research problem by gathering information on the status quo. It provides a reference point for tracking the project's progress; that is, to measure the degree and quality of change during an activity's implementation. From this point of view, base line survey was conducted in the growing areas and assembles markets of selected districts where the improved postharvest technologies and best practices would tried be intervened among the value chain actors.

### **Objectives:**

- i) To identify value adding activities practiced, marketing systems, quality and safety awareness level and postharvest losses of selected crops in the value chain.
- ii) To assess intervention opportunities of postharvest technologies and best practices in the value chain

**Methodology:** Survey was conducted at different levels of the distribution chain of selected from the growing areas of target fruits and vegetables in Rajshahi and Bogura districts. The crops were as mango, banana, carrot, cauliflower and brinjal and the survey locations were as growing areas and assemble markets of Rajshahi and Bogura districts and wholesale and retail markets of Gazipur city. Survey for mango and banana were initiated from Rajshahi district and that of carrot, cauliflower and brinjal were conducted from Bogura district. Pre-designed questionnaires were used to gather general and specific information by value chain actors (grower, supplier, wholesalers, processor, retailer and consumers). A sample size of 50 was used. Data were recorded on postharvest practices, in other words, value adding activities, quality, marketing channel, safety and losses perception, etc. Existing problem or constraints of the value chains from the growing level to markets actors were searched out and scope and opportunities of intervening of improved practices were selected from this survey.

### **Key findings:**

- There were opportunities to intervene and dissemination of improved production and pre-harvest technologies in the growers' field. Technologies that could be selected to intervene as:
  - Pre-harvest bagging of mango in Rajshahi area
  - Bunch covering of banana
  - Pheromone trap for mango and brinjal both in Rajshahi and Bogura districts.
- Opportunities those were found on intervening of improved harvesting techniques and postharvest handling practices in the value chains of study areas, are:
  - Improved harvesting tools for mango,
  - De-handing tools for banana
  - Plastic crate as harvest container for all crops
  - Hot water treatment for mango
  - Alum-water washing for banana
  - Washing machine for banana, brinjal and carrot and other root and fruit type vegetables.

- There was scope in organizing value chain actors to follow integrated postharvest handling technologies through establishing of local pack houses.
- There was scope on taking awareness creating programs, such as:
  - Training and demonstration on improved tools and technologies
  - Training on maintenance of personal hygiene and safety and quality measures during harvesting, handling, loading and unloading of target crops.

**Key words:** Survey, Value chains, Fruits, Vegetables

### **Activity # Establishment of pack house**

**Background:** A packing house is a facility where the products e.g. fresh fruits and vegetables is received and processed prior to distribution to market and a value chain is the whole series of activities that create and build value at every step. Packhouse operations include cleaning, sorting/grading, pre-treatments, packing, cooling, storage and dispatch to market. A packhouse is also called a collection center. Many collection centers in the country have no packhouse operations. They serve only as collection points, where farmers bring their produce for traders to collect. A packhouse enables quality assurance activities that ensure product quality and quantity meet market requirements and losses are minimized during transport and distribution to markets. Developing countries like Bangladesh incur serious postharvest losses of vegetables, usually ranging from 20-40% of production. A packhouse can serve as a hub for coordination and governance of a farm-packhouse-market organization in which market demand dictates production and packhouse activities. A farm-packhouse-market organization maximizes economy of scale, improves market access, and facilitates technical and business development interventions. Overall, the packhouse is the focal point of a farm business. Proper management ensures the business will prosper in a sustainable manner. Therefore, the present activity was undertaken to strengthen the capacity of the growers and traders in selected areas and creating linkage between farm and market.

### **Objective:**

- i) To perform intervene activities to motivate growers and suppliers in implementing improved postharvest technologies and best practice
- ii) To improve quality assurance activities in the assemble market/growing areas of selected value chains

**Methodology:** Establishment of pack house was actually a development activity. It was not a research program in true sense. Pack house was established in view to strengthening of value chain actors' capacity in adopting and performing of improved postharvest handling practices. Two pack houses including coolbot cold storage room were established. One is at Baneswar bazar, Rajshahi and another one is at Vatra, Sherpur in Bogura district. These pack houses were established by modifying the existing house/structures of interested farmer/farmers' group or fruits and vegetable supplier group in the target area. Necessary hardware facilities including sorting/grading table, weighing scale, water supply, water tank, hot water treatment plant, plastic crate etc. were provided there. These pack houses were utilized in intervening of improved technologies and best practices. Pilot demonstration and hands on training were arranged within the site of these pack houses. Training of the farmer' group, traders and other value chain actors was provided for skilfully operating of the packhouse based on the technical operations and technologies for packhouse, record keeping and marketing and other business development skills.

**Key findings:**

- The capacity of value chain actors, particularly the growers and traders involving the packhouse was improved. They were trained to operate hot water treatment machine vegetable washing machine and cool bot device.
- The growers and traders expressed their satisfaction in adoption of improved technologies.
- With the use of packhouse facilities fruits and vegetable growers around the packhouse got lucrative price by directly selling their products to city/distant markets.

**Key words:** Pack house, Establishment, Capacity

**Activity # Intervention of postharvest technologies and best practices in the value chain:**

**Background:** Proper postharvest handling practices are important to minimize postharvest losses and to maintain the quality of fruits and vegetables. On the other hand, value chain entails value addition at different stages of transfer. The value chain describes the activities required to bring a product from its conception to the final consumer. Efforts to reduce postharvest losses of high perishable produce such as fruits and vegetables in developing countries are considered crucial not only to avoid wastage but also to reduce the cost of preventing food losses. There is enormous scope of intervening of improved postharvest technologies and best practices developed and identified by scientist in different organizations. Researchers have identified many potentially useful postharvest technologies to be implemented in developing countries; however, there is no good alternative but dissemination of low-cost integrated technologies in the value chain in maintenance of quality and reducing losses. To achieve a good outcome, existing technologies should be improved and new technologies should be intervened. Thus, the present activity was undertaken with a general view and design of -

**Study on technical and economic feasibility of improved technologies in the value chain****Objective(s):**

- i) To determine the suitability and effectiveness of developed postharvest technologies and best practice in improving value chains.
- ii) To analyze the cost and benefit of integrating developed postharvest technologies and best practice in the value chains.

**Methodology, in general:** Under the title of design of study on technical and economic feasibility of improved technologies in the value chain design, five experiments were conducted on selected five crops. These crops were mango, banana, carrot, cauliflower and brinjal. The crop wise research title, background, objectives, methodology and findings are given below:

**a) Mango:**

**Title:** Postharvest Quality of Mango as affected by Traditional and Improved Practices Integrated in the value chain

**Background:** Mango (*Mangifera indica* L.) is one of the most important and popular fruit crops grown commercially in Bangladesh. It plays important role in the agricultural development of the country. The popularity of the fruit in domestic and international markets is due to its attractive fragrance, beautiful colour, taste and nutritional properties including dietary fiber, Vitamin C, provitamin A, carotenoids and diverse polyphenols (Talcott et al., 2005). In recent years, the total area and production of mango in Bangladesh were estimated to 44366 ha and 11.66 lakh metric tons, respectively (BBS, 2020). Mango fruits have a short harvest postharvest life due to its' high respiration rate and susceptible or sensitive nature to

microbial infestation and environmental factors. The fruit is also susceptible to insect pest and fungal infection resulting postharvest losses due to lack of proper pre-harvest management. Among the insect pests, fruit fly is known to be the most notorious that caused severe damage in the mango industries in many countries including Bangladesh (Ekesiet *et al.*, 2009). Anthracnose and stem end rot, on the other hand, are two major postharvest diseases of mango cause severe postharvest losses and affect fruit quality during the supply chain resulting commercial devaluation of the harvested fruits (Esguerra *et al.*, 2017). In addition, various factors such as maturity stages (Yahia, 1998), harvesting method (Abu-Bakr and Hafiza, 2004), postharvest treatment, packaging, handling procedures and mode of transport (Tucker and Seymour, 1991) are highly correlated with the quality and marketability of fruits. Traditional harvesting technique and postharvest handling practices prevailing in the mango industry of Bangladesh resulting high postharvest loss (31%) and severely diminish the quality of mango along the value chain (Rahman and Saha, 2015). Integration of improved pre-and postharvest practices, novel technologies and packhouse management have a great impact on retaining mango fruit quality in the supply chain. Fruit bagging is a one of the best pre-harvest practices to protect the fruit from insect pest particularly fruit fly infestation and fungal diseases (Sharma *et al.*, 2014). Hot water immersion has the benefit of controlling postharvest microbial diseases such as anthracnose and stem end rot (Couey, 1989). De-sapping is also effective to avoid sap burn the fruit, leaving a blemish that will develop during storage and transport (De La Cruz Medina and Garcia, 2002). Plastic crate is the best harvesting and transport container to shift fruits and vegetables safely with minimum or almost zero mechanical damage. There is enormous scope of intervening of integrated practices of improved methods in maintaining of quality of mango, however, there is inadequate data on managing quality and safety of mango fruit in the value chain system of Bangladesh. Therefore, this study was therefore conducted for evaluating the comparative impact of the traditional and integrated improved pre- and postharvest management practices in maintenance of quality and reducing postharvest losses of mango along the value chain.

**Objectives:**

- i) To determine the suitability and effectiveness of integrated postharvest technologies and best practice in improving value chains of mango.
- ii) To evaluate the comparative impact of the traditional and improved practices in reducing loss and managing quality of mango along the value chain.

**Methodology:** This study was conducted based on pack house site of Rajshahi. It was conducted between Rajshahi and Gazipur districts, starting from a contract grower's mango orchard and ended at the retail outlets. A popular commercial mango cultivar namely 'Langra' was used in this study. Pre-harvest fruit bagging was done in the selected mango trees on at marble sized fruits. In contrast, different pesticides were sprayed in the mango tree for 8 times to protect the non-bagged mangoes from insect-pests and diseases starting before flowering and ended at 15 days before harvest. Both bagged and non-bagged mangoes were harvested on 16 June 2019 at commercially mature stage. There were 9 integrated treatments including cool chain transportation and storage. Improved postharvest management practices such as, harvesting at optimum maturity stage, harvesting the mature fruits with harvesting tools, de-sapping, use of plastic crates as harvesting and transport container, sorting, grading, hot water treatment, use of sanitizers and careful loading and unloading during transportation etc. were considered for integration in the treatments. Bangladesh Agricultural Research Institute (BARI) has developed some improved postharvest tools and equipment i.e., BARI mango harvester, BARI de-sapping tray, BARI hot water treatment (HWT) plant, which were integrated in the 'improved practices during conducting the experiment. In the TP, on the other hand, mangoes were harvested using a bamboo pole with a net attached at the end that detached the fruit from the tree with or

without leaving stem attached to the fruit. Long stems were then detached by manual pulling allowing fresh latex to drip on the fruit. Bamboo baskets lined with newspaper were used as field containers, which transported to the collection centre for eventual marketing. Both bagged and non-bagged mangoes were packed in plastic crate (22 kg in each crate), were loaded on to a truck and transported together with the commercial load to the wholesale market in Gazipur district, some about 230 km away, and a 7-8 hour drive. After data collection at wholesale market, mangoes were distributed to three retail shops at Gazipur fruit wet market for subsequent observation and data collection. The experiment was piloted with nine treatments replicated thrice. Each fruit in a crate was evaluated daily during wholesale and 4-day retail period under ambient condition (27-33 °C, 85-90%RH).

**Key Findings:** Based on quality, postharvest losses and shelf life, the best integrated practices of mango were found as follows:

➤ Pre-harvest Bagging with brown fruit bag+Harvesting with BARI Mango Harvesting tool+Sorting out defective fruits+Keeping 0.5 cm pedicel with fruits+ De-sapping with BARI De-sapping tray+ Hot water treatment (55°C for 5 minutes) with BARI hot water treatment machine (may be mix 0.01% CCl<sub>2</sub> as a sanitizer) in hot water +Drying the surface water of hot water treated fruits in air+packed in plastic crate lining with clean newsprint paper +loaded carefully in truck for transport to target wholesale market+store at ambient condition+display the ripe mango at retail outlet.

- Special carefulness: In case of cool chain transport and cool room storage, calcinated calcium should not be used in hot water treatment for sanitizing of commercially mature mango. It may play adverse effect in ripening of mango. Thus, the organoleptic quality could not be good, particularly evident in pre-bagged mango.

**Key words:** Mango, Integrated practices, Quality, Postharvest losses, Shelf life

### c) Banana:

**Title:** Postharvest Quality of Banana as affected by Traditional and Improved Practices Integrated in the value chain

**Background:** Banana is a quick growing fruit crop available round the year. It is one of the most popular and widely grown fruit crop in Bangladesh. Banana is considered “one of the finest fruits and the most important in terms of food value, food security, food availability and above all, it is a crop that has a positive impact due to its profitability margins aimed at increasing household income and alleviating poverty (Fonsah, 2016). It is a rich source of carbohydrate and having plenty of vitamins particularly vitamin B. It is also a good source of potassium, phosphorus, calcium and magnesium (Fonsah and Chidebulu, 1995; 2012; Fonsah et al. 2007). In Bangladesh the cultivated and production of banana were estimated as 49,143.32 ha and 8.10 lakh metric tons, respectively (BBS, 2020) and the postharvest loss of banana in supply chain was reported as 26.63% (BARI Annual Report, 2008-2013, Molla *et al.*, 2012, Islam et al., 2013), denoted the necessity of improving postharvest management and quality maintenance of this fruit crop. Banana is a highly perishable fruit, prone to careless handling and heavily loading transportation, thus become inclining to disease infestation causing high post-harvest losses in the value chain at wholesale and retail level.

Integration of improved pre-and postharvest practices and packhouse management might have a great role on retaining of fruit quality in the supply chain. Collection of banana bunch at proper maturity stage, de-handing with banana harvesting tool and de-sapping of detached hands-on banana leaves were reported as good practices which could be done in banana field (FAO, 2018). Washing with alum [(KAl(SO<sub>4</sub>)<sub>2</sub>)] was reported as a useful method in removing of latex flow from the cut portion of banana crown (Siriwardana *et al.*, 2016). Plastic crate is no doubt, a suitable packaging container and clean newsprint paper or MAP could be used as lining material in the crate in minimizing bruising and abrasion during transportation. Thus,

there was good scope in intervening of integrated practices of improved methods in maintaining of quality of banana, however, there was no adequate data on managing quality and safety of banana fruit in the value chain system of Bangladesh. Therefore, this study was undertaken to evaluate the comparative impact of the traditional and integrated improved pre- and postharvest handling practices in maintenance of quality and reducing postharvest losses of banana in the value chain.

