A GUIDE TO

POSTHARVEST HANDLING OF FRUITS AND VEGETABLES

By

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PREFACE

Bangladesh, a country of tropical and subtropical climates, produces large volume of highly nutritious fruits and vegetables. However, still the present rate of consumption of fruits and vegetables (126 g per day per capita) is far below the minimum daily requirement of 400 g per capita as recommended by FAO and WHO. The problem is further compounded by huge postharvest losses of the commodities. The quality and safety issues of fruits and vegetables are also important concerns of the rank and file of the society. Consumers are reluctant to buy chemically treated fruits. The status of postharvest handling operations is also substandard in the country. However, no systematic study has so far been conducted in the country to actually collect information on the presently practiced pre- and postharvest operations in fruits and vegetables supply chain. In addition, reports with adequate details to indicate the magnitude of postharvest losses of fruits and vegetables at different levels of supply chain in Bangladesh are also scarce.

Hence, a research project was funded by the USAID and EC under the implementing authority of GoB and FAO to assess postharvest quantitative and nutritional losses of important fruits and vegetables in Bangladesh under the leadership of the author. After successful completion of the project, huge information was gathered and enormous postharvest losses of fruits and vegetables were observed. Presently, the country has very limited resource personnel in the sector of postharvest technology of fruits and vegetables. Therefore, the author feels that a comprehensive guide for handling of fruits and vegetables is a need of the time. With the enormous volume of farm level information obtained from the project, relevant research findings and 15 years experience from home and abroad on postharvest technology finally triggered the author to write and publish a postharvest handling guide in a view to assist all the stakeholders in fruits and vegetables supply chain. The guide will also be useful for the educationist, researcher, teachers, students and extension workers for finding some very valuable information on postharvest technology, quality and safety, and nutrient composition and their losses in important fruits and vegetables grown in Bangladesh. At last, but not the least, this is a very hastily prepared document, and I assume there may have mistakes and ambiguity. I would appreciate any suggestions, comments or criticism from the readers towards its further enrichment in the future.

The Author

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The present publication, **A Guide to Postharvest Handling of Fruits and Vegetables,** is an outcome of the Research Project entitled "Postharvest Loss Assessment: A Study to Formulate Policy for Loss Reduction of Fruits and Vegetables and Socio-Economic Uplift of the Stakeholders" implemented jointly by FAO and FPMU of the Ministry of Food and Disaster Management with the financial supports from USAID and EC. The author is grateful to all the concerned organizations in this regard. The author recognizes the help, cooperation and inspiration of Mr. Ad Spijkers, FAO Representative in Bangladesh and Mr. Ciro Fiorillo, Chief Technical Advisor, NFPCSP in completing the research project and writing up of this guide.

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Professor Dr Md Kamrul Hassan
(The Author)

ACRONYMS AND ABBREVIATIONS

ANOVA	**A**nalysis of Variance
BAN-HRDB	**B**angladesh Applied Nutrition and Human Resource Development Board
BARC	**B**angladesh Agricultural Research Council
BARI	**B**angladesh Agricultural Research Institute
BAU	**B**angladesh Agricultural University
BBS	**B**angladesh Bureau of Statistics
BCIP	**B**angladesh Country Investment Plan
BDHS	**B**angladesh Demographic and Health Survey
BSTI	**B**angladesh Standard and Testing Institute
BUET	**B**angladesh University of Engineering and Technology
CFB	**C**orrugated Fibre Board
CIPHET	**C**entral Institute of Postharvest Engineering and Technology
CNS	**C**entral Nervous System
CPA	**C**hlorophenoxyacetic Acid
C_2H_4	**E**thylene
CO_2	**C**arbon Dioxide
DAE	**D**epartment of Agricultural Extension
DI	**D**isease Incidence
DS	**D**isease Severity
EC	**E**uropean Commission
EC	**E**mulsifiable Concentrate
FAO	**F**ood and Agricultural Organizations
FPMU	**F**ood Planning and Monitoring Unit
GAP	**G**ood Agricultural Practices
GHI	**G**lobal Hunger Index
HACCP	**H**azard Analysis and Critical Control Points
HIES	**B**angladesh Household Income and Expenditure Survey
HKI	**H**elen Keller International
IFPRI	**I**nternational Food Policy Research Institute
IPHN	**I**nstitute of Public Health and Nutrition
LC	**L**etter of Credit
LD	**L**ethal Dose
LDPE	**L**ow Density Polyethylene
LSD	**L**east Significant Difference
MA	**M**odified Atmosphere
MAP	**M**odified Atmosphere Packaging
MCP	**M**ethyl Cyclopropene
MoA	**M**inistry of Agriculture
MoE	**M**inistry of Education
MoEF	**M**inistry of Environment and Forestry
MoFDM	**M**inistry of Food and Disaster Management
MoH	**M**inistry of Health
MRL	**M**aximum Residue Level
MSDS	**M**aterial Safety Data Sheet
N	**N**ewton
NFP	**N**ational Food Policy
NFPCSP	**N**ational Food Policy Capacity Strengthening Programme
NFPPoA	**N**ational Food Policy Plan of Action
NIPORT	**N**ational Institute of Population Research and Training
O_2	**O**xygen
PGR	**P**lant Growth Regulators
PoA	**P**lan of Action
PRA	**P**articipatory Rural Appraisal

SLI	**S**aleable Life Index
SP	**S**oluble Powder
TSS	**T**otal Soluble Solids
UNDP	**U**nited Nations Development Programme
USAID	**U**nited States Agency for International Development
VAD	**V**itamin A Deficiency
WHO	**W**orld Health Organization
WP	**W**ettable Powder

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Chapter 1

Introduction

The contribution of horticulture remains extremely important for ensuring food and nutritional security in Bangladesh. Horticultural crops in Bangladesh cover an area of 873 thousand hectares with a total production of 110 lakh metric tons (Monthly Statistical Bulletin 2009). The desired level of development in horticulture has not yet been achieved because of a number of constraints. Due to absence of proper postharvest management system, a bulk quantity of the harvested produce is damaged every year. More importantly, lack of proper storage and marketing facilities, and seasonal gluts force the farmers to sell their hard-earned produce at throw-away prices. The food and nutrition situation in Bangladesh is fragile due to inadequate and imbalanced diet intake. Consumption of a diversified diet to meet the needs of macro and micro nutrients needs to be promoted (Bhattacherjee *et al*. 2007; NFP 2008; BDHS 2009).

Fruits and vegetables are highly valued in human diet mainly for vitamins and minerals. However, the present consumption of fruits and vegetables in Bangladesh is 126 g/day/capita (23 g leafy vegetables, 89 g non-leafy vegetables and 14 g fruit), which is far below the minimum average requirement of 400 g/day/capita (FAO/WHO 2003). However, according to HIES (2005), the consumption of fruits and vegetables including potato is 253 g/day/capita, which indicates a poor dietary status in Bangladesh. In this regard, the high levels of low birth weight (33%), underweight (41%), stunting (43%) and wasting (17%) among children less than five years; anemia among infants, young children, adolescent girls and pregnant women; and poor diet diversification are of particular concerns (BDHS 2009; BCIP 2010). The prevalence of overweight (12.5%) among women that has increased by 10% between 2004 and 2007 also indicate the existence of double burden of malnutrition in Bangladesh (BDHS 2009). A large proportion of Bangladeshi population is food insecure due to poor diet quality. The usual diet is heavily dependent on rice, and most of the energy in the diet is contributed by cereals. Rice accounts for 68% of the total calorie consumption in the year 2005. Therefore, even though rice is not a good source of protein, it constitutes about half of total protein consumption in the diet. High prevalence of micronutrient deficiency i.e. hidden hunger is common in the society, and the situation could be improved significantly by increasing the consumption of high quality and micronutrient-rich foods like fruits and vegetables.