**Objectives:**

- i) To maintain quality and reduce postharvest losses of carrot in the value chain.
- ii) To assess suitability and effectiveness of integrated postharvest practices to be intervened in banana value chain.

**Methodology:** This study was conducted based on pack house site of Bogurai. It was conducted between Bogura and Gazipur districts, starting from a contract grower's banana orchard and ended at the retail outlets. A popular commercial banana cultivar of the locality namely 'Rongin Sagor kola', might be in the banana group *Musa × paradisiaca* was used to initiate the study. Recommended cultural practices of Pomology division were applied in produce banana plants in contract grower's field. Commercially mature banana when the fingers in most of the hands especially in the second hand of the bunch became three-fourth round, were selected to harvest. Selected bunch were collected carefully by cutting the base of the peduncle with engaging of two persons at a harvest on 23 October 2019. Mature hands were detached with banana de-handing tools (steel-iron made special type Da) and de-sapping was done by keeping the banana hands on bedding banana leaves in the field. Banana hands brought to pack house for washing with 1% alum i.e.  $KAl(SO_4)_2$  mixed water in washing house or washing machine. Washed banana was packed in plastic crate after drying of surface water in air. Thus, seven integrated treatments were applied in comparing of improved practices to traditional practice, in where whole bunch was considered to transport and the transport vehicle, truck was loaded heavily by heaping of banana bunches. Banana in PC and heaped banana bunches were transported separately to the wholesale market in Gazipur district, some about 140 km away, and a 6-hour drive. After data collection at wholesale market, packed banana hands and non-packed bunches were distributed to three retail shops at Gazipur fruit wet market for subsequent observation and data collection. Three plastic crates with treated banana hands and three non-washed and non-packed bunches were taken, respectively. Each of them was considered as a replication. Thus, the experiment was set with nine treatments replicated thrice. Each fruit in a crate was evaluated daily during wholesale and 4-day retail period under ambient condition (27-31 °C, 75-80% RH).

**Key Findings:** Considering quality, postharvest losses and shelf life, the best handling practices of banana were selected as follows:

- Careful harvesting of banana by observing and judging of optimum maturity of second hands in the bunch+ de-handing by BARI de-handing tool (special type Da)+de-sapping of detached banana hands on bedding banana leaves in the orchard+ washing the selected banana hands with the uniform sized fingers in alum mixed clean water +drwater of the fingers in air+packing the healthy banana hands in PC lining with clean newsprint paper or with MAP (1% perforated polyethylene sheet) +loaded the packed bananas carefully in truck carefully +transported the loaded truck to city market.
- This is the effective protocol which resulted 63.64% to 81.17% reduction in loss by preventing the transpiration and mechanical damage and diseases and decay and about 94-98% bananas could be sold at retail outlets.

**Key words:** Banana, Integrated practice, quality, postharvest loss, shelf life.

#### **d) Carrot:**

**Title:** Technical and Economic Feasibility of Integrated Improved Practices in Maintenance of Quality and Reducing Postharvest Losses in Carrot Value Chain

**Background:** Carrot (*Daucus carota* subsp. sativus) is an important salad and cooking type commercial vegetable in Bangladesh. It is an excellent source of the pro-vitamin A carotene and is supposed to have anti-cataract and anti-cancerous properties (Sen, 1996, Pandey, 2021). A total of 19,432 metric tons of Carrot was produced from 2058.70 ha land in Bangladesh in 2018-19 (BBS, 2019). Carrots can be stored at low temperature for a considerable time but lose their physiochemical and organoleptic properties in a few days when they are stored in ambient conditions (Caron *et al.*, 2003). In carrots, mass loss and the incidence of disease in the root are the principal causes of postharvest loss during storage and commercialization (Oliveira *et al.*, 2001). Removing of dirt from harvested roots is an awkward issue. In traditional postharvest management practices (TPMP), washing is done manually by using of water and human legs in Bangladesh. It might be unhygienic. At local assembling market, the traders purchase carrots from farmers, and directly pack into plastic sacks having 100 to 120 kg capacity for sending them to the distant wholesale markets. These heavy packages are roughly handled during loading, unloading and subsequent handling, which result in bruising, cracking and compression damage of the roots. Due to getting mechanical damage, carrots become more susceptible to microorganisms causing decay and also suffer from nutritional loss at the retail outlets. At the end, the consumers get poor quality and unsafe carrots from the retailers. From this point of view this study was undertaken to determine the suitability and effectiveness of integrated improved practice in maintenance of postharvest quality and enhancing marketable life of carrots to be intervened to the value chain actors in carrot value chain

#### **Objectives:**

- i) To maintain quality and reduce postharvest losses of carrot in the value chain.
- ii) To assess technical and economic feasibility of integrated improved postharvest practices to be intervened in carrot value chain.

**Methodology:** This study was conducted based on pack house site of Bogura. It was conducted between Bogura and Gazipur districts, starting from a contract grower's fields and ended at the retail outlets. Carrots var. Orange Kings (an exotic variety) cultivated with recommended productions of Olericulture Division of HRC, BARI. Whole plants of carrots were collected directly from the field and brought to pack house to perform postharvest activities. For traditional postharvest management practices (TP), sorting, grading and washing were not done. Carrots were directly packed in plastic net bags of 100 kg capacity and sealed with nylon string. On the other hand, precooling, sorting, grading and washing with clean water were done in improved practices (IP). Precooling was achieved by keeping harvested carrots in coolbot cold room in the packhouse. Washing was done in clean water or calcinated calcium mixed water, either in washing house or by washing machine. Washed carrots were dried in air to remove surface water and packed in 20 kg capacity plastic crates with or without modified atmosphere packaging (MAP). Polyethylene of 30 $\mu$  thickness with 1% perforation was used as MAP. The carrots were then loaded in a 12-ton truck together with other commercial loaded vegetables and started to transport in the night (11:00 pm) of the same day and reached Vogra wholesale market at Gazipur about 6:00 pm of the following day. Distance from pack house site, Bogura to Bogra Wholesale market, Gazipur is 140 km. After collecting the necessary data at wholesale market, the produces were brought to the postharvest laboratory of Horticulture Research Centre of BARI using a pick-up van. The whole postharvest activities of this study were accomplished between 13-28 January, 2020.

**Key Findings:** Based on quality, postharvest losses and shelf life, the best integrated practices for carrot were as:

- GAP (Recommended cultural and plant protection measures)+sorting by discarding all defective ones+Selecting only moderate size optimally matured carrots+ Trimming (removal of green top by cutting with sharp knife) + Washing in calcinated calcium (1g\_CCa in 10L water) through washing machine drying surface water of carrots in air+packed in plastic crate lining with clean newsprint paper (single layer)+transported by truck with careful loading (single crop loading).
- This practice of integrated approach resulted in 88.7% reduction in loss by preventing the transpiration and mechanical damage, and 100% carrots could be sold at retail outlets.

**Key words:** Carrot, Integrated practices, CCa, washing machine.

#### **d) Cauliflower:**

**Title:** Technical and Economic Feasibility of Improved Postharvest Handling Practices in cauliflower Value Chain

**Background:** Cauliflower (*Solanum melongena* L.) is an important and popular vegetable crops grown commercially mostly in winter in Bangladesh. It contains important nutrient components with functional properties like biologically essential minerals, ascorbic acid, soluble phenols (Nino-Medina *et al.*, 2014), potassium, calcium, sodium and iron (Mohamed *et al.*, 2003; Raigon *et al.*, 2008). In Bangladesh the cultivated and production of cauliflower in 2018-19 were estimated as about 20190 ha and 2.84 lakh metric tons, respectively (BBS, 2020). High postharvest losses of cauliflower in the various points of value chain and physical damage occurred during handling and transportation such as assessed as 14% (Hossain *et al.*, 2014) indicated the necessity of improving postharvest management and quality maintenance of this vegetable crop. Good postharvest handling practices like protection of curd from physical injury during transportation and suitable packaging might be incorporated in integrated approach of handling practices which would play in maintenance of quality and reducing postharvest losses in the value chain. This study was, therefore undertaken with designing of three integrated treatments of improved practice along with traditional one to find out the suitable option.

#### **Objectives:**

- i) To maintain quality and reduce postharvest losses of cauliflower in the value chain.
- ii) To assess technical and economic feasibility of integrated improved postharvest practices to be intervened in brinjal value chain.

**Methodology:** This study was conducted based on pack house site of Bogura. It was conducted between Bogura and Gazipur districts, starting from a contract grower's fields and ended at the retail outlets. Cauliflowers var. 'Alfa chan' (an exotic snow ball type variety) produced with recommended productions of Olericulture Division of HRC, BARI. Cauliflowers collected directly from the farmer's field and brought to pack house to perform postharvest activities. For traditional postharvest management practices (TP), sorting, grading and washing were not done. In TP cauliflowers were directly packed in synthetic netted bags of 50 kg capacity and sealed with nylon string. On the other hand, precooling, sorting, grading and washing with clean water were done in improved practices (IP). Precooling was achieved by keeping harvested cauliflowers in coolbot cold room in the packhouse. In IP, cauliflower curd was covered with a piece of clean newsprint paper and packed in 10 kg cauliflower holding capacity plastic crates lining with newsprint paper or with modified atmosphere packaging (MAP). Polyethylene sheet of 30 $\mu$  thickness with 1% perforation was used as MAP. MAP was also applied with thin polyethylene bag by making 1% holes in it. Some curds were kept in this bag placed either in plastic crate or in nylon netted bag. Thus, 3 integrated treatments of IP along with TP were applied to evaluate of their suitability in maintenance of curd quality. The cauliflowers were then loaded in a 12-ton truck together

with other commercial loaded vegetables and started to transport in the night (11:00 pm) of the same day and reached Vogra wholesale market at Gazipur about 6:00 pm of the following day. Distance from pack house site, Bogura to Bogra Wholesale market, Gazipur is 140 km. After collecting the necessary data at wholesale market, the produces were brought to the postharvest laboratory of Horticulture Research Centre of BARI using a pick-up van. After recording of the recovery of good quality (sound), mechanically damaged and unmarketable cauliflowers done from the top, middle and bottom portions of net bag. It was done from the whole cauliflowers for plastic crate. After randomly taken from the transport containers, 30 cauliflowers were distributed to three retail outlets of Gazipur wet vegetable market. Cauliflowers taken from net bags were stacked on display floor of the retailer's shop as they practiced in wet markets. Those were taken from plastic crate were kept in the similar type of clean crates. Another 30 cauliflowers were randomly taken from different portions of each container were left in the laboratory at ambient condition (20-25°C, 55-60% RH) for biochemical analysis and regular evaluation. Cauliflowers kept in retail shops and laboratory were evaluated daily and regular interval basis during the 3-day retail period and till the end of marketable life. The whole postharvest activities of this study were accomplished between 05-15 February, 2020.

**Key findings:** Based on quality, postharvest losses and shelf life, effective integrated practices were as:

- GAP (Recommended cultural and plant protection measures+Sorting by discarding all defective ones +Selecting only fully size, compact structured, cauliflowers+Trimming (cut the leaf parts top of the curd)+Covering curd face with clean newsprint paper+kept in plastic crate+transport only cauliflowers by truck (single crop loading).

**Key words:** Cauliflower, Integrated practices, newsprint paper covering, curd

#### e) Brinjal:

**Title:** Feasibility of Improved Practices in Maintenance of quality and Reducing Postharvest Losses of Brinjal in the Value Chain

**Background:** Brinjal (*Solanum melongena* L.) is one of the most important and popular vegetable crops grown commercially round the year in Bangladesh. It contains important nutrient components with functional properties like biologically essential minerals, ascorbic acid, soluble phenols (Nino-Medina *et al.*, 2014), potassium, calcium, sodium and iron (Mohamed *et al.*, 2003; Raigon *et al.*, 2008). In Bangladesh, postharvest loss of brinjal was estimated at 29.4% from harvesting to consumption (Hassan, 2010), which mainly attributed to lack of improved postharvest handling operations. Kayser *et al.* (1916) reported that this loss was 23.38 and mainly due to absence of postharvest, lack of available storage facilities and poor and costly transportation facilities. In traditional practices (TP), generally farmers and traders do not carry out sorting, grading or washing for marketing brinjal. At local assembling market in Bogura area, the traders purchase brinjals from farmers, and directly pack into plastic sacks over 60 to 100 kg capacity for sending them to the distant wholesale markets. These heavy packages are roughly handled during loading, unloading and subsequent handling, which result in bruising, cracking and compression damage of the crop. Due to getting mechanical damage, brinjals become more susceptible to microorganisms causing decay and also suffer from nutritional loss at the retail outlets. At the end, the consumers get poor quality and unsafe brinjals from the retailers.

Non-chlorine (CCa) sanitation (Mamun *et al.* 2012), coolbot cold storage, modified atmospheric packaging and plastic crate packed transportation were reported as good options (Rahmam *et al.*, 2016) in maintenance of fresh produce quality. Improved practices such as, harvesting at optimum maturity stage, use of plastic bucket as harvesting container, sorting, grading, washing with calcinated calcium mixed clean water, use of plastic crates as

packaging container, and careful loading and unloading during transportation etc. could be followed as interventions in the value chain. While researchers have identified many potentially useful technologies, there is no good alternative but intervention and integration of improved technologies in the value chain to maintenance of quality and reducing losses. The technical and economic effectiveness of improved postharvest technologies can be established by testing them under actual value chain system. This study was undertaken to assess the suitability and effectiveness of integrated technologies and best practices which would be served as the basis in the formulation of interventions of improved practices in the value chain towards quality maintenance and loss reduction of brinjal.

### **Objectives:**

- i) To maintain quality and reduce postharvest losses of brinjal in the value chain.
- ii) To assess technical and economic feasibility of integrated improved postharvest practices to be intervened in brinjal value chain.

**Methodology:** The study was conducted with a local brinjal cv., called as ‘Jessori’ in the study area. The plants were grown in contract grower’s field with the recommended production practices of Olericulture division, HRC, BARI. Brinjals collected directly from the farmers field and brought to pack house to perform postharvest activities. For traditional postharvest management practices (TP), sorting, grading and washing were not done. Brinjals were directly packed in plastic made synthetic sacks of 50 kg capacity and sealed with nylon string. On the other hand, precooling, sorting, grading and washing with clean water were done in improved practices (IP). Precooling was achieved by keeping harvested brinjals in coolbot cold room in the packhouse. Washing was done in clean water or calcinated calcium mixed water, either in washing house or by washing machine. Washed brinjals were dried in air to remove surface water and packed in 20 kg capacity plastic crates with or without modified atmosphere packaging (MAP). Polyethylene of 30 $\mu$  thickness with 1% perforation was used as MAP. The brinjals were then loaded in a 12-ton truck together with other commercial loaded vegetables and started to transport in the evening (11:00 pm) of the same day and reached Vogra wholesale market at Gazipur about 7:00 pm of the following day. Distance from pack house site, Bogura to wholesale market, Gazipur is 140 km. After collecting the necessary data at wholesale market, the produces were brought to the postharvest laboratory of Horticulture Research Centre of BARI using a pick-up van. After recording of the recovery of good quality (sound), mechanically damaged and unmarketable fruits from the top, middle and bottom portions of the three types of containers, 50 sample brinjals were randomly taken from the top, middle and bottom portions of each container, were placed in separate plastic crates and distributed to three retail outlets of Gazipur wet vegetable market. Another 50 brinjals were randomly taken from different portions of each container were left in the laboratory also for daily evaluation. Both in the TP and IP, there were three plastic crates with each crate having 50 brinjals that was considered as a replication. Each brinjal in a crate was evaluated daily during the 3-day retail period under ambient condition (18-22°C, 60-65% RH). The whole postharvest activities of this study were accomplished between 22-31 January, 2021.

**Key Findings:** Based on quality, postharvest losses and shelf life, the best integrated practices for brinjal were as:

- Recommended cultural and plant protection measures (HRC, BARI)+ Harvesting commercially mature brinjals looks glossy and optimum growth in development +Sorting out diseased, insect infested and defective fruits+Selecting uniform size, glossy brinjals+ *Washing in calcinated calcium (1g CCa in 10L water) mixed water in washing house/through washing machine* +Drying surface water under ceiling fan

+Packed in plastic crate lining with clean newspaper print paper (just a layer inside around plastic.

**Key words:** brinjal, integrated practices, CCa, washing machine.

### **Implementing component-2: FMPE, BARI**

#### **Title: A high capacity self-propelled drum type root crop washing machine**

**Background:** The total production of vegetables of Bangladesh is 3.8 and 13.0 million tons. Total carrot production was 16306 tonnes in 4533 acres of cultivated land in 2017-18 (BBS, 2019). Islam (2004) reported that the postharvest losses of fruits and vegetables during all stages of postharvest operations were 43% of which handling and distribution accounted for 22.5%. After harvesting, vegetables are transported in the market without sorting, grading and washing. There are many micro-organisms, and dust on the surface of the vegetables. Unhygienic products are sold in the markets. Some traders/retailers wash products with impure water of local ponds /canals. These washed products are harmful for human health that causes different diseases. Besides, a huge quantity and quality of products are lost. Washing is a standard postharvest handling operation for many fruits and vegetables to remove adherences, dirt, latex and external pathogenic structures. Unfortunately, in Bangladesh fruits and vegetables are hardly washed before entering into the marketing channel, and this contributes to poor quality and considerable losses of the produce. Self-propelled drum type root crop washing was developed by BARI financed by PIU-BARC, NATP-2, PBRG-016 to reduce postharvest losses and marketing hygienic products.

**Objectives:** i) Design and fabrication of self-propelled drum type high capacity root crop washing machine  
ii) Performance evaluation of the washing machine  
iii) Economic analysis of the machine

**Methodology:** It was fabricated with MS flat bar, MS plate, MS shaft, wood, FL bearing, chain-sprocket, wheel, self-starter diesel engine, motor, gear reducer etc. The main parts of it are: i) Main frame; ii) Octagonal drum; iii) Power transmission system; iv) water circulation system; v) delivery chute; vi) self-propelled system and vii) Mechanical stirring system.

**Key findings:** A large capacity self-propelled drum type carrot washing machine was developed. Capacity of the machine was 5.50 tons per hour. Washing efficiency and the cleaning efficiency of the machine were about 98% and 99.0% respectively. Washing cost by the machine was 0.12 Tk./kg and payback period & benefit cost ratio were 14 days and 1.7 respectively.

**Key words:** Washing machine, carrot, efficiency and capacity

#### **Title: A self-propelled hydraulic lifter for bagging of mango**

**Background:** A lot of mango is produced everywhere in Bangladesh especially Rajshahi, Satkhira, Rangpur, Chapainawabganj, Shibganj, Chittagong. Different varieties of mango are scattered in country. Mango production in Bangladesh is about 12.7 lakh metric tons and the produced area is 417 hectares (BBS, 2019). Mango is called the king of all fruits. Mango is everyone's favorite and about 16 commercial varieties of high yielding mangoes are produced. Among these, about 12 varieties of mango have been developed by the Bangladesh Agricultural Research Institute. In Bangladesh, the mango production period varies from one and half month from place to place. BARI Mango-2, 3, 4 and 6 and commercial varieties Fazli, Langra, several varieties like Khirsapa, Ashwini etc. have gained popularity. Mangoes of local variety occupies the lion share of total mango production. After 30-35 days of flowering, 3 times spraying and bagging can protect the mangoes from dust and different types of insects like fruit fly. According to the experts, fruit fly can attack the

mangoes before 30-35 days of ripening. Only 5% of mango tree can be covered with the bagging systems and among them only 40-50% mangoes can be covered with bags. The remaining 95% of the trees are sprayed with pesticides about 60-70 times from the time of flowering to harvesting to protect mango from fruit fly. Due to which this mango does not become suitable for export abroad. Older varieties of mango trees are taller and wider besides improved varieties are relatively shorter and less wide. Bagging is done by hand, so people try to do bagging by climbing on the branches of trees as much as they can. Bagging cannot be done in the distant baskets above and around the tree. Farm Machinery and Postharvest Process Engineering of Bangladesh Agricultural Research Institute imported hand operated hydraulic lifters from abroad and converted it into self-propelled hydraulic lifters. With this lifter, mango is covered with bag and tied with stem manually upto 34 feet high tree.

**Objectives:**

- a) To adoption of a hydraulic lifter for bagging of mango
- b) To evaluate the performance of the lifter and make an economic analysis of the hydraulic lifter

**Methodology:** Performance of imported hydraulic lifter was tested for bagging of mango at Farm Machinery and Postharvest Process Engineering Division, and horticultural mango orchard of Bangladesh Agricultural Research Institute, Gazipur. The overall size of the device is  $4 \times 2.5 \times 2$  m. The machine two parts, one is hydraulic unit and the other is self-propelled mechanical unit. Arms of hydraulic unit can be operates through oil pump. Hydraulic unit has 4 barrels and self-propelled mechanical unit has self-starter, water cooling engine, Alternator, starting devices, brake systems, batteries, dynamo, etc. The hydraulic lifter can be operated with electricity and alternate energy. The mango is covered with bag and tied with stem easily.

**Key findings:** Speed of lifter for up and down was recorded to be 4.5 and 16 m/min. Capacity is 200-300 numbers bags per hour and bagging cost is Tk 0.25-0.35 per bag and diesel engine, save labor and reduce drudgery

**Key words:** Self-propelled hydraulic lifter, bagging, fruits

### **Title: A protocol of storing washed carrot in commercial cold storage**

#### **Background:**

Harvested fresh vegetables are transported in the market without sorting, grading and washing. There are many micro-organisms, and dust on the surface of the vegetables. The products are infected by micro-organisms easily. Unhygienic products are sold in the markets. Some traders/retailers wash products with impure water of local ponds /canals. These washed products are harmful for human health that causes different diseases. Besides, a huge quantity and quality of products are lost. Sanitation is a great concern to produce handlers, not only to protect the produce against post-harvest diseases, but also to protect the consumers' food borne illnesses. *E. coli* 0157:H7, salmonella, *Chyptosporidium*, Hepatitis, and *Cyclospora* are among the disease-causing organisms that have been transferred via fresh fruits and vegetables (Burditt, 1982; Mitchamet *al.*, 1997). Washing is a standard postharvest handling operation for many fruits and vegetables to remove adherences, dirt, latex and external pathogenic structures. Unfortunately, in Bangladesh fruits and vegetables are hardly washed before entering into the marketing channel, and this contributes to poor quality and considerable losses of the produce. Cold storage owner, farmers and traders stored carrot with mud without sorting, grading and washing.

#### **Objectives:**

- a) To develop suitable package of carrot for long time stored in cold storage
- b) To determine the quality and shelf-life of washed and unwashed carrots in cold storage
- c) To make an economic analysis of the storage of carrot in cold storage

**Methodology:** Matured carrots harvested from farmers' fields at Masuritala, Vakurta, Saver, Dhaka (GPS position 23° 51' 30.0024" N and 90° 16' 0.0120" E) and transported to Farm Machinery and Postharvest Process Engineering Division of Bangladesh agriculture Research Institute for washing and packaging. About one tonne of matured harvested carrots was used. Metallic sound, size, shape, colour (hue angle 57-64°) and firmness (4.7 kgf/cm<sup>2</sup>) of carrots were chosen as maturation indicator. Matured carrots were trimmed, sorted and graded manually. Sanitizer of NaOCl (3.8 ml/2 litre) and CCA (1g/10litre of water) were used. Carrot was washed with the sanitizer mixed water by using the root crop washing machine for 5-6 minutes. Washed carrots were dried in ambient air for 2-3 minutes, sorting, grading and packed into jute sack (traditional practice), plastic crate, CFB carton with lining of polyethylene of 0.05 mm thickness. The packaged carrot was then transported to the commercial cold storage of ASKEO MSP Centre Limited, Ashulia, Saver, Dhaka and to Genda MSP Centre Limited, Genda, Saver, Dhaka. All treatments were stored in cold storage at 0-1° C and 97-99% rh. Total Aerobic Bacterial Count (TABC), Total Coliform Count (TCC), Total faecal coliform (TFC) & Yeast and Mold counts and safety parameters include the presence and absence of *E.coli* and *Salmonella* of washed and unwashed carrots were determined in research laboratory of WAFFEN (Water Food Feed Environment), Banani, Dhaka.

**Key findings:** Washed carrot packed in plastic crate with polyethylene lining was better quality. CCA washed carrot packed in plastic crate and CFB carton with polyethylene lining was the best quality. In all the chemical parameter analyzed, non-washed carrot showed higher values compared with washed carrots. CCA washed samples showed significantly higher than that of NaOCl washed carrots. Matured carrot should be sorted, graded and washed with CCA sanitizer packed in plastic crate and CFB carton with thin polyethylene for storing of 5-6 months at 0.1-4.34 °C and 76-94% rh in commercial cold storage.

**Key words:** Carrot, CCA, NaOCl, Microbial load, storage

### **Title: Treatment combination of temperature and exposure period for BARI Aam-3 in hot water**

#### **Background:**

Mango (*Mangifera indica* L.) is an important, popular and commercial fruit crop in Bangladesh that plays an important role in the agricultural development of the country. The popularity of the fruit in domestic and international markets is due to its attractive fragrance, beautiful colour, taste and nutritional properties. Among the insect pests, fruit flies are known to be the most notorious that caused severe damage to the mango industries in many countries including Bangladesh (Ekesi et al., 2009; Isabirye et al., 2015). Anthracnose and stem end rot (SER), on the other hand, are two major postharvest diseases of mango cause severe postharvest losses and affect fruit quality during the supply chain resulting commercial devaluation of the harvested fruits (Sivakumar et al., 2011; Esguerra et al., 2017). Hot water immersion has the benefit of controlling postharvest microbial diseases such as anthracnose and SER (Couey, 1989; McGuire, 1991).

#### **Objectives:**

- a) To determine the optimum temperature and time for mango hot water treatment
- b) To determine the physio-chemical properties between treated and untreated mangoes

#### **Methodology:**

BARI Aam-3 was collected from Rajshahi those were treated with different treating temperature (50, 55 and 57 °C) and exposure time (3, 5, 7 and 9 minutes) using BARI developed hot water treatment plant at FMPE Division, BARI, Gazipur.

**Key findings:** The treatment combinations increased the shelf-life of the variety of BARI Aam-3 by 33% compare to untreated fruits. Disease severity of treated mango was reduced

by 79% over untreated fruits. On the basis of disease severity, colour parameter, shelf-life, firmness and organoleptic test, the better treatment combinations of BARI Aam-3 were found to be 50°C for 5, 7 and 9 minute, 55°C for 5, 7 and 9 minutes, 57°C for 3 minutes. The best treatment combination of BARI Aam-3 is 55°C for 5 minutes.

**Key words:** BARI Aam-3, Hot water treatment plant, disease, shelf-life

**Implementing component-3: CARS, DU**

Study on the intervention of postharvest technologies in the value chains of cauliflower. Picture from the field during harvest and post-harvest treatment and packaging.



**IP=Integrated practices; MAP=Modified atmospheric packaging**

## **B. Implementation Status**

### **1. Procurement (Component wise)**

**Coordinating component: PHTD, BARI**

N/A

#### **Implementing component-1: PHTS, HRC, BARI**

Description of equipment and capital items	PP Target		Achievement		Remarks	
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)		
a) Office equipment:						
i)	Laptop	1	60000.00	1	60000.00	
ii)	Colour Printer	1	20000.00	1	20000.00	
iii)	Photocopy machine	1	185000.00	1	185000.00	
iv)	Digital Camera	1	25000.00	1	25000.00	
	Total		290000.00			
b) Lab & field equipment:						
i)	Digital Brix meter	1	80000.00	1	80000.00	
ii)	Gas Analyzer (CO <sub>2</sub> , C <sub>2</sub> H <sub>4</sub> , O <sub>2</sub> )	1	1000000.00	1	849999.00	
c) Other capital items: Furniture						
i)	Executive Chair	1	20000.00	1	20000.00	
ii)	Book shelf	1	10000.00	1	10000.00	
iii)	Side table	1	10000.00	1	10000.00	

#### **Implementing component-2: FMPE, BARI**

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment					
Desktop	1	54000.00	1	52000.00	
Scanner	1	10000.00	1	9000.00	
Colour printer	1	20000.0	1	17500.00	
(b) Lab & field equipment					
Chroma meter	1	1300000.00	1	1090000.00	
Hygrometer	1	80000.00	1	30000.00	
Firmness meter	1	780000.00	1	649000.00	
Hydraulic Lifter	1	438000.00	1	500000.00	
(c) Other capital items					

#### **Implementing component-3: CARS, DU**

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment	100%	100%	100%	100%	completed
(b) Lab & field equipment	100%	100%	100%	100%	completed
(c) Other capital items	100%	100%	100%	100%	completed

**2. Establishment/renovation facilities:**  
**Coordinating component: PHTD, BARI**  
 N/A

**Implementing component-1: PHTS, HRC, BARI: N/A**

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
-	-	-	-	-	-.