Due to tropical and subtropical climates, a variety of fruits and vegetables are grown in Bangladesh. Unfortunately, a considerable proportion of the harvested produce never reaches the consumers mainly because of postharvest losses. The estimated postharvest losses of fruits and vegetables lie in the range of 20-40% (Wills *et al.* 2004). Hence, there is general support among scientists for the proposition that increased returns to growers and other stakeholders in the supply chain might come from proper management after harvest rather a further boost to crop production in the field. The principal reasons for postharvest losses are: (i) physiological and biochemical processes i.e. increase in the rates of respiration, ethylene production and transpirational loss of water, (ii) microbial decay, (iii) high perishability, and (iv) sub-standard postharvest handling infrastructures. Therefore, it is urgent to formulate national policy to reduce enormous postharvest losses, to maintain quality, and to elevate the rate of per capita consumption of fruits and vegetables of the people of Bangladesh. Reliable statistical data are meager to indicate the magnitude of postharvest losses of fruits and vegetables in Bangladesh. However, there

are some anecdotal evidences and inadequate reports on postharvest losses of perishables. Hence, a systematic research was needed to estimate the levels of postharvest losses, both quantitative and qualitative (nutritional), of the commercially important fruits and vegetables in Bangladesh.

In the past, production-oriented research has received greater attention than postharvest research. Nowadays, postharvest quality and produce safety are considered the most important concerns of the rank and file of the society. There is enormous potential for fruits and vegetables for both the domestic and foreign investments if governemnt of Bangladesh addresses critical requirements like international safety and quality standards for this industry.

From the foregoing discussion, it is clear that emphasis should be given to formulate national policy to minimise postharvest losses of fruits and vegetable, and the government would take initiatives and allocate resources to improve the postharvest handling conditions, and therby improve the socio-economic status of the stakholders in the fruits and vegetables supply chain. The present attempt to publish a guide entitled **"A Guide to Postharvest Handling of Fruits and Vegetables"** is made to disseminate the outcomes of the research project along with some suitable postharvest management technologies to the stakeholders in order to minimize loss, and maintain quality and safety of fruits and vegetables in supply chain.

Chapter 2

Preharvest factors on postharvest quality

The postharvest quality of fruits and vegetables are largely determined by preharvest factors such as production location, soil type, irrigation, rootstock, shading and nutrition. Monselise and Goren (1987) divided the preharvest factors into primary and secondary. The primary factors include climate, nutrition and plant growth regulators, and the secondary factors include soil quality and management, rootstock, irrigation, pruning and crop load manipulation. The influences of important preharvest factors on postharvest quality of fruits and vegetables are described below.

2.1 Temperature

Atmospheric temperature has been found to influence fruit shape, size, colour and other quality parameters. Temperature variation during the early stage of fruit development caused variation in shape of orange fruit (Monselise and Goren 1987). Temperature caused undesirable thick peel and puffiness in citrus (Pantastico 1975). Pineapple fruits grown in winter months or in cool growing areas had reduced eating qualities due to lower sugar/acid ratio (Hofman and Smith 1998).

2.2 Radiation

Radiation interception by fruit has marked effects on the quality attributes of fruits. It has been found difficult to determine whether the effect of radiation is through light or heat (Jackson 1980). Any factor that reduces radiation interception results in reduced soluble solids, higher acidity and abnormal skin colour development. Low light intensity can reduce the firmness of fruits at harvest and during storage (Combrink *et al.* 1995). Low light intensity increases postharvest disease incidence because of reduced physical and physiological integrity of the fruit; reduces fruit size and fruit elongation; and decreases ripening characteristics (Hofman 1998). Shade increases diseases in Kiwi fruit (Tombesi *et al*. 1993). Chilling injury during storage was reported in grapefruit because of high radiation interception by the fruit, which may be attributed to the increase in weight loss due to changes in wax and cuticular structures (McDonald *et al.* 1993). They also reported that reduced exposure to sun decreased chilling injury of grapefruit.

2.3 Relative humidity

Relative humidity plays an important role in determining fruit quality. Higher relative humidity around the fruit reduces water and Ca movement into the fruit. In contrast, higher relative humidity around the plant increases Ca accumulation into the fruit by reducing leaf evapotranspiration (Hofman 1998). Similar results have been observed in tomato fruit, where higher relative humidity around the plant increases fruit Ca, and decreases shelf life due to Ca toxicity (Adams and Holder 1992; De Kreij *et al*. 1992). High relative humidity around the plant has also been reported to be associated with increased maturity bronzing in banana fruit (Campbell and Williams 1976).

2.4 Nutrition

Several nutrient elements, especially N, Ca, Mg and K have been found to influence the quality attributes of fruits. The application of Ca and high fruit Ca concentration resulted in increased firmness; reduced disease incidence, chilling injury, physiological disorders (skin splitting) and ripening; and improved storability (Hofman 1998). According to Simmons *et al*. (1995), the application of gypsum (Ca containing fertiliser) did not show any significant effect on shelf life and other quality attributes of mango fruits. Whitney *et al*. (1991) reported that the spraying of Mg decreased fruit Ca and increased bitter pits in apples. Potash has been found to improve fruit qualities. In bananas, high K increased total soluble solids and vitamin C and reduced acidity (Mustaffa 1988). In pineapple, the influence of K is detrimental. Vis (1989) reported that high K application increased acidity in pineapples. Application of excessive N element is very detrimental in terms of postharvest quality attributes.

2.5 Irrigation

Irrigation has immense influence on fruits and vegetables quality. Generally, the excessive availability of water can result in larger fruit, reduced firmness and flavour, and more disorders. Ebel *et al*. (1993) reported that excessive irrigation decreased fruit firmness through increased fruit size. Water stress also affects fruit qualities. Sirkul and Turner (1995) showed that low irrigation reduced fruit growth rate and green life of bananas. In case of mango, lowering irrigation during rapid fruit expansion stage reduced storage duration and fruit Ca concentration (Simmons *et al*. 1995).

2.6 Plant growth regulators (PGR)

The application of plant growth regulators in the fruit development stage has important effects on the quality parameters of fruits. Different types of growth regulators are applied to the plants to improve the fruit qualities, which include gibberellins, cytokinin and auxins (Hofman 1998). Pradhan e*t al.* (1988) observed that the application of gibberellins during fruit development increased fruit weight. Another growth regulator, Cultar was found to increase the size and other quality attributes of avocado fruit (Wolstenholme *et al*. 1990). Cytokinin and auxin have been reported to increase shelf life and reduced fruit splitting in persimmon and citrus, respectively (Almela *et al*. 1994; Itai *et al*. 1995).

In Bangladesh, PGRs are used in horticultural crops to increase the size of the edible portion of fruits and vegetables and to obtain early bearing. In the case of mango, maximum growers of Chapai Nowabgonj and Rajshahi apply PGRs from the stage of flowering to entire harvesting season. The PGRs, namely Biogeem, Ferti and Yield are used in the production of mango in Chapai Nowabgonj and Rajshahi districts (Plate 2.1). In case of banana, majority of growers of Ghatail and Shakhipur Upazillas under Tangail district apply plant growth regulators to banana crops from the stage of flowering to the entire harvesting season at a rate of 5-15 mL/10-16 L of water. Among different plant growth regulators, Okozim, Planofix, Agron and Voxal Super are commonly used by the banana growers. Similar findings were also reported by Bhuiyan *et al.* (2009), who mentioned that 40.7 and 30.7% of the banana growers were found to be the low to medium users of PGRs in banana cultivation, especially for quick maturity and high yield.