**Implementing component-2: FMPE, BARI: N/A**

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
-	-	-	-	-	-.

**Implementing component-3: CARS, DU: N/A**

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
-	-	-	-	-	-.

**3. Training/ study tour/ workshop/ conference organized:**  
**Coordinating component: PHTD, BARI**  
 N/A

**Implementing component-1: PHTS, HRC, BARI**

Description	Number of participants			Duration (Days/weeks/Months)	Remarks
	Male	Female	Total		
a) Training	55	5	60	One day/batch; 03 January 2021 04 January 2021 29 January 2021	3 batch, each batch had 20 participants
b) Workshop	-	-	-		
c) Others (if any)	-	-	-		

**Implementing component-2: FMPE, BARI**

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					
(c) Others (Demonstration)	67	17	80	11 June 2020 12 June 2020	

**Implementing component-3: CARS, DU**

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training	32	28	60	2 days	Rajshahi & Bogura
(b) Workshop	16	14	30	1 day	CARS
(c) Others (if any)	2	1	3	5 days	BAB

### C. Financial and physical progress (Combined)

Items of expenditure/ activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	3783360	3003699	3229773.96	-226074.96	107.53	
b. Field research /lab expenses and supplies	6443207	6712026	6810120	-98094	101.46	
c. Operating expenses	1373877	1065651	1131861.95	-66210.95	106.21	
d. Vehicle hire and fuel, oil & maintenance	1277039	1056121	1110496.05	-54375.05	105.15	
e. Training /seminar/ workshop etc.	788500	557777	607300	-49523	108.88	
f. Publications and printing	392250	148201	82250	65951	55.50	
g. Miscellaneous	387531	243769	291061	-47292	119.40	
h. Capital expenses	4031999	4182000	3702994	479006	88.55	
<b>Total</b>	<b>18477763</b>	<b>16969244</b>	<b>16965856.96</b>	<b>3387.04</b>	<b>99.98</b>	

### Financial and physical progress (Component wise)

#### Coordinating component: PHTD, BARI

Items of expenditure/ activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	516360	392766	356910	35856	90.87	
b. Field research /lab expenses and supplies	0	0	0	0	0	
c. Operating expenses	191984	146031	165298	-19267	113.19	
d. Vehicle hire and fuel, oil & maintenance	217046	165095	183598	-18503	111.21	
e. Training /seminar/ workshop etc.	237400	180577	233400	-52823	129.25	
f. Publications and printing	142250	108201	42250	65951	39.05	
g. Miscellaneous	44000	33468	44000	-10532	131.47	
h. Capital expenses	0	0	0	0	0	
<b>Total</b>	<b>1349040</b>	<b>1026138</b>	<b>1025456</b>	<b>682</b>	<b>99.93</b>	

#### Implementing component-1: PHTS, HRC, BARI

Items of expenditure/ activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	1475878	1452618	1470878	-18260	101.26	Due to unavailability of fund.  After submission of PCR, in-total 349242 BDT was deducted by PIU-BARC.*
b. Field research /lab expenses and supplies	2896207	2900000	2896207	3793	99.87	
c. Operating expenses	541893	460982	518292.95	-57310.95	112.43	
d. Vehicle hire and fuel, oil & maintenance	659993	570000	604993.05	-34993.05	106.14	
e. Training /seminar/ workshop etc.	249600	187200	187200	0	100.00	
f. Publications and printing	200000	0	0	0	0.00	
g. Miscellaneous	159760	116530	159760	-43230	137.10	
h. Capital expenses	1259999	1410000	1259999	150001	89.36	
<b>Total</b>	<b>7443330</b>	<b>7097330</b>	<b>7097330</b>	<b>0.00</b>	<b>100.00</b>	

\* Ref Memo : NATP-2/PIU-BARC-106/PBRG Fund Release/2018-3006 Dated: 28/10/2021

### Implementing component-2: FMPE, BARI

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	1179192.00	734355	978025.96	-243670.96	133.18	
b. Field research/lab expenses and supplies	1582000.00	1847026	1948913	-101887	105.52	
c. Operating expenses	305000.00	158638	148271	10367	93.46	
d. Vehicle hire and fuel, oil & maintenance	215000.00	136026	136905	-879	100.65	
e. Training/workshop/seminar	181500.00	70000	66700	3300	95.29	
f. Publications and printing	20,000.00	40000	40000	0	100.00	
g. Miscellaneous	130000.00	40000	33530	7670	83.83	
h. Capital expenses	2682000.00	2682000	2352995	327805	87.73	
<b>Total</b>	<b>6294692.00</b>	<b>5708045</b>	<b>5705339.96</b>	<b>2705.04</b>	<b>99.96</b>	

### Implementing component-3: CARS, DU

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	611930	423960	423960	0	100	N/A
b. Field research/lab expenses and supplies	1965000	1965000	1965000	0	100	N/A
c. Operating expenses	335000	300000	300000	0	100	
d. Vehicle hire and fuel, oil & maintenance	185000	185000	185000	0	100	N/A
e. Training/workshop/seminar etc.	120000	120000	120000	0	100	N/A
f. Publications and printing	30000	0	0	0	100	
g. Miscellaneous	53771	53771	53771	0	100	N/A
h. Capital expenses	90000	90000	90000	0	100	N/A
<b>Total</b>	<b>3390701</b>	<b>3137731</b>	<b>3137731</b>	<b>0.00</b>	<b>100.00</b>	

### D. Achievement of Sub-project by objectives (Tangible form): Technology generated/ developed

#### Coordinating component: PHTD, BARI

N/A

### Implementing component-1: PHTS, HRC, BARI

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
General objective:  i) To improve the quality and safety of fruits and vegetables by introducing new tools, machinery and means of harvesting, handling, packaging and	<u>Expt. 1.</u> Postharvest quality of mango as affected by traditional and improved practices integrated in the value chains	While conducting the experiment and training, BARI Mango Harvesting tool, de-sapping tray and hot water treatment machine were shown to mango growers and traders. The tools and machines were preserved in pack house.	Mango growers and traders of Rajshahi area showed interest to use BARI Mango Harvesting tool, De-sapping tray and BARI Hot Water Treatment machine, desired intensive in using of HWT

<p>cool chamber facilities.</p> <p>Specific objective:</p> <p>ii) To intervene and dissemination of improved post-harvest technologies to the value chain actors and other stakeholders through training and demonstration.</p>			machine.
	<u>Expt. 2.</u> Postharvest quality of banana as affected by traditional and improved practices integrated in the Value chains	Farmers and traders were involved in conducting the experiment. They were shown to Banana de-handing tools, washing house and BARI Fruit and Vegetable washing machine.	Farmers are traders showed interest on Banana de-handing tools. They liked washing machine but expected incentive to collect the machine.
	<u>Expt. 3.</u> Technical and economic feasibility of integrated postharvest management practices in maintenance of quality and reducing losses in carrot value chain	While conducting the experiment, washing methods through washing machine was demonstrated. The washing machine was installed in Bogura Pack house compound.	Farmers are traders of Bogura pack house sited expressed their interest in using of washing machine, however demanded subsidy to buy/collect the washing machine.
	<u>Expt. 4.</u> Technical and economic feasibility of improved postharvest handling practices in cauliflower value chain	Curd covering and Packaging technique was shown and trialed by the growers and traders.	Traders showed interest in using plastic crate as transport, however need to increase size as it would be suitable in carrying more numbers of cauliflower.
	<u>Expt. 5.</u> Technical; and economic feasibility improved postharvest handling practices in brinjal value chain	Washing method in washing house and washing machine were demonstrated to the farmers and traders during conducting the experiment and training.	Farmers and traders expressed their interest in using washing method and washing machine.

<p>General objective:</p> <p>ii) To strengthen postharvest management capacity across the value chain of selected fruits and vegetables.</p> <p>Specific objective:</p> <p>iii) To improve capacity of value chain actors in maintenance of quality and reducing postharvest losses of fruits and vegetables</p>	<p>Two Pack houses were established in two sites:</p> <p>1. Inside NCDP Growers' Market, Building, Baneswar Bazar, Rajshahi (with permission of DG, DAM, MoA, GoB and granted by DAM, Rajshahi)</p> <p>2. Inside the building granted by Vatra Uttorpara CIG (Phasol) Samobai Samiti Limited, Village-Vatra, Upazilla-Sherpur, Zilla-Bogura.</p>	<p>The pack houses were used in:</p> <ul style="list-style-type: none"> <li>➤ Performing the activities of intervening of improved technologies to motivate growers and suppliers in respective sites.</li> <li>➤ Improving of learning capacity of the value chain actors (growers, suppliers and traders) in using of improved technologies and best practices through participatory research trials, pilot demonstration and hands on training.</li> </ul> <ul style="list-style-type: none"> <li>▪ Postharvest tools, machines, packaging materials, etc. sorting and grading tables, and cool bot were provided in the pack house.</li> </ul>	<p>Growers and traders attached and involved with the respective pack houses were using the houses and cool bot cool room for postharvest handling, sorting, grading, packaging and processing of their fruits and vegetables of in these pack houses.</p>
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### Implementing component-2: FMPE, BARI

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
<p>i) To develop and up-scaling of improved tools, machinery and means of harvesting, handling, and packaging of fruits and vegetables.</p>	<p>Expt.# 1. Improvement and fine tuning of washing machine for mango</p>	<ul style="list-style-type: none"> <li>➤ Leafy &amp; fruit vegetable and fruit washing was developed</li> <li>➤ Washing and cleaning efficiency of the machine for mango, banana and brinjal were found to be 99% and 97% respectively.</li> </ul>	<p>Farmers of Bogura area showed interest to use the machine for washing vegetable</p> <p>Payback period: 14 days Benefit cost ratio was 1.7.</p> <p>It is needed in carrot growing area during harvesting time of carrot</p>
	<p>Expt. # 2. Modification and fine tuning of washing machine for banana</p>	<ul style="list-style-type: none"> <li>➤ Capacities of machine were 1.0-2.0 t/h for vegetable and 1.0-1.5 t/h for fruits.</li> </ul>	
	<p>Expt. # 3. Improvement and fine tuning of washing machine for brinjal</p>	<ul style="list-style-type: none"> <li>➤ The washing costs were 0.20-0.25 Tk./kg.</li> </ul>	
	<p>Expt. # 4. Improvement and fine tuning of washing machine for carrot</p>	<ul style="list-style-type: none"> <li>➤ Improved carrot washing machine was moved to other place easily.</li> <li>➤ A large capacity self-propelled drum type carrot washing machine was developed.</li> <li>➤ Capacity: 5.50 tons per hour</li> <li>➤ Washing efficiency and the</li> </ul>	

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
		cleaning efficiency were about 98% and 99.0% respectively ➤ Washing cost: 0.12 Tk./kg.	
ii) To validate the postharvest tools and machineries in maintenance of quality and reducing losses in the value chain and economic analysis of the machine.	Expt. # 5. Effects of cold storage temperature and humidity for different packaging on shelf-life and quality of carrot	Fresh harvested washed carrot can be stored for 5-6 months at 0-2 °C for 85-95% relative humidity using CFB carton and plastic crate.	Cold storage companies already used the technology Farmers showed interest to store the washed carrot
	Expt. # 1. Adoption of a hydraulic lifter for bagging of mango	The lifter was modified into self-propelled machine operated using electricity and diesel engine	Mango grower initially interest to use the machine for bagging mango and multipurpose
	Expt. # 2. Determination of combined effects of temperature and exposure time on treating mango in hot water	BARI Aam-3 would be treated at 55° C for 5 minutes. The shelf-life is extended by 5-6 days. Postharvest loss (disease) was reduced by 85% (disease)	It is expected that exporters would be used the technology
	Expt. # 3. Effect of different packaging on the quality and shelf-life of banana for long distance transportation	Matured banana (local variety Rangin Sagar) should be harvested from banana orchard and wrapped banana hands with cling paper or news print paper packed in plastic crate or CFB carton and transported to wholesale market for reduction postharvest quality and quantity losses from 59 to 0.03%.	Farmers and trader whom were seen the experiment procedure in the field interested to use the procedure in future
iii) To intervene and dissemination of improved technologies to the relevant stakeholder through training and demonstration	Training	One training program conducted	
	Field demonstration	Two field demonstrations conducted at Baneswar, Rajshahi on 11 June 20 and at Bogura on 12 June 2020 conducted.	Made farmers and traders aware on postharvest technologies

### Implementing component-3: CARS, DU

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
Carrot, & cauliflower and brinjal quality safety and shelf life extension was done.	Washing with sanitizers, drying and packaging in plastic crates and/or traditional practices	Scientific paper and yearly report	Improve quality, safety and shelf life
Survey questionnaires' preparation	Integrated with other component partners	Scientific paper and yearly report	A complete survey study
Banana microbial analysis of field collected samples and storage study	Washing with sanitizers, drying and packaging in plastic crates and/or traditional practices	Scientific paper and yearly report	Improve quality, safety and shelf life
Mango experiment started at the field but sample collection and analysis was done in 2020	Washing with sanitizers, drying and packaging in plastic crates and/or traditional practices	Scientific paper and yearly report	Improve quality, safety and shelf life

### E. Information/ knowledge generated/ policy generated

#### Coordinating component: PHTD, BARI

N/A

### Implementing component-1: PHTS, HRC, BARI

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
<p>General objectives:</p> <p>iii) To reduce postharvest losses of fruits and vegetables.</p> <p>Specific objectives:</p> <p>i) To provide knowledge and supports to the contract growers and suppliers in maintaining produce quality during production and postharvest handlings of</p>	<p><u>Expt. 1.</u></p> <p>Postharvest quality of mango as affected by traditional and improved practices integrated in the value chains</p>	<p>The results of the experiment shared to value growers and traders which was obtained from integration of IP with pre-harvest bagging, HWT or 0.00.00.01% CCA mixed HWT at 55 for 5 minutes and packing in PC resulted 73.45 PHT loss of mango. During the conducting of research, use of BARI Mango Harvesting tool, De-sapping tray and BARI Hot Water Treatment machine were showed to farmers and traders.</p>	<p>Mango growers and traders of Rajshahi area showed interest to use improved practices and tools and machine which were shown in conducting research.</p>
	<p><u>Expt. 2.</u></p> <p>Postharvest quality of banana as affected by traditional and improved practices integrated in the</p>	<p>Results of the study was shared to value chain actors. It found that washing with alum water and packing in PC with or without MAP resulted 63.64% to 81.17% PHT loss. During execution of research, methods and tools were demonstrated.</p>	<p>Farmers of Bogura area showed interest to apply integration of improved practices including banana de-handling tools. They were interested in using of alum water</p>

fruits and vegetables	Value chains		washing methods and PC packing technique.
	<u>Expt. 3.</u> Technical and economic feasibility of integrated postharvest management practices in maintenance of quality and reducing losses in carrot value chain	Results of this study shared to vegetable growers and traders that integrated practices of washing carrots in calcinated calcium (1g_CCa in 10L water) through washing machine, drying surface water in air and packed in plastic crate lining with clean newsprint paper and careful loading to transport resulted in 88.7% reduction in loss, and 100% carrots could be sold at retail outlets.	Farmers and traders showed interest to use improved washing methods with CCa and PC packaging.
	<u>Expt. 4.</u> Technical and economic feasibility of improved postharvest handling practices in cauliflower value chain	Integrated practices as: recommended production practices and improved handling practices including sorting, trimming, covering curd face with clean newsprint paper, plastic crate packing lining with newsprint paper or MAP and careful loading were found to be effective in maintenance of quality of cauliflower, resulted in 84.96% PHT loss in the value chain. The result was shared to the growers and traders through demonstration and training.	Farmers and traders showed interest in applying of recommended production practices and improved postharvest handling practices with like newsprint wrapping/covering method of cauliflower curd and MAP packaging.
	<u>Expt. 5.</u> Technical; and economic feasibility improved postharvest handling practices in brinjal value chain	Integrated approach of recommended cultural and plant protection measures, pheromone trap and harvesting at optimum maturity stage with improved postharvest handling practices including washing in 0.00.00.01% CCa and packing in PC lining with clean newsprint paper or MAP was found to be effective in maintenance of quality that resulted in 79.53% loss for a total postharvest period of 5 days.	Farmers and traders showed interest in applying of recommended production practices with pheromone trap protection measure. They show positive attitude in using of washing method with calcinated calcium and packaging in plastic crate lining with newsprint paper and MAP.

### Implementing component-2: FMPE, BARI

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
i) To develop and up-scaling of improved tools, machinery and means of harvesting, handling, and packaging of fruits and vegetables.	Expt.# 1. Improvement and fine tuning of washing machine for mango	Leafy & fruit vegetable and fruit washing was developed for selling fresh and safety products.	Farmers of Bogura area showed interest to use the machine for washing of vegetable
	Expt. # 2. Modification and fine tuning of washing machine for banana		
	Expt. # 3. Improvement and fine tuning of washing machine for brinjal		
	Expt. # 4. Improvement and fine tuning of washing machine for carrot	A large capacity self-propelled drum type carrot washing machine was developed.	It is benefited for commercial purpose
ii) To validate the postharvest tools and machineries in maintenance of quality and reducing losses in the value chain and economic analysis of the machine.	Expt. # 5. Effects of cold storage temperature and humidity for different packaging on shelf-life and quality of carrot	Fresh harvested washed carrot storage protocol was developed. Hygienic product was gained.	Cold storage owners interested to use the technology
	Expt. # 1. Adoption of a hydraulic lifter for bagging of mango	Self-propelled hydraulic lifter was improved that was operated by electricity and diesel engine	Mango growers would be benefited using the machine
	Expt. # 2. Determination of combined effects of temperature and exposure time on treating mango in hot water	Hot water treatment combination of BARI Aam-3 was developed	Reduced postharvest loss and extension of shelf-life and increase selling price
	Expt. # 3. Effect of different packaging on the quality and shelf-life of banana for long distance transportation	Quality and safety banana protocol was developed	Improved postharvest quality and reduction quantity losses from 59 to 0.03%.
iii) To intervene and dissemination of improved technologies to the relevant stakeholder through training and demonstration	Training	One training program will be conducted	
	Field demonstration	Made awareness among farmers and traders on postharvest machinery and tools	Farmers and traders would be benefited using the machines and tools

### Implementing component-3: CARS, DU

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
To develop safe postharvest sanitizing protocols in maintenance of quality of selected fruits and vegetables.	i) Conducted survey and arranging workshop in relation to food safety and quality issues.	Workshop & survey	Public awareness
ii) To assure safety and quality of improved postharvest technologies to be intervened.	ii) Conducted study on the efficacy of non-chlorine sanitizer, natural salt and/or in combination of both against the microbes & pesticide residue on cauliflower, carrot and brinjal (sample collecting from the selected growing areas of value chain)	Use sanitizers to kill microorganisms	Problem identification and its remedy to practice at the farm level
iii) To develop and transfer improved technologies and safety and quality guidelines to the relevant stakeholders.	Development of improved technology for carrot preservation	Treated carrot stored in a cold storage	Shelf life extension of 5-6 months is possible.

### F. Materials Development/ Publication made under the Sub-project

#### Coordinating component: PHTD, BARI

N/A

### Implementing component-1: PHTS, HRC, BARI

Publication	Number of Publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/booklet/leaflet/flyer etc.	-	-	There was target to publish two booklets. Due to unavailability of fund, lastly it was discarded.
Journal publication	Md. Nazrul Islam, Eshita Shahanaz, Md. Nurul Amin, Md. Alim Uddin and Ashfak Ahmed Sabuz and Md. Latiful Bari (2021). A study of low-cost integrated postharvest technologies for maintenance of quality and safety and reducing postharvest losses of brinjal. Journal of postharvest Biology and Technology (under review).		

Video clip/TV program	-		
News-paper/popular article	No. 2		Local newspaper of Rajshahi and Bogura
Other publications, if any	-	-	

### Implementing component-2: FMPE, BARI

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/booklet/leaflet/flyer etc.		2	১. ফল ও সবজি যৌতকরণ যন্ত্রের পরিচিতি এবং রক্ষণাবেক্ষণ নির্দেশিকা ২. আম সংগ্রহোত্তর যন্ত্রের ব্যবহার বিধি ও রক্ষণাবেক্ষণ নির্দেশিকা
Journal publication	1	1	Use of non-chlorine sanitizer and low-cost packages enhancing microbial safety and quality of commercial cold-stored carrots, Journal of Food Processing and Preservation, 45(1):2021
Video clip/TV program		2	ফল সংরক্ষণে নিরাপদ পদ্ধতি, সময় রাজশাহীতে হট ওয়াটার ড্রিটম্যান্ট, ৭১
News Paper/Popular Article		3	1. ফল সংরক্ষণে নিরাপদ পদ্ধতি 2. Call for using hot water treatment plant in postharvest mango 3. Call for using hot water treatment plant in postharvest mango
Other publications, if any			

### Implementing component-3: CARS, DU

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/booklet/leaflet/flyer etc.	0	0	
Journal publication	2	1	International Journal of Food processing and Preservation
Video clip/TV program	0	2	Local video clip
News Paper/Popular Article	0	2	Local Newspaper
Other publications, if any	0	0	

**G. Description of generated Technology/knowledge/policy:**

i) Technology Fact Sheet (title, introduction, description, suitable location/ecosystem, benefits, name and contact address of author).

**Coordinating component: PHTD, BARI**

N/A

**Implementing component-1: PHTS, HRC, BARI**

Technology Fact Sheet: 6

## FACT SHEET-1

### Establishment and Uses of Packhouse in Postharvest handling of Fruits and Vegetables

#### Introduction

Pack house is a structural unit used for postharvest handling processes of farm produce. It's an important adherence of postharvest management practices of fruits and vegetables through which quality of the produce can be maintained that play great role in reducing of losses in subsequent handling and marketing endeavors. A pack house for fruits and vegetable should be established with accumulation of sorting, grading, washing, and packaging amenities. Thus, two pack houses were established in two areas of Rajshahi and Bogura districts with a view of intervening of improved postharvest practices of mango, banana, carrot, cauliflower and brinjal. These technology on pack house establishment could be used in handling of other fruits and vegetables and might be adaptable in other areas in the country.

#### Usefulness/Where to be applicable:

- Applicable in fruits and vegetables growing areas and local assemble markets.
- Growers and suppliers e.g. farmers, beparies wholesalers in the value chains can use and follow packhouse technology.

**Establishing Principle:** In principle, floor area of pack house should be kept 20 sq-m for handling of 1000 kg fresh products. There should be two units/areas, one for product receiving area/entry area and another for product exiting/departure area. Sorting and grading table, washing tank, basin/sink for hand washing etc. should be set in receiving area. Drying and packaging table should be set in exiting area. Weighing balance, seating chairs, table for accounting and management, accounting book and register could be set within the receiving unit or any other convenient positions. Sanitizing and personal hygiene maintenance materials e.g. soap, Apron, face masks, hand gloves, etc. should be facilitated in pack house. In addition, there could an option in establishing a cool bot cold room to facilitate short-time storage of packed fruits and vegetables. Hot water treatment machine can be installed to treat mango and suitable fresh produces. Washing machine can be installed to perform washing of banana and carrot and other root and fruit type vegetables.

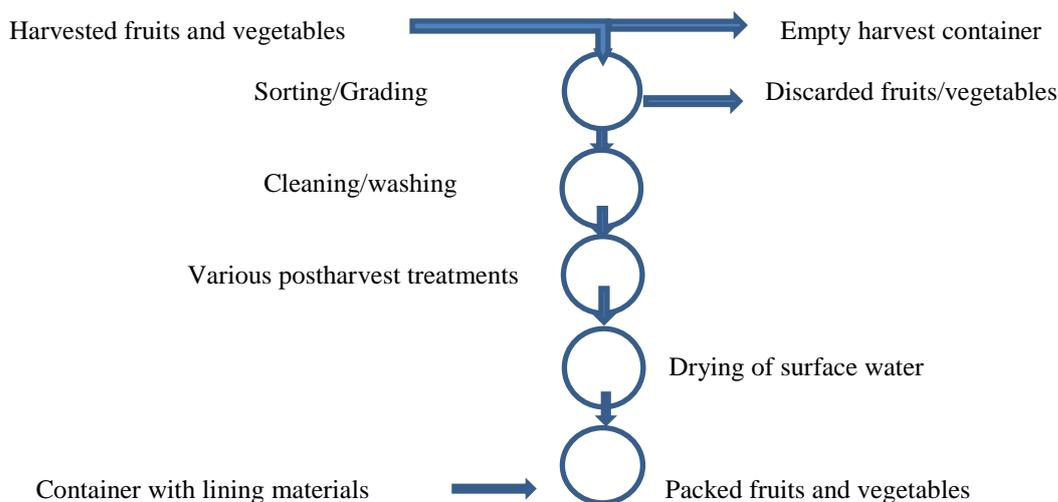


Fig: General flow diagram of postharvest practices of fruits and vegetables in pack house

#### Technology Developed by:



Integration of Postharvest Technologies and Best Practices in the value chains of Fruits and Vegetables (ID#016), HRC, BARI Component  
Postharvest Technology Section, HRC, BARI, Gazipur-1701

#### Financed By:



PBRG, NATP-2, PIU- BARC

## FACT SHEET-2

### Integrated Postharvest Handling Protocol in Mango Value Chain

**Description:** The following steps should be taken sequentially at different stages in the value chain and all the market actors (farmer/producer, trader, storekeeper, wholesaler, retailer and buyer) should take part in maintenance of quality of mango from harvesting to retailing.

Maturity determination	<ul style="list-style-type: none"> <li>Mango should be selected to harvest at commercially mature stage. Maturity could be assessed by observing fruit size when it attains maximum in growth as of its varietal trait, yellowish flesh colour, appearance of waxy substance on fruit surface and natural falling of few fruits from the trees in normal weather condition.</li> </ul>
Harvesting	<ul style="list-style-type: none"> <li>Fruits should be collected by harvesting tools (BARI mango harvesting tool). It is made by long bamboo stick, nets and sharp knife. While harvesting, keep a portion of stalk/pedicel. Collected mangoes should be kept on a plastic made sheet or on polythene sheet or directly in a plastic crate placing in a shady place in orchard.</li> </ul>
De-sapping	<ul style="list-style-type: none"> <li>Injured, diseased or damaged fruits should be sorted out primarily in orchard shade .</li> <li>Fruit stalk should be cut above half a centimeter from the basal end. Fruits should be kept upside down in a de-sapping tray hole (through BARI de-latexing tray) for exudation of latex flow.</li> </ul>
Brought to pack house	<ul style="list-style-type: none"> <li>Mangoes should be brought to pack house by keeping them in plastic crate lining with newsprint paper.</li> <li>To remove field heat, mango should be kept in air by switching on ceiling fan/hand fan for 2 hours.</li> </ul>
Sorting and grading	<ul style="list-style-type: none"> <li>Sorting should be done by removal of diseases, insect infested and defective fruits.</li> <li>Grading will be done based on fruit size, colour and maturity according to market demand.</li> <li>These practice will be done on sorting and grading table.</li> </ul>
Hot water treatment	<ul style="list-style-type: none"> <li>Selected mangoes will be treated in hot water at 55°C for 5 minutes (through BARI hot water treatment plant)</li> <li>Calcinated calcium could be mixed with hot water (0.1%/ml) for non-bagged fruits.</li> <li>No need of using of calcinated calcium for pre-harvest bagged fruits.</li> </ul>
Drying surface water	<ul style="list-style-type: none"> <li>Surface water of hot water treated fruits should be dried out in air through ceiling fan or stand fan.</li> </ul>
Packing in plastic crate	<ul style="list-style-type: none"> <li>Clean newsprint paper should be used as lining material in plastic crates and selected mangoes should be packed in layers in plastic crate.</li> <li>Depending on the variety, 18-20 kg of mango will be packed in a plastic crate.</li> </ul>
Loading and transport	<ul style="list-style-type: none"> <li>Plastic crates should be loaded in layers in vehicle (trucks) to be sent to distant markets.</li> <li>No goods other than mango should be loaded in the vehicle (single crop loading).</li> </ul>
Wholesale storage	<ul style="list-style-type: none"> <li>Ventilation system should be maintained in wholesaler's (Pikar's) store (Arata)</li> <li>Mangoes cannot be kept in piles in storehouse.</li> </ul>
Display in retail outlet	<ul style="list-style-type: none"> <li>Ventilation should be maintained in retail shop and mangoes should not be kept in heap, should be kept tidy in racks.</li> </ul>

#### Features:

- Integrated, in other words, accumulation of stepwise improved postharvest technologies and best practices from harvesting to retailing.
- Suitable for applying in-country value chains of Bangladesh.

#### Usefulness/Where to be applicable:

- Growers and traders involved in mango value chains can (Bepari, wholesalers and retailers) take part of this integrated approach of postharvest handling practices.
- Suitable for in-country assemble market, distant market venues and super markets.