Plate 2.1 Plant growth regulators, Biogeem (A), Ferti (B) and Yield (C), which are currently used by the mango growers of Rajshahi and Chapai Nowabgonj, Bangladesh.

Litchi is one of the most important commercial fruits of Bangladesh that received large amounts of PGRs of various trade names. The PGRs used for litchi are Okozim, Planofix, Pencozeb, Litosen, Voxal Super, Vitaplus, Phenphen and Folimore.

2.7 Harvest maturity

The stage of maturity at harvest affects fruit quality. Generally, the fruits harvested at the advanced stage of maturity have increased fruit size and eating qualities (taste and aroma) but decreased shelf life. Harvest maturity influences physiological and storage disorders of mango. Fruits harvested at more advanced stage of maturity showed uneven ripening of the flesh such as spongy tissue and soft nose (Hofman 1998). Mango fruits harvested 7 days before optimum maturity showed better storage performance but failed to arrest skin discolouration, and caused uneven ripening (Hassan *et al*. 1998). Maturity indices of important fruits and vegetables have been given in Chapter 8 (Section 8.4).

2.8 Miscellaneous

Apart from the factors discussed above, the position of the branch and crop load manipulation have also been found to influence fruit qualities. In the case of apple, the fruits located in the centre of the cluster had higher sugar content than those of terminal ones (Marguery and Sangwan 1993). The mango fruits on the longer panicles are generally larger and remain on the tree until maturity (Hofman 1998). Crop load (leaf: fruit ratio) is another important factor, which largely determines the fruit quality. Low leaf:fruit ratio in banana caused reduced green life resulted from taking longer time to attain minimum marketable size. On the other hand, high leaf:fruit ratio increased sugars and soluble solids concentrations because of reduced competition for carbohydrate but increased fruit disorders and disease severity (Hofman 1998). Fruit thinning has both good and bad effects on the quality attributes of the fruits. It reduced the competition for nutrients, light and space, which resulted in attractive shape and size of the product. Fruit thinning has also been reported to cause splitted or cracked skin of tomato fruits, and are responsible for low market qualities (Ihret *et al*. 1993).

Chapter 3

Predominant insect pests, diseases and disorders of fruits and vegetables in Bangladesh

Insect pests, diseases and disorders are serious problems in growing fruits and vegetables. Long list of insect pests, diseases and disorders are available in text books and published documents. However, information in relation to the present status of predominant insect pests, diseases and disorders, and their control measures are meager. The present chapter describes some important insect pests, diseases and disorders of commercially important fruits and vegetables of Bangladesh. The information presented in this chapter is mainly the outputs of the research project carried out in selected districts of Bangladesh (Hassan 2010).

3.1 Pests and diseases of mango

Insect pests

Presently, the most serious insect of mango in the leading growing areas is mango hopper. Hopper attack is found to be the highest in Gomostapur of Chapai Nowabgonj. Hopper contributes to shooty mould problem that seriously affects fruit set. Fruit fly is also a serious pest of mango. The highest fruit fly incidence is observed in Bholahat and the lowest in Gomostapur of Chapai Nowabgonj. Nowadays, stem borer also seems to be an important pest of mango in the Chapai Nowabgonj and Rajshahi districts (Hassan 2010).

Diseases

The most serious field diseases of mango are dieback and gummosis in Chapai Nowabgonj and Rajshahi (Plate 3.1). The highest dieback infected area is Chapai Nowabgonj Sadar and Gomostapur, whereas the highest gummosis affected area was Bagha of Rajshahi. The minimal gummosis severity was noticed in Charghat Upazilla under Rajshahi district.

Control measures

Almost all the mango growers of Chapai Nowabgonj and Rajshahi districts use range of insecticides and fungicides to control insect pests and diseases, respectively. Growers generally apply insecticides and fungicides at the rate of 10-15 mL/16-20 L of water starting from flowering to harvesting. In addition to the use of chemical pesticides, some growers particularly in Rajshahi use sex pheromone trap to control fruit fly (Plate 3.2). The growers do not know the measures to control gummosis. To control gummosis, the infected portion should be scrapped followed by the application of hot coal tar or Bordeaux paste (100 g copper sulphate and 100 g quick lime are mixed with 500 mL of water separately, which are then mixed together to make 1 L of Bordeaux paste).

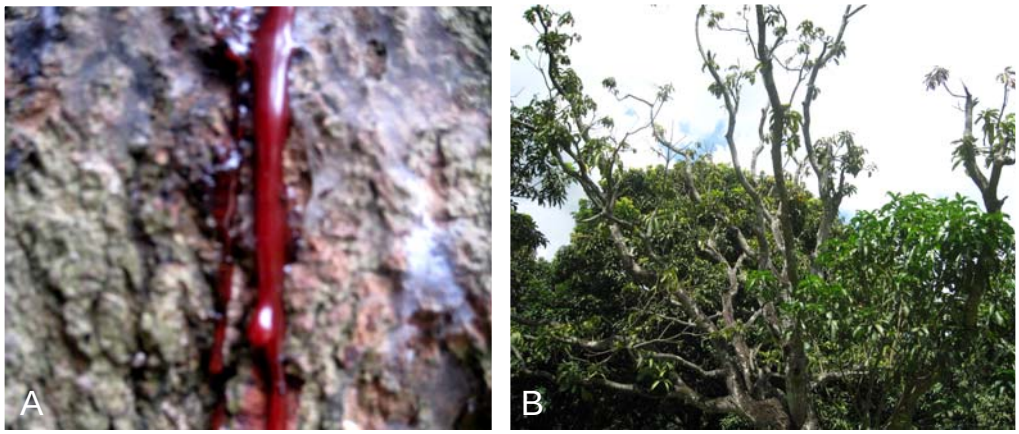

Plate 3.1 Gummosis (stem bleeding) (A) and die back (B) of mango, the predominant field diseases in Chapai Nowabgonj and Rajshahi districts.

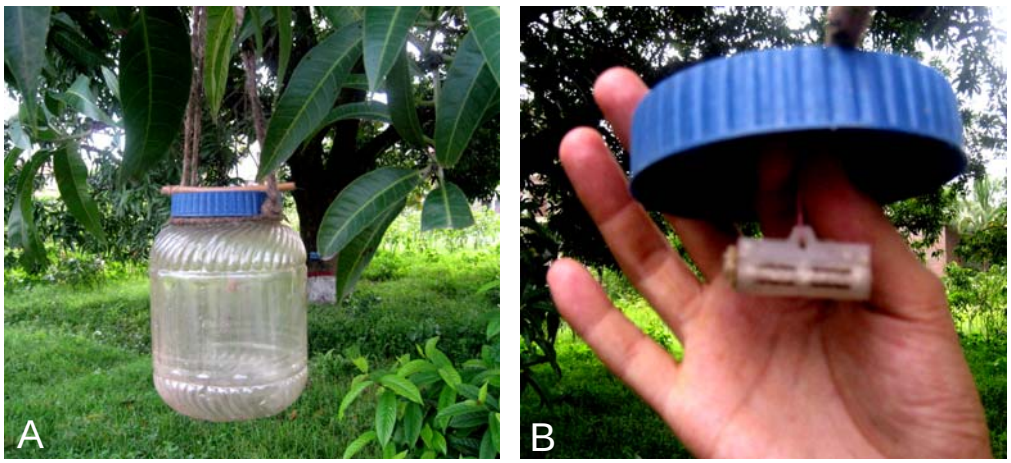

Plate 3.2 Use of sex pheromone trap to control fruit fly of mango in Rajshahi.

3.2 Pest and diseases of banana

Insects

The most serious insect of banana is the banana leaf and fruit beetle in Tangail (Plate 3.3). Banana weevil is also found to be a serious pest of banana.

Plate 3.3 Banana fruits damaged by banana fruit beetle.

Diseases

The most serious disease of banana is Sigatoka leaf spots (caused by *Mycosphaerella musicola*). According to 64-68% of the growers of Tangail, Sigatoka is the most serious disease of banana. Panama caused by *Fusarium oxysporum* f.sp. *cubense* (longitudinal splitting of pseudostem) is also a serious disease of banana in the Tangail region of Bangladesh.

Control measures

Almost all the growers use insecticides and fungicides in the production of banana. Among the insecticides, Carrate is the mostly used. In terms of fungicides, Still, Tilt and Thiovit are the predominantly used fungicides. For Sigatoka, Propiconazole or Carbedazim (0.1%) and for Panama disease, corm injection of 3 mL of 2% Carbedazim by making a 10 cm hole at 45^{o} angle at the 5^{th} and the 7^{th} months are recommended (TNAU 2008).

3.3 Pest, diseases and disorders of litchi

Insects

The predominant insect pests of litchi are litchi mite and fruit borer. Other problems are related to fruit fly, ant, cutworm and caterpillar.

Diseases and disorders

Ruptured skin, sun burn, fruit rot and fruit drop are the most prevalent in Dinajpur, the leading litchi growing district of Bangladesh. Sun burn and fruit cracking are physiological disorders, which are attributed to the scorching sunshine along with high temperature and excessive use of growth regulating chemicals, respectively (Plate 3.4). Higher rate of pulp growth and development due to excessive use of PGRs and contrasting non-proportionate growth of peel may have resulted in cracking of litchi (Plate 3.4). However, involvement of other physiological reasons cannot be ruled out.

Control measures

A wide range of pesticides are used by the growers of three Upazillas of Dinajpur to control pest attack. The growers, however, hardly use any fungicides to control diseases. To control sun burn, the growers occasionally apply cold water spray to the crop.

Plate 3.4 Fruit cracking due to the use of higher doses of application of plant growth regulators (A). Application of plant growth regulators and pesticides to the litchi fruit using foot pump (B, Masimpur, Dinajpur).

3.4 Pest and diseases of jackfruit

The most serious insect pests of jackfruit in Mymensingh and Gazipur districts are fruit borer and trunk borer (Plates 3.5). Half to three-fourth of the jackfruit growers have problems with fruit borer, whereas one-fourth to half of the growers have problems with trunk borer infestation. The trunk borer bores into the tender shoots and buds. The affected parts should be nipped off and destroyed. Application of carbaryl (Sevin 50%) at a rate of 4 g/L of water spray in the flowering season is advisable (Samaddar 2002). The most serious disease of jackfruit is the Rhizopus rot of inflorescence. Up to 80% of the growers in the surveyed areas have problems with Rhizopus rot caused by *Rhizopus artocarpi*, which results in premature fall of young fruit. This can be controlled by applying Dithane M 45 at a rate of 0.2% or Bavistin at a rate of 0.05% at 15-day interval during fruit growth (Gupta and Panday 1985). Die back, leaf spot and anthracnose are also observed in the jackfruit plantation in Mymensingh and Gazipur districts. Sometimes, the borer-damaged portion of the fruit is scrapped out followed by the application of lime paste to prevent the further spread of the damage and subsequent rot (Plate 3.6).

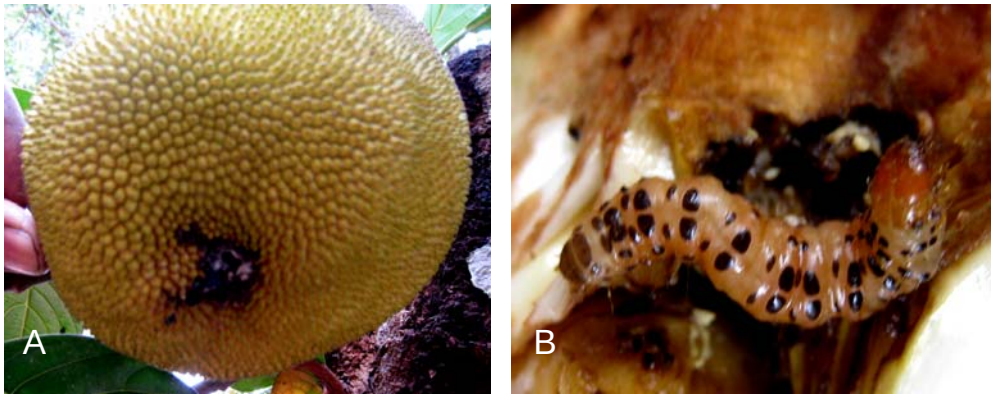

Plate 3.5 Damage to jackfruit by borer (A) and the most serious pest of jackfruit, the fruit borer (B).

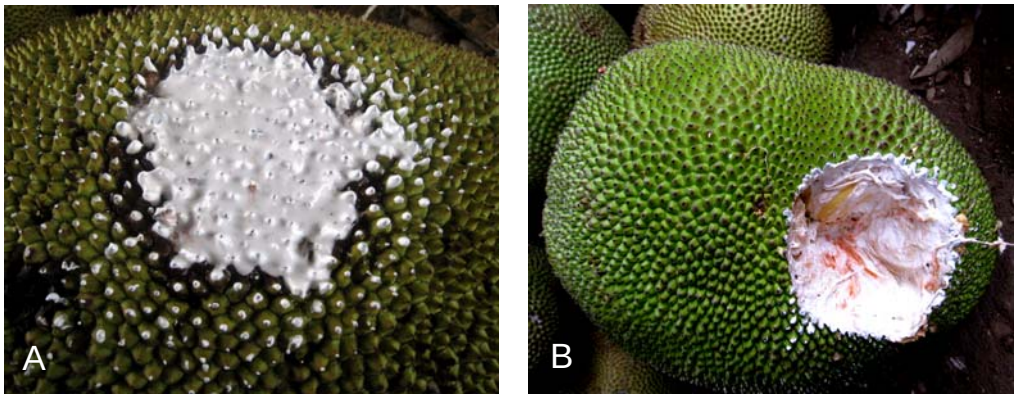

Plate 3.6 Damaged portion of jackfruit is scrapped out followed by the application of lime pest to stop further spread of damage and rot (A & B). These fruits lost their market value by almost cent percent but sold to people who could not afford to buy good quality jackfruit.

3.5 Pest and diseases of pineapple

Pineapple is a hardy plant and infestation with insect pest is not a serious problem. But physiological disorders, especially sunscald (Plate 3.7) is observed to be the most serious problem in pineapple production in Tangail district. Growers mentioned that sunscald may cause damage by 100% if proper measure is not taken. The growers generally cover the fruits by straw to protect them from the effects of scorching sunlight. Shade trees are also planted to provide shade and protection to the plants.

Plate 3.7 Damages to pineapple fruits due to sun burn.

3.6 Pest and diseases of papaya

In papaya, red mite and fruit fly are found to be the predominant insect pests in Pabna. Papaya mosaic and leaf curl are also found to be the most serious diseases in the papaya plantation in Ishurdi of Pabna, one of the leading papaya growing zones in Bangladesh.