#### Benefits from the Technology:

- ❖ Will be useful in maintenance of postharvest quality of mango in different points of value chains.
- ❖ Will be useful in reducing postharvest weight loss and qualitative loss of mango.
- ❖ Will be useful in increasing marketable life of mango.

#### Impact of Technology (Human health, soil and Environment)

- There is no risk to human health.
- Not harmful to soil and environment
- Eco-friendly.



a. Harvesting of mango with harvesting tool



b. Harvesting mango with stalk



c. Use of secateurs to cut the mango stalk



d. keeping half cm stalk and de-sapping



e. Sorted mango in pack house



f. Hot water treatment



g. Drying of surface water after HWT



h. Packaging in plastic crate



i. Packed mango kept for marketing

Fig. Pictorial view of stepwise improved and integrated postharvest management practices in the mango value chains (Left to right, from one to next row)

**Technology Developed by:**



Postharvest Technology  
Section  
HRC, BARI, Gazipur-1701

**Financed By:**



Integration of Postharvest Technologies and Best Practices in the value chains of Fruits and Vegetables (NATP-2, PIU-BARC PBRG Sub-project ID No. 016) BARI Component

## FACT SHEET-3

### Integrated Postharvest Handling Protocol in Banana Value Chain

#### Features:

- Integrated, in other words, accumulation of stepwise improved postharvest technologies and best practices for banana
- Suitable for applying in-country value chains of banana in Bangladesh.

**Description:** The following steps should be taken sequentially at different stages of the supply chain and all the value chain actors (farmer/producer, trader, storekeeper, wholesaler, retailer and buyer) should take part in maintenance of quality of banana from harvesting to retailing.





Fig. Stepwise postharvest management practices of banana in the value chains (Left to right)

#### Usefulness/Where to be applicable:

- Growers and traders involved in banana value chains can (Bepari, wholesalers and retailers) take part of this integrated approach of postharvest handling practices.
- Suitable for in-country assemble market, distant market venues and super markets.

#### Benefits from the Technology:

- ❖ Will be useful in maintenance of postharvest quality of banana in the value chains.
- ❖ Will be useful in reducing postharvest weight loss and qualitative loss of banana.
- ❖ Banana could be marketable for more days than non-integrated practice.

#### Impact of Technology (Human health, soil and Environment):

- There is no risk to human health.
- Not harmful to soil and environment.
- Eco-friendly technology.

#### Technology Developed by:



Postharvest Technology  
Section  
HRC, BARI, Gazipur-1701

#### Financed By:



Integration of Postharvest Technologies and Best Practices in the value chains of Fruits and Vegetables (NATP-2, PIU-BARC PBRG Sub-project ID No. 016) BARI Component

## FACT SHEET-4

### Integrated Postharvest Handling Protocol in Carrot Value Chain

**Features:**

- Integrated/accumulation of stepwise improved postharvest technologies and best practices for carrot
- Suitable for applying in-country value chains of carrot in Bangladesh.

**Description/Information on technology utilization:**

The following steps should be taken at different stages of value chain and all actors (farmer/producer, trader, storekeeper, wholesaler, retailer) should take part in maintenance of quality of carrot:





a. Washing of carrot in clean water through washing machine.



a. Washing of carrot in aqueous calcinated calcium through washing machine.



c. Packing of carrots in plastic carrot lining with clean newsprint paper



d. Modified atmospheric packaging of carrots inside plastic crate

Fig. Partial view of stepwise postharvest management practices of carrot in the value chains

**Usefulness/Where to be applicable:**

- Growers and traders involved in carrot value chains can (Bepari, wholesalers and retailers) take part of this integrated approach of postharvest handling practices.
- Suitable for in-country assemble market, city distant markets and super markets.

**Benefits from the Technology:**

- ❖ Will be useful in maintenance of postharvest quality of carrot in the value chains.
- ❖ Will be useful in reducing postharvest weight loss and qualitative loss of carrot
- ❖ Carrots could be marketable for more days than non-integrated practice.

**Impact of Technology (Human health, soil and Environment):**

- There is no risk to human health.
- Not harmful to soil and environment.
- Not hazardous to environment

**Technology Developed by:**

Postharvest Technology Section  
HRC, BARI, Gazipur-1701



**Financed By:**

Integration of Postharvest Technologies and Best Practices in the value chains of Fruits and Vegetables (NATP-2, PIU-BARC PBRG Sub-project ID No. 016) BARI Component



## FACT SHEET-5

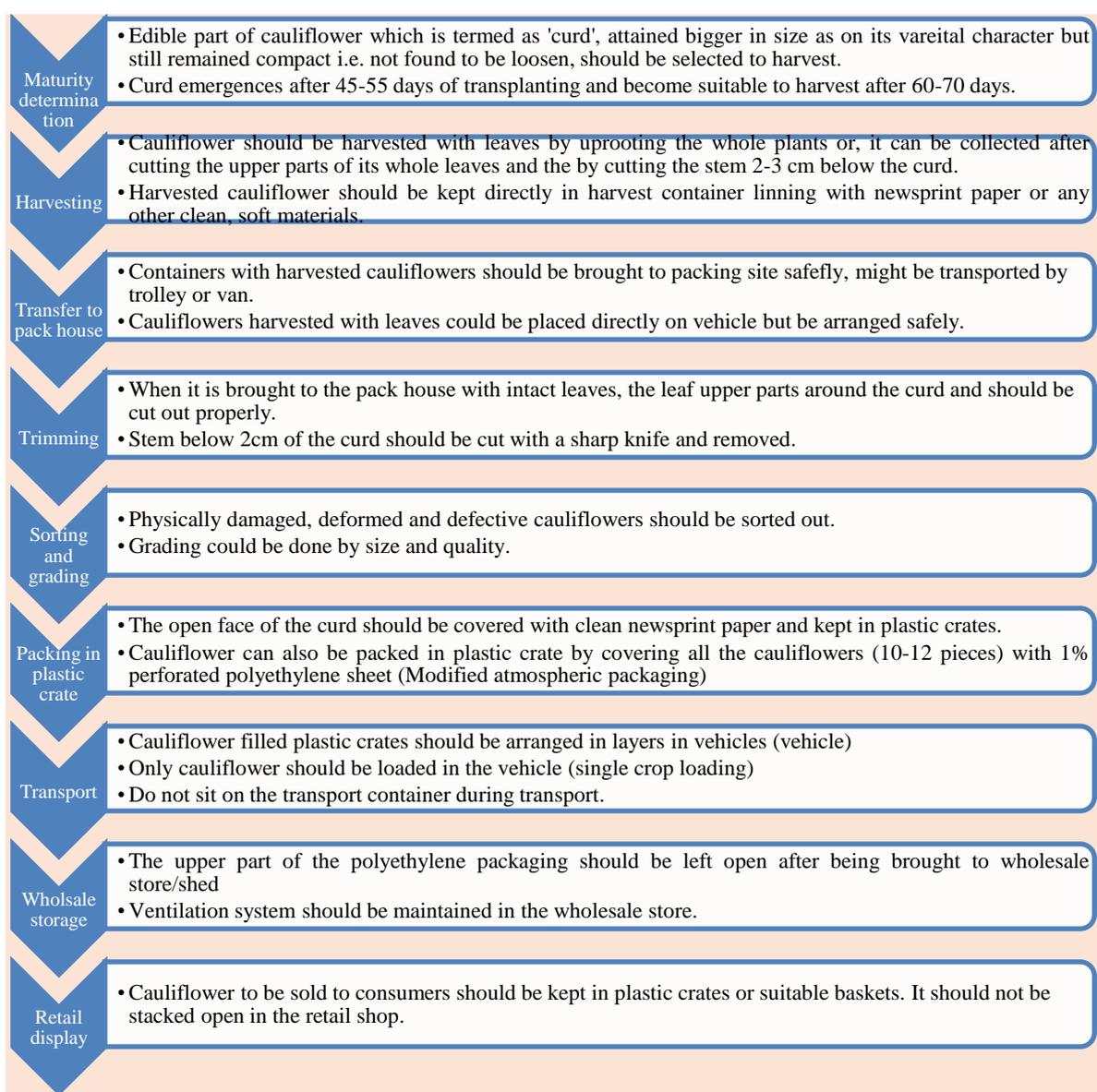
### Integrated Postharvest Handling Protocol in Cauliflower Value Chain

#### Features:

- Integrated, in other words, accumulation of stepwise improved postharvest technologies and best practices for cauliflower
- Suitable for applying in-country value chains of cauliflower in Bangladesh.

#### Description/Information on technology utilization:

The following steps should be taken sequentially at different stages of the supply chain and all the value chain actors should take (farmer/producer, trader, storekeeper, wholesaler, retailer and buyer) should take part in maintenance of quality of cauliflower from harvesting to retailing.





a. Selected commercially mature cauliflower to harvest

b. Harvesting of cauliflowers and brought to be loaded

c. Cauliflowers loaded to be brought to pack house



d. Removing of field heat in pack house

e. Trimming of cauliflower

f. Covering curd face by newsprint paper



g. Cauliflowers wrapped by newsprint paper and packed in plastic crate to be dispatch to distant market

h. Cauliflower kept individually in perforated polyethylene bag inside plastic crate to be dispatch

i. Cauliflowers kept in plastic crate by covering them with 1% perforated polyethylene sheet (MAP)

Fig. Partial view of stepwise postharvest management practices of cauliflower in the value chains

#### Usefulness/Where to be applicable:

- Growers and traders involved in cauliflower value chains can (Bepari, wholesalers and retailers) take part of this integrated approach of postharvest handling practices.
- Suitable for in-country assemble market, city distant markets and super markets.

#### Benefits from the Technology:

- ❖ Will be useful in maintenance of postharvest quality of cauliflower in the value chains.
- ❖ Will be useful in reducing postharvest weight loss and qualitative loss of cauliflower
- ❖ Will be useful in increasing marketable life of cauliflower.

#### Impact of Technology (Human health, soil and Environment)

- There is no risk to human health.
- Not harmful to soil and environment. Not hazardous to environment.

#### Technology Developed by:

Postharvest Technology Section  
HRC, BARI, Gazipur-1701



#### Financed By:

Integration of Postharvest Technologies and Best Practices in the value chains of Fruits and Vegetables (NATP-2, PIU-BARC PBRG Sub-project ID No. 016) BARI Component



## FACT SHEET-6

### Integrated Postharvest Handling Protocol in Brinjal Value Chain

#### Features:

- Integrated, in other words, accumulation of stepwise improved postharvest technologies and best practices for brinjal
- Suitable for applying in-country value chains of brinjal in Bangladesh.

#### Description/Information on technology utilization:

The following steps should be taken sequentially by value chain actors (farmer/producer, trader, storekeeper, wholesaler, and retailer) and should take part in maintenance of quality.





a. Selection of commercially mature brinjal and collecting in plastic bucket



b. Harvesting of brinjal in plastic crate



c. Keeping harvested brinjal on plastic sheet for primary sorting



d. Sorting of brinjal on sorting table in pack house



e. Washing of brinjal in calcinated calcium water



f. Washing of brinjal through washing machine



g. Drying of surface water of washed brinjal in air in pack house



h. Packaging of brinjal in plastic crate lining with clean newsprint paper



i. Packaging of brinjal in plastic crate with 1% perforated polyethylene sheet (MAP)

Fig. Partial view of stepwise postharvest management practices of brinjal in the value

**Usefulness/Where to be applicable:**

- Growers and traders involved in brinjal value chains can (Bepari, wholesalers and retailers) take part of this integrated approach of postharvest handling practices.
- Suitable for in-country assemble market, city distant markets and super markets.

**Benefits from the Technology:**

- ❖ Will be useful in maintenance of postharvest quality of cauliflower in the value chains.
- ❖ Will be useful in reducing postharvest weight loss and qualitative loss of cauliflower
- ❖ Will be useful in increasing marketable life of cauliflowers.

**Impact of Technology (Human health, soil and Environment)**

- There is no risk to human health.
- Not harmful to soil and environment.
- No negative effects on environment.

**Technology Developed by:**

Postharvest Technology  
Section  
HRC, BARI, Gazipur-1701



**Financed By:**

Integration of Postharvest Technologies and Best Practices in the value chains of Fruits and Vegetables  
(NATP-2, PIU-BARC PBRG Sub-project ID No. 016), BARI Component



## Implementing component-2: FMPE, BARI

### FACT SHEET-1

#### Self-Propelled Drum Type Root Crop Washing Machine

##### Background:

The total production of vegetables of Bangladesh is 13.0 million tons. Total carrot production was 16306 tonnes in 4533 acres of cultivated land in 2017-18 (BBS, 2019). Islam (2004) reported that the postharvest losses of fruits and vegetables during all stages of postharvest operations were 43% of which handling and distribution accounted for 22.5%. After harvesting, vegetables are transported in the market without sorting, grading and washing. There are many micro-organisms, and dust on the surface of the vegetables. The products are infected by micro-organisms easily. Unhygienic products are sold in the markets. Some traders/retailers wash products with impure water of local ponds /canals. These washed products are harmful for human health that causes different diseases. Besides, a huge quantity and quality of products are lost. Sanitation is a great concern to produce handlers, not only to protect the produce against post-harvest diseases, but also to protect the consumers' food borne illnesses. *E. coli* 0157:H7, salmonella, *Chyptosporidium*, Hepatitis, and *Cyclospora* are among the disease-causing organisms that have been transferred via fresh fruits and vegetables (Burditt, 1982; Mitchamet *et al.*, 1997). Washing is a standard postharvest handling operation for many fruits and vegetables to remove adherences, dirt, latex and external pathogenic structures. Unfortunately, in Bangladesh fruits and vegetables are hardly washed before entering into the marketing channel, and this contributes to poor quality and considerable losses of the produce. Self-propelled drum type root crop washing was developed by BARI financed by PIU-BARC, NATP-2, PBRG-016 to reduce postharvest losses and marketing hygienic products.

**Fabrication of machine:** It is fabricated with MS flat bar, MS shaft, wood, FL bearing, chain-sprocket, wheel, self-starter diesel engine, motor, gear reducer etc. The main parts of it are: i) Main frame; ii) Octagonal drum; iii) Power transmission system; iv) water circulation system; v) delivery chute; vi) self-propelled system and vii) Mechanical stirring system.