3.7 Pest and diseases of orange

Different types of bugs and beetles are found to cause damage to orange plants in Moulvibazar. Die back is observed to be the most serious disease in orange plantation in the Juri and Borolekha Upazillas of Moulvibazar.

3.8 Pest and diseases of brinjal

Insects

Insects of different kinds are found to cause serious problems to brinjal crop. The most serious insect of brinjal is shoot and fruit borer. To control insect damage, higher doses of insecticides with shorter intervals are very often practiced by the growers.

Diseases

In the case of brinjal, the major disease is wilt (64% in Raipura and 52% in Shibpur Upazillas of Norshingdi district).

Control measures

All the brinjal growers use pesticides to grow brinjal. The growers use insecticides and fungicides along with PGRs as cocktail. The major insecticides are of the Cypermethrin (Superthion) and Dimethoate (Tafgor 40EC) groups, whereas the major fungicides are Dithane M 45, Thiovit, Minicaper and Redomil. Presently, the consumers are reluctant to buy chemical-sprayed vegetables due to the perceived health risks. A considerable proportion of the chemicals would present in the edible portion as residues. Bhuiyan ***et al.*** (2009) observed that the levels of pesticide residues would be beyond the MRLs if harvested earlier than the recommended withholding period. They reported that the levels of MRLs of Ripcord insecticide (Cypemethrin group) of brinjal collected from Tangail and Norshingdi were 0.37 and 0.67 ppm, respectively at 3 days after spraying. Therefore, sex pheromone trap is gaining popularity in the control of insect pests to avoid chemical residues in vegetables. The trap is in use to control insect pests in a number of vegetables like brinjal, where porous plastic tubes containing 2-3 mL pheromone attract male moth for 6-7 weeks (Alam *et al*. 2008) (Plate 3.8). Still, the rate of adoption of the technology is lower, and the growers are increasing their production cost by spending for both the pheromone trap and the chemical pesticides side by side. However, they admitted that, the sex pheromone trap alone can control insect pest by 80%. Some of the brinjal growers of Raipura and Shibpur Upazillas of Norshingdi district adopted sex pheromone trap to control insect attack.

Plate 3.8 Sex pheromone trap currently in use to control shoot and fruit borer of brinjal.

3.9 Pest and diseases of okra

Insects

Insects of different kinds are found to cause serious problems to okra crop. Fruit borer is found to be the major insect which causes severe damage to okra pods in Comilla. Higher doses of the insecticides are applied with shorter intervals to control insect pests by the growers.

Diseases

Diseases, namely yellow mosaic, rots and leaf curl are found to cause serious damage to okra crop. However, the most serious problem of okra cultivation is due to the infection by Yellow Mosaic Virus according to 96% of the growers of the surveyed Upazillas of Comilla. In Chandina Upazilla of Comilla, leaf curl (viral disease) is found to cause significant damage to okra crop.

Control measures

Most of the growers use chemicals for controlling insect and disease attacks. The commonly used insecticides and fungicides in the surveyed Upazillas are Dursban, Suntap, Sumithion and Carrate (insecticides), and Bavistin, Knowin Power, Indofil and Redomil (fungicides). Amongst the pesticides, Dursban, Bavistin and Knowin Powder are mostly used. The growers of the surveyed Upazillas are found to apply pesticides at the rates varied from 10-20 g/10-16 L of water (≈ 1-2 g/L water). The recommended doses of some important pesticides are: 2 mL/L (Dursban 20EC), 2.4 g/L (Suntap 50SP), 1 mL/L (Carrate 2.5 EC), 2.24 ml/L (Sumithion 50EC), 1 g/L (Bavistin 50WP), 2 g/L (Knowin 50WP) and 2 g/L (Redomil Gold) (Rahman 2008). The findings of the survey suggest that generally the growers use the recommended doses of pesticides except for the fact that the growers often use cocktail of pesticides with shorter interval to ensure total control of pests and diseases.

3.10 Pest and diseases of tomato

The important insect pests of tomato are fruit borer, aphid and fruit fly. Leaf miners are serious pests of summer tomato in Bagharpara of Jessore. Leaf curl, a viral disease, is found to be the most serious pest that causes damage to tomato crop. In Bogra, 62% of the tomato growers are found to apply pesticides to control insect pests. In Jessore, the growers of Chougacha are mostly restrained from application of pesticides. Only 36% of the growers are found to use pesticides. In case of summer tomato cultivation in Bagharpara under Jessore district, all growers are found to apply pesticides to control insect attack.

3.11 Pest and diseases of cauliflower

The most serious pest of cauliflower is the caterpillar of cabbage butterfly. Almost all the growers have the problem with this caterpillar. In case of disease, leaf curl is the most serious problem. Cent percent of the growers are found to apply pesticides to control the insect pests.

Chapter 4

Nature of damage of fruits and vegetables in Bangladesh

Different types of damage of horticultural produce are observed in the entire marketing channel. The major damages include bruises, cuts and rots for most horticultural produce, and latex injury for mango, banana and papaya. The important damages of fruits and vegetables in the supply chain are briefly discussed in this chapter.

4.1 Mango

Postharvest damages of mango fruits include bruises, cuts and sap burn. Bruises are the major causes of postharvest damage at the growers' hand. This is probably due to the conventional harvesting methods, ignorance of the pickers, and most importantly due to the carelessness of the pickers. Substantial loss occurs at the intermediary levels mainly due to inadequate and faulty transport system. Various types of cushioning or padding materials like straw and shredded papers/newspapers are generally used inside package to reduce damage during long distance transportation. Straw is found to be better cushioning option than paper in relation to postharvest loss reduction of mango. At the retailers' levels, maximum damage occurs due to bruises and diseases.

4.2 Banana

During harvest, cuts and bruises cause damage to banana fruits. Substantial loss occurs from 'Bepari' due to improper transport system. Although different types of damage occur, bruises are observed to be the major reasons of postharvest loss (Plate 4.1). Considerable damage also occurs due to latex injury, particularly at the 'Bepari' level. At the wholesale and retail levels, rots due to fungal infections also cause substantial loss.

Plate 4.1 Postharvest bruises (A & B) and microbial damage (C) of banana fruits.

4.3 Litchi

Ruptured skin, fruit rot and pericarp browning are the major causes of spoilage of litchi. At the growers' level, the major causes of damage are due to the ruptured skin (66.80-100%) and detachment of fruits from the peduncle (Plate 4.2). At the 'Bepari' level, bruises, rots and vibration damage are the major causes of spoilage. No noticeable precautionary measures were adopted by the 'Bepari' to reduce damage except the use of ample litchi leaves inside the bamboo package.

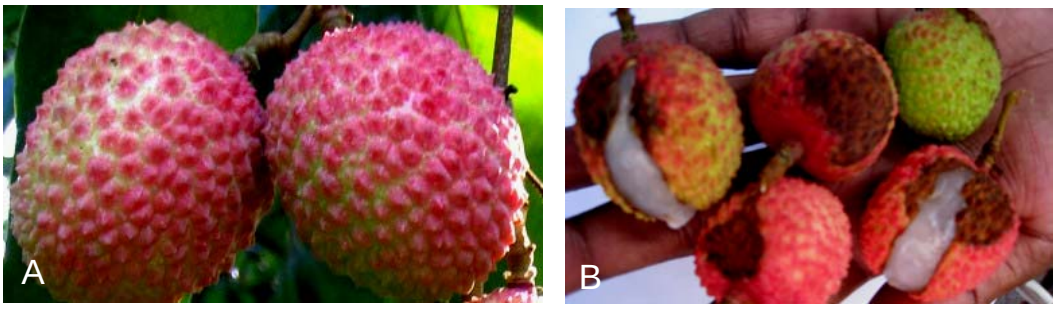

Plate 4.2 Attractive litchi fruits (A) becomes unsaleable due to skin cracking (B).