Washing machine



Testing of the machine

##### Features of the machine:

- Root crops can be washed by the machine quickly and easily
- It can remove adherences, dirt, latex and external pathogen structures
- Machine is fabricated with locally available materials
- It can save 67% money compared to traditional practice
- It can save 50% time compared to traditional practice
- Washing efficiency and the cleaning efficiency were about 98% and 99.0% respectively

##### Economic analysis:

Washing cost: 0.12 Tk./kg.  
Payback period: 14 days  
Benefit cost ratio was 1.7.  
Price: Tk. 300000

##### Results

Capacity: 5.50 tons per hour  
Roller speed: 22 rpm

## FACT SHEET-2

### Self-Propelled Hydraulic lifter for bagging of mango

#### **Background:**

The total production of fruits in Bangladesh is 3.8 million tons. Everywhere in Bangladesh Rajshahi, Satkhira, Rangpur, Chapainawabganj, Shibganj, Chittagong a lot of mango is produced. Different varieties of mango are scattered. Mango production in Bangladesh is about 12.7 lakh metric tons and the produced area is 417 hectares (BBS 2017). Mango is called the king of all fruits. Mango is everyone's favorite. About 16 commercial varieties of high yielding mangoes are produced. Among these, about 12 varieties of mango have been developed by the Bangladesh Agricultural Research Institute. In Bangladesh, the production period of mango varies place to place from one to one and half months. BARI Aam-2, 3, 4 and 6 and commercial varieties Fazli, Langra. Several varieties like Khirsapat, Ashwini etc. have gained popularity. Mangoes of local variety occupies the lion share of total mango production. After 30-35 days of flowering, 3 times spraying and bagging can protect the mangoes from dust and different types of insects like fruit fly. According to the experts, fruit fly can attack the mangoes before 30-35 days of ripening. Only 5% of mango tree can be covered with the bagging systems and among them only 40-50% mangoes can be covered with bags. The remaining 95% of the trees are sprayed with pesticides about 60-70 times from the time of flowering to harvesting to protect mango from fruit fly. Due to which this mango does not become suitable for export abroad. Older varieties of mango trees are taller and wider besides improved varieties are relatively shorter and less wide. Bagging is done by hand, so people try to do bagging by climbing on the branches of trees as much as they can. Bagging cannot be done in the distant baskets above and around the tree. To overcome this problem, the Department of Farm Machinery and Postharvest Process Engineering of Bangladesh Agricultural Research Institute imported hand operated hydraulic lifters from abroad and converted them into self-propelled hydraulic lifters. With this lifter, you may be able to bag mangoes above 34 feet high tree.

**Fabrication of machine:** The overall size of the device is  $4 \times 2.5 \times 2$  m. The machine two parts, one is hydraulic unit and the other is self-propelled mechanical unit. Arms of hydraulic unit can be operated through oil pump. Hydraulic unit has 4 barrels and self-propelled mechanical unit has self-starter, water cooling engine, Alternator, starting devices, brake systems, batteries, dynamo, etc. The hydraulic lifter can be operated with electricity and alternate energy.



Self-propelled Hydraulic Lifter



Testing Lifter

#### **Features of the lifter:**

- It is a self-propelled hydraulic lifter
- It is possible to bag high trees easily and in a short time
- 2-3 workers can bag at a time
- This device can easily move up and down, right and left, front and back.
- The device can be taken from one place to another
- The hydraulic lifter can be operated with alternate energy instead of electricity

#### **Results**

Speed of lifter for up and down was recorded to be 4.5 and 16 m/min. Capacity is 200-300 numbers bags per hour and bagging cost is Tk 0.25-0.35 per bag

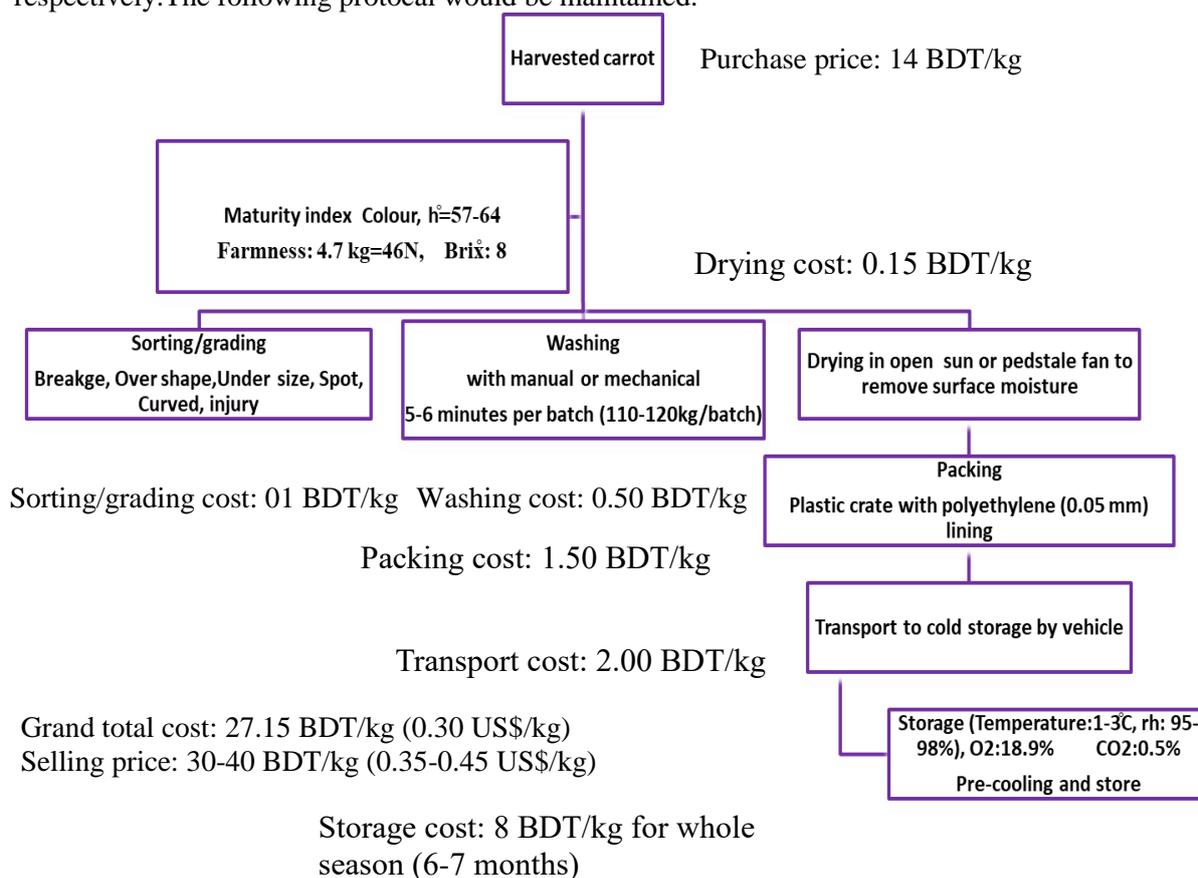
## FACT SHEET-3

### A storing protocol of washed carrot in commercial cold storage

#### Background:

Harvested fresh vegetables are transported in the market without sorting, grading and washing. There are many micro-organisms, and dust on the surface of the harvested vegetables. Unhygienic products are sold in the markets. Some traders/retailers wash products with impure water of local ponds /canals. These washed products are harmful for human health that causes different diseases. Besides, a huge quantity and quality of products are lost. Sanitation is a great concern to produce handlers, not only to protect the produce against postharvest diseases, but also to protect the consumers' food borne illnesses. *E. coli* 0157:H7, salmonella, *Chyptosporidium*, Hepatitis, and *Cyclospora* are among the disease-causing organisms that have been transferred via fresh fruits and vegetables (Burditt, 1982; Mitchamet *al.*, 1997). Washing is a standard postharvest handling operation for many fruits and vegetables to remove adherences, dirt, latex and external pathogenic structures. Unfortunately, in Bangladesh fruits and vegetables are hardly washed before entering into the marketing channel, and this contributes to poor quality and considerable losses of the produce. Traders and cold storage owners keep harvested carrot with mud in the cold storage.

**Developed protocol:** At first storage variety of carrot is to be selected and harvested matured carrot at early in the morning or afternoon. Donot harvest carrot after immediate rainfall on the carrot field. and donot harvested carrot in the sunshine. As soon as possible, keep harvested carrot in the shad place or bagging and transported in the shedy place or packhouse. Within one days harvested carrot should be sorted graded (uniform size), cleaned, washed, dried and packed in package with lining polyethylene sheet (0.05mm thickness) and immediately stored in inside the cold storage at 1-2 °C for 90-95% relative humidity. Before entering inside the cold storage, packed carrot should be kept in pre-cooling room at 15-20 °C. In jute sack should be turnover 3-4 times during the storage period. Cleaning efficiency and washing efficiency should be maintained at 96% and 98% respectively. The following protocol would be maintained.

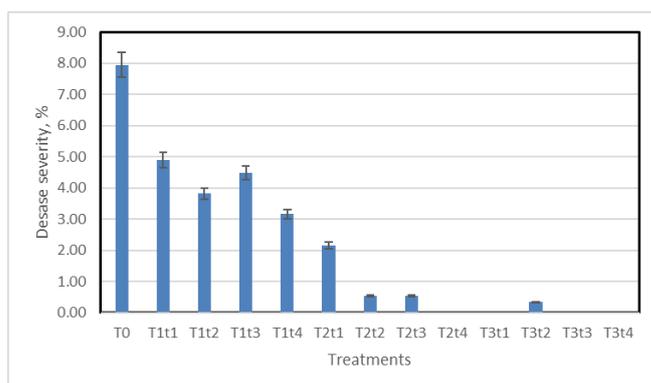


## FACT SHEET-4

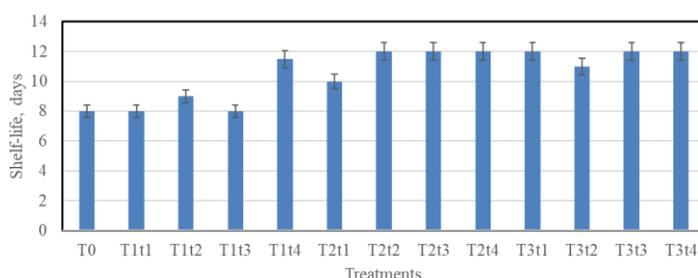
### Hot water treatment combination of temperature and exposure period for BARI Aam-3 Background:

Mango (*Mangifera indica* L.) is an important, popular and commercial fruit crop in Bangladesh that plays an important role in the agricultural development of the country. The popularity of the fruit in domestic and international markets is due to its attractive fragrance, beautiful colour, taste and nutritional properties. Among the insect pests, fruit flies are known to be the most notorious that caused severe damage to the mango industries in many countries including Bangladesh (Ekesi et al., 2009; Isabirye et al., 2015). Anthracnose and stem end rot (SER), on the other hand, are two major postharvest diseases of mango cause severe postharvest losses and affect fruit quality during the supply chain resulting commercial evaluation of the harvested fruits (Sivakumar et al., 2011; Esguerra et al., 2017). Hot water immersion has the benefit of controlling postharvest microbial diseases such as anthracnose and SER (Couey, 1989; McGuire, 1991).

BARI Aam-3 was collected from Rajshahi those were treated with different treating temperature (50, 55 and 57 °C) and exposure time (3, 5, 7 and 9 minutes) using BARI developed hot water treatment plant during 26 June 2019 at FMPE Division, BARI, Gazipur. The treatment combinations increased the shelf-life of the variety of BARI Aam-3 by 33% compare to untreated fruits. Disease severity of treated mango was reduced by 79% over untreated fruits. The higher firmness (7.75-9.32N) was found in treatments of T<sub>1</sub>t<sub>4</sub> (50°C for 9 min), T<sub>2</sub>t<sub>2</sub> (55°C for 5 min), and T<sub>2</sub>t<sub>4</sub> (55°C for 9 min) compared to untreated mango (6.47N). These treatments showed good rigidity of mango on the basis of disease severity, colour parameter, shelf-life, firmness and organoleptic test, the better treatment combinations of BARI Aam-3 were found to be 50°C for 5, 7 and 9 minute, 55°C for 5,7 and 9 minutes, 57°C for 3 minutes. The best treatment combination of BARI Aam-3 is 55°C for 5 minutes.



Untreated mango



Treated mango

### **Implementing component-3: CARS, DU**

N/A

### **ii) Effectiveness in Policy Support (if applicable)**

### **H. Technology/Knowledge generation/Policy Support (as applied):**

#### **i) Immediate impact on Generation of technology (Commodity & Non-commodity)**

#### **Coordinating component: PHTD, BARI**

N/A

### **Implementing component-1: PHTS, HRC, BARI**

- Mango growers, traders and small-scale entrepreneurs visited pack house and cool bot cool room established at Baneswar bazar, Rajshahi and inspired.
- Stakeholders in fruit and vegetable producing and business sectors inspired by observing hot water treatment machine and fruit and vegetable washing machine installed in the pack house.
- Carrot growers showed interest to washing machine, however, expressed to get incentive by reducing of the price of washing machine.

### **Implementing component-2: FMPE, BARI**

- Carrot trader visited the developed high capacity self-propelled root crop washing machine
- Mango experts observed developed a self-propelled hydraulic lifter for bagging of mango and they would be used the machine this year
- Cold storage owner already use the protocol of storing washed carrot in commercial cold storage
- Exporters and traders became awareness treatment combination of temperature and exposure period in hot water for BARI Aam-3 through demonstration

### **Implementing component-3: CARS, DU**

N/A

### **ii) Generation of new knowledge that help in developing more technology in future**

#### **Implementing component-1: PHTS, HRC, BARI**

New knowledge on handling of physiologically mature mango with integrated postharvest management practices including calcinated calcium mixed hot water treatment will help guide in generation of appropriate technologies for handling of mango in cool chain system. Since the fruits, especially the bagged mangoes were found not to be ripe properly in cool room at 20 C, there is opportunity in developing appropriate protocol for cool chain management of mango.

New knowledge on handling with integrated postharvest management practices including alum mixed clean water and plastic crate packing on quality and ripening pattern of dessert type banana at ambient condition found in this study will help guide in developing of new research program in future.

New knowledge on handling with integrated postharvest management practices including calcinated calcium wash through washing machine and packaging in plastic crate with MAP might be useful in generating new research protocol in future.

Knowledge on handling of vegetables with integrated practices including sorting, grading, washing and plastic crate packing might be useful in developing more technologies in future.

### **Implementing component-2: FMPE, BARI**

New knowledge on gear system for controlling of rotating drum during loading and unloading, self-starting of diesel engine, break system, water spray mechanism parameters has been developed that will help guide development of precision root crop washing machine in future

New knowledge on self-propelled system, alternator system instead of electric system for controlling hydraulic lifter has been developed that will help guide development of precision lifter in future.