4.4 Pineapple

Cuts and bruises are found to be the principal causes of spoilage of pineapples at the growers' hands in the surveyed Upazillas of Tangail district. Similarly, bruises and vibration damage are also found to cause damage pineapples at the intermediary levels.

4.5 Jackfruit

The principal causes of damage of jackfruits are due to different types of bruises. At the 'Bepari' level, bruises and vibration damage are mostly found (Plate 4.3). At the retailers' level, different types of rot and diseases are the major reasons of postharvest losses (Plate 4.3).

Plate 4.3 Damage to jackfruit by fungal pathogen (A); damage becomes serious due to rain water (B); damage due to vibration during transport (C).

4.6 Papaya

The principal causes of damage to papaya fruits at the growers' level are due to different types of bruises and latex injury. At the 'Bepari' level, bruises, latex injury and vibration damage are mostly found. At the wholesaler' level, latex injury and diseases are found to be the major reasons of damage. Similar nature of damage is also found at the retailers' level, where diseases are found to be serious problems.

4.7 Orange

As usual, bruises are found to be the major reason of damage to orange at the growers' level. Similar nature of damage is also observed at the retailers' hand, where bruises, vibration damage and diseases are observed to cause substantial spoilage.

4.8 Tomato

At the growers' level, cuts and bruises are the predominant types of spoilage. However, no such damages are found in case of summer tomato in Jessore, where the problem is mainly related to fruit cracking. Similar types of damage occur to tomato fruits at the 'Bepari' level during long distance transportation. The 'Bepari', however, occasionally use padding materials to reduce mechanical damage during transportation. Noticeably, most 'Bepari' involved in summer tomato trade use bamboo and plastic crates along with straw and shredded papers to reduce loss. Postharvest damage also occurs due to lower prices at the peak season and lack of low temperature storage and processing facilities (Plate 4.4).

Plate 4.4 Highly nutritious and antioxidant rich tomato fruits are lost after harvest (A&B: Sayedabad wholesale market, Dhaka; and C: Nimshar Bazar, Comilla).

4.9 Cauliflower

At the growers' levels, cuts and over maturity of the curds are the major problems. At the 'Bepari' level, the discolouration of the curds is observed to be the most serious problem in cauliflower transportation (Plate 4.5A). Presently, almost all the 'Bepari' use individual paper wrap to reduce transport damage, weight loss and discolouration. Discolouration is also the major kind of damage to cauliflower curd at the retailers' levels that renders the curds unsaleable and ultimately causes loss. Red rot (Plate 4.5B), characterized by pinkish or rusty brown colours on the curd surface due to boron deficiency, is also a serious problem, which could be minimized by applying borax or sodium borate at a rate of 20 kg/ha or 0.25-0.50% borax solution at a rate of 1-2 kg/ha (Datta 1963; Chatterjee and Kabir 2002).

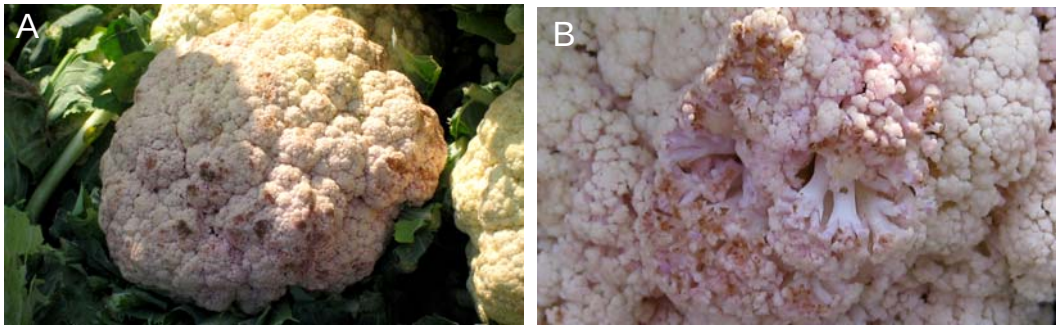

Plate 4.5 Discolouration (A) and red rot (B) of cauliflower curd.

4.10 Brinjal

In the case of brinjal, detachment of fruit from the stalk is found to be the major cause of postharvest damage. Majority of the retailers experience damage due to fruit separation from the stalk. Other damages include shrinkage, bruises, cuts and diseases.

4.11 Cucumber

In the case of cucumber, the maximum damage occurs due to cuts. Huge losses are faced by the 'Bepari' every year due to lack of proper transport system. Maximum loss of cucumber occurs due to bruises and vibration damage during transportation. Shrinkage is also an important postharvest problem for cucumber due to weight loss.

4.12 Okra

Most of the commercial growers pick okra carefully by hand with protective gloves put on to protect hands from irritation and infection. Some growers harvest okra with the help of sharp knife. Therefore, damage to okra pods during harvest is negligible. During transportation, considerable losses of okra pods occur at the hands of 'Bepari' every year due to bruises particularly due to lack of proper transport system. Broken pods are also found to be important problems during transportation. In case of retailers, the maximum damage occurs to okra pod due to bruises. Other damages include cuts, rots, discolouration, over maturity (fibrousness), shrinkage and insect infestation.

Chapter 5

Postharvest loss of fruits and vegetables

Due to tropical and sub-tropical climates, a range of nutritionally rich and delicious fruits and vegetables are grown in Bangladesh. Unfortunately, a considerable proportion of the harvested produce never reaches the consumers mainly because of postharvest losses. The estimated postharvest losses of fruits and vegetables as reported from overseas are 15-50% (Okezie 1998) and 20-40% (Wills *et al*. 2004). The estimates of postharvest losses of banana, citrus and papaya were 20-80%, 20-95% and 40-100%, respectively (NAS 1978). Paull (1993) speculated that sometimes these figures are guesses, and in many cases may be coloured by isolated incidents. Reliable data on the magnitude of postharvest losses of fruits and vegetables, especially in Bangladesh are meager. However, some anecdotal evidences and reports with inadequate details are published time to time. For instance in mango, postharvest losses were 0-16.3% (Quroshi and Meah 1991), 30-35% (Mondal *et al.* 1995) and 27.2% (Azad 2001). Postharvest losses of fruits and vegetables were 25-50 and 25-40% as reported by Amiruzzaman (1990) and Miaruddin and Shahjahan (2008), respectively. So, there is no doubt that enormous amounts of fruits and vegetables are lost every year. The present Chapter describes the postharvest losses of the commercially-important fruits and vegetables as estimated in the USAID and EC-funded research project as mentioned earlier. The postharvest losses of individual fruits and vegetables were estimated using structured and pre-tested interview schedules at four stages of supply chain including growers, 'Bepari' (large-scale trader), wholesalers and retailers. This is indeed a timely approach when the government of Bangladesh underscored the needs for assuring food and nutritional security of the people of Bangladesh, and there is no scope for food losses in the country.

5.1 Postharvest quantitative loss

Postharvest losses of fruits and vegetables in supply chain were separately calculated and presented in Table 5.1. In general, the losses were greater at the hands of the intermediaries, especially the 'Bepari' and wholesalers. However, in case of jackfruit and litchi, the losses were higher at the growers' level (Table 5.1). The higher postharvest loss at the intermediary levels would possibly due to the lack of proper transportation and storage facilities. On the other hand, the higher losses of jackfruit and litchi at the growers' levels could be attributed to the fact that these fruits are seriously damaged by fruit borer (jackfruit), and fruit cracking and pericarp browning (litchi), and these affected fruits are often unmarketable.

Table 5.1 Postharvest losses of important fruits and vegetables at the different levels of horticultural supply chain

Commodity	Postharvest losses at different levels of supply chain (%)			
	Growers	'Bepari'	Wholesalers	Retailers
Fruits				
Mango	4.4	8.1	8.1	6.8
Banana	7.7	5.1	8.6	3.2
Jackfruit	16.1	11.4	9.2	6.8
Papaya	6.1	13.7	12.2	7.9
Litchi	8.5	5.1	6.1	5.1
Pineapple	10.4	11.6	14.1	7.0
Orange	5.2	5.7	4.0	8.7
Vegetables				
Tomato	6.9	9.1	8.0	8.9
Cauliflower	4.2	9.2	10.3	10.7
Okra	9.4	9.8	4.9	8.3
Brinjal	6.9	7.4	8.4	6.6
Cucumer	7.2	4.5	10.7	4.7
Redamaranth	5.5	9.2	7.8	6.1
Mean	7.6	8.5	8.6	7.0

As an example, the detail method of postharvest loss estimation of mango has been presented in Tables 5.2 to 5.5. In mango, the postharvest loss estimation was carried out in 4 Upazillas of Chapai Nowabgonj and 2 Upazillas of Rajshahi. The highest loss at the growers' level was observed in Bholahat Upazilla of Chapai Nowabgonj, whereas the lowest loss was found in Gomostapur Upazilla of the same district (Table 5.2).

Table 5.2 Average postharvest loss of mango at the growers' level in Chapai Nowabgonj and Rajshahi districts

District	Average postharvest loss of mango at the growers' level in Chapai Nowabgonj and Rajshahi					
	Chapai Nowabgonj				Rajshahi	
Upazilla	CN Sadar (N=25)	Shibgonj (N=25)	Bholahat (N=25)	Gomostapur (N=25)	Charghat (N=25)	Bagha (N=25)
Loss (%)	6.1	4.8	6.7	2.1	3.9	3.0
Standard deviation	3.0	2.6	3.1	1.2	1.6	2.1

At the 'Bepari' level, the loss was higher in Baneshar Bazar assemble market of Rajshahi district. In contrast, the losses were lower in the surveyed markets of Chapai Nowabgonj, the leading mango growing district of Bangladesh (Table 5.3). This result would be attributed to the use of recently introduced plastic crates for long distance transportation instead of the age-old conventional method of mango packaging with bamboo baskets and jute sacks.

Table 5.3 Average postharvest loss of mango at the 'Bepari' level in the assemble markets of Chapai Nowabgonj and Rajshahi districts

District	Average postharvest loss of mango at the 'Bepari' level in Chapai Nowabgonj and Rajshahi			
	Chapai Nowabgonj			Rajshahi
Upazilla	CN Sadar (N=25)	Gomostapur (N=25)	Kansat (Shibgonj) (N=25)	Baneshar Bazar (N=25)
Loss (%)	8.5	8.5	6.6	10.1
Standard deviation	4.6	6.7	4.8	6.2

Considerable losses of mango were also observed at the wholesalers' and retailers' levels (Tables 5.4, 5.5). At the wholesalers' level, the losses were higher in the wholesale markets of Dhaka than Mymensingh (Table 5.4). An opposite scenario, was however, observed in case of the retailers (Table 5.5).

Table 5.4 Average postharvest loss of mango at the wholesalers' level in the urban markets of Dhaka and Mymensingh

District	Average postharvest loss of mango at the wholesalers' in Dhaka and Mymensingh		
	Dhaka		Mymensingh
Upazilla	Karwan Bazar wholesale market (N=50)	Badamtali wholesale market Dhaka (N=25)	Mymensingh Sadar (N=25)
Loss (%)	11.0	9.1	7.5
Standard deviation	5.0	6.0	6.4

Table 5.5 Average postharvest loss of mango at the retailers' level in the retail markets of Chapai Nowabgonj, Dhaka and Mymensingh

District	Average postharvest loss of mango at the growers' level in Chapai Nowabgonj, Dhaka and Mymensingh			
	Chapai Nowabgonj	Rajshahi	Dhaka	Mymensingh
Upazilla	Chapai Nowabgonj Sadar (N=25)	Sadar (N=25)	Sadarghat & Sutrapur N=25)	Mymensingh Sadar (N=25)
Loss (%)	5.5	4.7	5.5	8.7
Standard deviation	4.0	3.0	4.2	4.9

Commodity specific postharvest quantitative losses were calculated by averaging the losses observed at the different levels of the supply chain. The total postharvest loss was found to be the highest in jackfruit (43.5%) followed by pineapple (43.0%), papaya (39.9%) and cauliflower (34.4%) (Fig 5.1). The highest loss in jackfruit is possibly attributed to the fact that jackfruit is seriously damaged by fruit borer and soft rot since the growers of the surveyed region, Mymensingh and Gazipur, hardly apply any pesticides or fungicides to reduce damage in the field. The second important reason for higher loss in jackfruit is the excessive use of ripening chemicals, which accelerate fruit ripening and

dramatically shorten shelf life. The higher loss of pineapples is mostly due to the excessive use of plant growth regulators. Even though, pineapple is a non-climacteric fruits, the growers use chemical ripening agents just to degreen the fruit skin, but the chemical does not significantly accelerate ripening of non-climacteric fruits like pineapple (Wills *et al.* 2004). Inadequate and suboptimal transport of produce from the local assembles markets to the wholesale markets also greatly contribute to the significant losses of fruits and vegetables. The postharvest losses is comparatively lower in orange (23.6%), banana (24.6) and litchi (24.9%) (Fig 5.1).

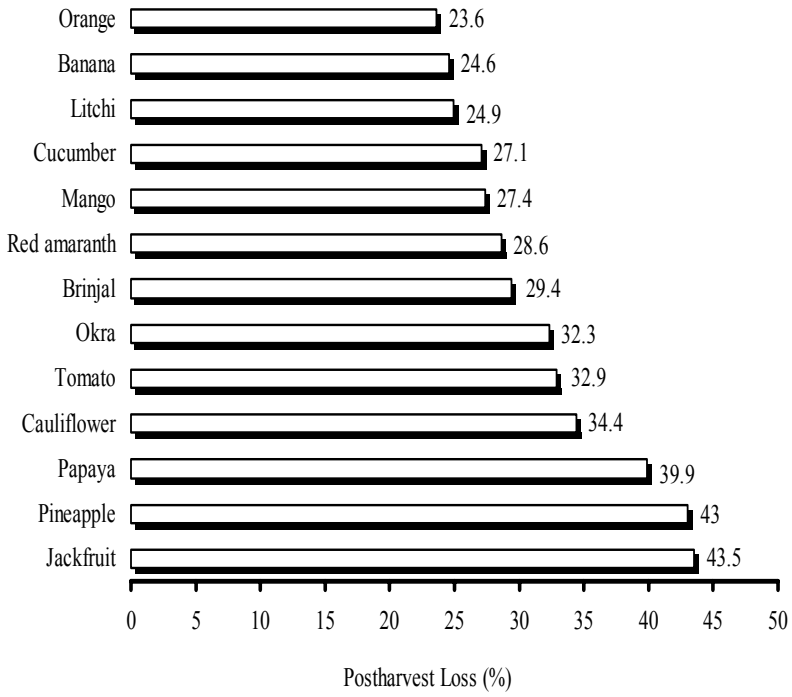

Fig 5.1 Estimated postharvest losses of selected fruits and vegetables in Bangladesh.