New knowledge on carrot physical and chemical parameters, microbial loads identification, cold storage relative humidity, temperature and loading and unloading mechanism has been developed that will help good quality and safety carrot in future

New knowledge on disease incident, severity, mango physical and chemical properties, warm water treatment temperature and exposure period has been developed that will help guide prepared a good quality, safety and chemical free mango in future.

### **Implementing component-3: CARS, DU**

N/A

### **iii) Technology transferred that help increased agricultural productivity and farmers' income**

#### **Implementing component-1: PHTS, HRC, BARI**

Farmers and traders had been trained on integrated improved practices including harvesting technique, sorting, grading, washing and packaging. They were learned on operation of the hot water treatment machine and washing machine and maintaining of personal hygiene, safety and quality measures. Also, the long-term economic gain of utilizing pack house and improved practices, in general, use of plastic crate as packaging container was discussed in training and demonstration conducted.

### **Implementing component-2: FMPE, BARI**

Farmers, carrot, mango & banana growers, and traders have been trained on operation and repair of the developed carrot washing machine, leafy and fruit washing machine, hot water treatment plant, hydraulic lifter and also trained up to manufacturers for fabricating the machines that will increase production and reduce drudgery and operating cost and thus help increase productivity and farmers' traders and manufacturers income.

### **Implementing component-3: CARS, DU**

N/A

### **iv) Policy Support**

#### **Implementing component-1: PHTS, HRC, BARI**

Encourage local suppliers of packaging material and manufacturing of the harvesting tools, hot water treatment and fruit and root crops (carrot) washing machine (technological support, training support, provision of subsidy, soft loans, etc.)

### **Implementing component-2: FMPE, BARI**

Encourage local manufacturing of the carrot washing machine, leafy and fruit washing machine, hot water treatment plant, hydraulic lifter (technological support, training support, provision of subsidy, soft loans, etc.)

**Implementing component-3: CARS, DU**

N/A

**I. Information regarding Desk and Field Monitoring****Coordinating component: PHTD, BARI**

N/A

**Implementing component-1: PHTS, HRC, BARI****i) Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):**

<b>Description</b>	<b>Output</b>
Consultation meeting with Department of Agricultural Extension (DAE), Rajshahi and Bogura and Department of Agricultural Marketing (DAM), Rajshahi	Some information on value chain activities, related actors and their marketing channels of the area were known from knowledge sharing meeting with consultation of the officers of DAM, Rajshahi. It will help in designing of the research program and associated project activities.
Consultation meeting with NCDP Growers Market Association, Baneshwar bazar, Rajshahi.	Knowledge sharing meeting with the members of Market association helped in find existing postharvest handling practices in their areas and needs to be improved as they expected.
Consultation meeting with Vatra CIG Somiti, Vatra, Sherpur, Bogura	Information shared in the discussion meeting helped in planning, designing and execution of research program training conduct and associated project activities

**Implementing component-2: FMPE, BARI**

<b>Description</b>	<b>Output</b>
Consultation meeting with manufacturers	Some design parameters outline was achieved from knowledge sharing meeting among manufacturers and PI and Co-PI for improving the machine
Consultation meeting with scientists and technicians	Some design and performance parameters outline were achieved from knowledge sharing meeting among scientists, technicians and PI & Co-PI for fine tuning the machine

**Implementing component-3: CARS, DU**

N/A

**ii) Field Monitoring (time& No. of visit, Team visit and output): N/A**

<b>Time</b>	<b>No. of visit</b>	<b>Team visit</b>	<b>Output</b>

**iii) Weather data, flood/salinity/drought level (if applicable) and natural calamities: N/A**

**J. Sub-project auditing (covers all types of audit performed):****Implementing component-1: PHTS, HRC, BARI**

Types of audit	Major observation/issues/objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
FAPAD	No observation/issues raised	-	17.11.2019	-
FAPAD	No observation/issues raised	-	02.11.2020	-

**Implementing component-2: FMPE, BARI**

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
FAPAD	Irregular Expenditure	15238.00	17.11.2019	Replied the audit objection
FAPAD	-	-	02.11.2020	

**Implementing component-3: CARS, DU**

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial audit 1 <sup>st</sup> year	Passed	1169620	Ongoing stage	
2 <sup>nd</sup> year financial audit	Passed with some observation	2652000	Ongoing stage	
3 <sup>rd</sup> year financial audit	Yet to be done	3390701	completed stage	

**K. Lessons Learned:**

- Postharvest Losses of the target crops were found to be reduced in integrated arrangement of improved technologies and best practices.
- Establishment of Pack house was found be useful in performing postharvest operations.
- Growers showed positive attitude to use BARI Mango Harvester (Harvesting tools) and Banana de-handing tools.
- Calcinated calcium sanitizer could be used in reducing diseases and quality losses, especially for vegetables.
- Hot water treatment was found to be effective in extending shelf life of mango.
- Quality of transported vegetables were found to be better in integrated postharvest technologies than traditional practices of non-integrated technologies including plastic bag/gunny bag packing.
- Banana varieties of sagar Kola (Rangin sagar and napali sagar) should be identified by physical characteristics
- For successful and timely completion of any sub-project, allocation of fund/resources need to be ensured
- To achieve any successes/visible output in any agricultural sub-project, minimum time duration of the project should be 4-5 years
- Value chain analysis of selected crops
- Point of contamination along the chain

**L. Challenges (if any):**

- Research activities were hampered due to Corona Pandemic.
- Market access and price fluctuation of the produce may play role on adoption of improved practices by the value chain actors.
- Money disbursement was not timely due to the administrative delay of the University of Dhaka. It took more than 2 months to receive the fund in project account after the disbursement from the NATP.

**M. Suggestions for future planning (if any):**

- Calcinated calcium washing might be suitable for transporting and storing of physiologically matured mango thorough cool chain system.
- Hot water treatment plant and washing machine could be introduced/used by growers and traders' association through cooperative basis.
- There are opportunities in conducting study to find out optimum ripening temperature and humidity of physiologically mature mango transported and storage in cool chain system, particularly for the mangoes treated with hot water and calcinated calcium washing.
- Pesticide of different types are used at 7-10 days intervals from fruiting to harvesting by mango growers for protecting fruit fly and disease. After harvesting, these pesticides should be identified and their residue level would be determined. Otherwise, hot water treatment effect on mango shelf-life and disease could not properly measured.
- Carrot should be grown in line and maintain plant to plan spacing and follow the GAP (Good Agricultural Practice) and postharvest handling (Trimming, sorting, grading, washing, drying and packaging) for long time storing in commercial cold storage.
- A lot of pesticide of different types are used at 7-10 days intervals from fruiting to harvesting by mango growers for protecting fruit fly and disease. After harvesting these pesticide would be identified and determination of residue of them. Otherwise hot water treatment effect on mango shelf-life and disease could not be measured properly.
- Fund should be given directly to the project account to maintain expenditure and timely completion of the project
- Cooperation and coordination should be enhanced to maintain the time frame of completion.

Signature of the Coordinator

Date .....

Seal

Counter signature of the Head of the

organization/authorized representative

Date .....

Seal

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## Appendix-I



Pictorial view of showing hands on training, demonstration of tools and machines in the pack house.

## Appendix-II



Pictorial view of showing visit, monitoring, demonstration and distribution of harvesting tools among the growers and growers-cum-traders in the training programs.

### Appendix-III

Price estimation of leafy & fruit vegetables and fruit washing machine\*

Sl.No	Parts Name	Size	Quantity	Price/Unit, Tk	Total Price, Tk
1	MS Angle	38×38×4 mm	54kg	58	3132
2	MS Sheet	16 SWG (1.6 mm)	95kg	92	8740
3	Conveyer Net	9.14 m× 1 m	9.14rm	1800	16452
4	Plane Rod	5Ømm × 0.64 m (50 PC)	32m	60	1920
5	Plane Rod	6Ømm× 0.64 m (50 PC)	32m	22	704
6	Oil Seal	45Ø×20Ø×8mm	20no	45	900
7	Lylon bar	2.13 m×0.0254 m	2 m	400	800
8	Nut Bolt	Different Size	5kg	120	600
9	Motor	2 HP 1φ 1450 RPM	1no	7000	7000
10	Gear Box	1:30	1 no	6000	6000
11	Pump	2HP	1 no	7500	7500
12	Sprocket	428(Double chain 19 T)	1 no	900	900
13	Sprocket	428(28 T) 127Ø mm	8 no	530	4240
14	Sprocket	28 T single	1 no no	430	430
15	Sprocket	44 T	2	650	1300
16	Bearing	UCG204	2 no	350	700
17	Roller	102 Ø mm, 483 mm (L) (4ps)	3rm	1500	4500
18	Chain	428	20.5 no	260	5330
19	Bearing	F205	2 no	400	800
20	Bearing	UCP205	6 no	350	2100
21	Pulley	76 mm(B Double)	2 no	450	900
22	V-Belt	B-30	2 no	145	290
23	Pipe	51 Ø mm	3m	420	1260
24	Pipe	32Ø mm	3m	400	1200
25	Nipple	51 mm	6 no	95	570
26	Socket	53 mm	2 no	180	360
27	Tee	54 mm	2 no	150	300
28	Bone plug	55 mm	1 no	60	60
29	Bone plug	32Ø mm	1 no	45	45
30	Bone plug	32Ø mm× 25.4Ø mm	1 no	30	30
31	Nipple	32Ø mm	4 no	60	240
32	Elbow	51×32 mm	1 no	135	135
33	Union Socket	32Ø mm	1 no	125	125
34	Union Socket	19 Ø mm	2 no	60	120
35	Tee	19 Ø mm	6 no	35	210
36	Tee	32Ø mm× 25.4Ø mm	2	36	72
37	Nipple	19 Ø mm	1 no	25	25
38	Pipe	25Ø mm	3 no	128	384
39	Ball valve	32Ø mm	1 no	700	700
40	Ball valve	52Ø mm	1 no	1000	1000
41	Ball valve	19Ø mm	1 no	400	400
42	Flow meter	38 × 32 mm	1 no	3500	3500
43	Filtre	32Ø mm	1 no	1500	1500
44	Filtre	127Ø mm	1 no	3000	3000
45	Bone pluge	19Ø mm	3 no	25	75
35	Elbow	19 Ø mm	4 no	25	100
36	Clamp	19 Ø mm	6 no	7	42
37	Clamp	25.4 Ø mm	14 no	20	280
38	Ball Valve	25.4 Ø mm	1 no	350	350
39	MS Plate	0.3 m× 0.25m×0.012m	5kg	75	375
40	Rubber Wheel	102Ø mm	4 no	800	3200
41	Pannel Board	0.5 m× 0.36 m×0.2 m	1 no	6500	6500
42	MS angle bar	19mm×19mm× 1.6mm	4kg	58	232
43	Star screw	5mm	50kg	5	250
44	Guard GP sheet	0.559 mm (0.6 m×0.05 m)	5kg	60	300
45	Coveyor guard GP sheet	0.559 mm (5m×0.05 m)	5 kg	60	300
46	Elbow	25.4 mm× 19mm	2 no	135	270
A	Material cost:				<b>102748</b>
B	Labour cost				8219.84
C	Overhead cost (power consumption, machine depreciation, house rent, etc.) (20% of B)				1643.968
D	Incidental expenses (8% of A)				8219.84
E	Total cost(A+B+C+D)				120831.65
F	Manufacturer profit (18% of E)				21749.697
	<b>Total price</b>				<b>142581.34</b>

\*Source: Farm Machinery and Postharvest Processing Engineering Division, BARI, Gazipur

### Appendix-IV

#### Price estimation of self-propelled drum type carrot washing machine

Sl. No.	Name of items	Dimension	Quantity	Unit price, Tk	Total Cost, Tk.
1	MS plate	1380×1380×10 mm	133kg	90	11970
2	MS plate	457×457×6mm	10kg	90	900
3	MS Shaft	60 mmØ, 0.61m	13.5kg	120	1620
4	MS Flat bar	50.8×4.76 mm,176m	204kg	65	13260
5	Diesel Engine	22 HP self starter	1pc	47500	47500
6	Engine pully double groove	127 Ø mm	1pc	800	800
7	Gear box pully	102Ø mm	1pc	400	400
8	Drive pully	254Ø mm	1pc	900	900
9	Chain Sprocket	55 T	1pc	5000	5000
10	Chain Sprocket	21 T	1pc	2000	2000
11	Chain	60 No	1pc	5000	5000
12	Ball Valve	25.4 mm	1pc	400	400
13	Gurd nipple	25.4 mm	1pc	80	80
14	Elbow	38.10mm	1pc	150	150
15	Havy duty battary	12 V 100AH	1pc	10000	10000
16	Angle bar	50.8×50.8×6.35 mm, 19m	95kg	65	6175
17	Electric motor with pump	1.5 HP	1pc	8500	8500
18	Suction pipe	38.10 Ø mm	10m	150	1500
19	Delivery pipe	25.4Ø mm	5m	100	500
20	U channel, 16m	76×38.1×6 mm	160kg	90	14400
21	Wheel		1pc	3000	3000
22	Wheel	185/65 R	4pc	7000	28000
23	Gear box	1.667361	1pc	25000	25000
24	MS sheet	76×38.1×6 mm	10kg	65	650
25	Wood	2cft	2cft	2000	4000
26	Steering system	1 set	1set	10000	10000
27	Nut bolt	10 kg	10kg	200	2000
A	Material cost:				203705
B	Labour				20370.5
C	Overhead cost (power consumption ,machine depreciation, house rent,etc) etc) (25% of B)				5092.625
D	Incidental expenses (10% of A)				20370.5
E	Total cost(A+B+C+D)				249538.6
F	Manufacturer profit (20% of E)				49907.73
	<b>Total price</b>				<b>299446.4</b>

### Appendix-V

Photographs showing on technical activities (Value chain Survey in the growing sites and assemble markets of Brinjal, Cauliflower and Carrot in selected areas of Bogura District and site selection for pack house establishment in Bogura and Rajshahi District)



## Appendix-VI

Photographs showing on workshop/training activities (Hands on training on the post harvest processing of vegetables for the safety along the value chain). Training at the pack house site at baneshwar area of Rajshahi district and vatara area of bougura district. In addition, field demonstration of the technology to the farmers



Hands on training at the pack house site at Vatara union of Bogura district.



Hands on training at the pack house site at Baneshwar area of Rajshahi



Conducted field demonstration on 11 March 2020 at Rajshahi



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