The foregoing discussion suggests that the postharvest losses of fruits and vegetables are enormous. Improved pre- and postharvest practices can greatly improve the situation as observed in another piece of study, which examined the postharvest losses of summer tomato (Dadpur of Bagharpara Upazilla, Jessore) in supply chain, especially at the growers' and 'Bepari' levels. In summer tomato, improved pre- and postharvest practices are followed, and the losses are much lower (2.2 and 4.5% at the growers' and 'Bepari' levels, respectively) as compared to those grown under conventional production system (6.9 and 9.1% at the growers' and 'Bepari' levels, respectively) (Fig. 5.2). Higher postharvest losses of tomato in the conventional production system may be attributed to the lower prices at the peak season due to higher supply, which restrain the growers and other intermediaries to adopt improved practices both at the pre- and postharvest levels.

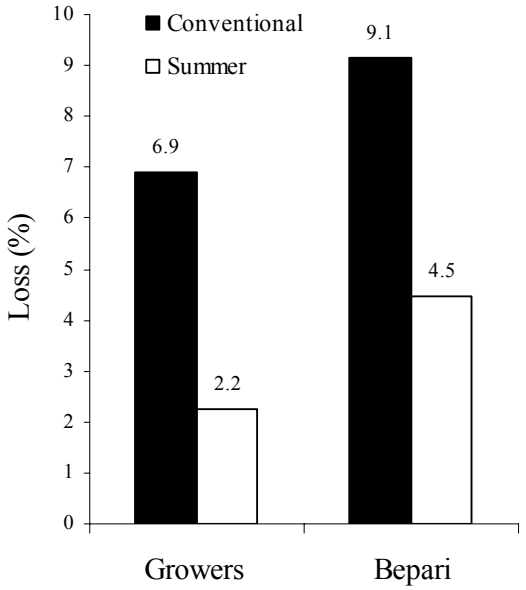

Fig 5.2 Postharvest losses of tomato at the growers' and 'Bepari' levels in summer and conventional tomato production in Jessore (N=75, Conventional; N=25, Summer tomato).

5.2 Economic loss due to postharvest spoilage

The postharvest quantitative losses as shown in Fig. 5.1 were converted to economic values. The results showed that the annual losses of the selected fruits and vegetables were 2047 and 3442 crore taka based on harvest and retail prices, respectively (Table 5.6).

Table 5.6 Economic loss of fruits and vegetables due to postharvest spoilage

Fruits and vegetables	Production in metric ton (BBS 2008)	Actual Loss (%)	Harvest Price Tk/ kg	Retail price/ kg	Loss based on harvest Price (Crore Tk.)	Loss based on retail Price (CroreTk.)
FRUITS						
Mango	767000	27.4	44.99	62.74	945.50	1318.53
Jackfruit	926000	43.5	6.48	14.37	261.02	578.83
Banana	1005000	24.6	12.10	22.92	299.15	566.65
Litchi	44000	24.9	130.00	293.59	142.43	321.66
Pineapple	238000	43.0	5.68	9.70	58.13	99.27
Papaya	96000	39.9	16.05	34.70	61.47	132.91
Orange	12000	23.6	43.80	69.48	12.40	19.68
				Sub-total (Fruits)	1780.1	3037.53
VEGETABLES						
Tomato	143000	32.9	12.85	16.58	60.46	78.00
Cauliflower	156000	34.3	9.33	15.00	49.92	80.26
Brinjal	222000	29.4	18.95	28.36	123.68	185.00
Okra	39000	32.3	15.00	27.96	18.90	35.22
Cucumber	53000	27.1	9.45	17.76	13.57	25.51
				Sub-total (Vegetables)	266.53	403.99
GRAND TOTAL					2046.63	3441.52

These losses actually have two-fold social impacts. Firstly, the country is facing enormous annual monetary loss. Secondly, the consumers are deprived from the consumption of the highly nutritious fruits and vegetables. The losses are due mainly to the sub-standard postharvest handling practices, inadequate transport, lack of storage facility and ignorance of the stakeholders. This is obvious that cent percent loss would not be checked but definitely a significant proportion of the loss could be avoided, and thereby, crores of taka would be saved annually. The reduction of the losses in a systematic way requires knowledge of postharvest biology and its applied technical aspect and handling. In the developed world, improved postharvest technologies like low temperature storage, CA storage and MA storage have been started long before to reduce loss and maintain quality of produce. In India, different types of improved postharvest management practices have been introduced. For example, improved fruit pack house and vegetables packaging with modified atmosphere technologies are in use (CIPHET 2009). However, the situation of postharvest management of horticultural commodities in Bangladesh is still sub-standard. Immediate intervention is needed to improve the present status of postharvest management so that the losses are minimized, and quality and safety standards are maintained.

Chapter 6

Constraints of stakeholders in horticultural supply chain in Bangladesh

Scores of problems are faced by the growers and other intermediaries in fruits and vegetables supply chain. The particular problems of the particular crops at different levels of the supply chain are discussed in the present Chapter.

6.1 Mango

At the growers' levels, the problems are mainly related to unavailability, high price and poor quality of fertilizers, lack of irrigation water, insect infestation and disease attack. Irrigation problem occurs because of higher temperature and low precipitation in the Chapai Nowabgonj and Rajshahi districts and due to higher price of fuel to operate shallow and deep tubewells. However, a considerable proportion of the growers are ignorant and unable to recognize their own problems. At the intermediary levels, the problems are mainly related to transport, lack of proper storage facility and capital. The most common problem is due to the lack of storage facilities. Second most important problem was the lack of proper transport facility. The problems of the wholesalers are mainly due to lack of proper storage, funds and obtaining LC (Letter of Credit) in time. At the retailers' level, lack of storage is also found to be an important constraint.

6.2 Banana

The major problem of the growers of Tangail district is related to fertilizers (availability, price and adulteration). The main problems are related to TSP fertilizers. The growers are often cheated by smuggled inferior quality TSP. Similar problems are also found with MoP. At the intermediary level ('Bepari'), the principal constraint is due to the lack of adequate transport facility. The floor of most of the assemble markets are so dirty especially during the rainy season, the 'Bepari' and other stakeholders cannot perform their works properly. In addition, the produce comes in contact with the mud and dirt, which expose the produce to hazardous chemicals and harmful microorganisms. So, the floors of the assemble markets should be smoothly constructed for easy and rapid movement of the produce. Inadequate supply of banana is observed to be the most important problem of the banana retailers.

6.3 Litchi

At the growers' levels, availability of agricultural inputs are found to be the major concerns, whereas at the intermediary levels, lack of storage and transport facilities and pericarp browning are observed to be the major constraints. The problems related to skin browning and lack of storage are also acknowledged by the retailers of litchi fruits.

6.4 Pineapple

The major constraints of the growers of pineapples are related to agricultural inputs like adequate supply of good quality fertilizers, pesticides and planting materials. The growers also have strong demand of a cold storage facility for short-term storage of pineapples so

that they could temporarily store pineapples during lower demands and unfavourable weather condition, and subsequently sell their fruits at reasonable prices. The 'Bepari' and the wholesalers have particular problems with cold storage and transportation.

6.5 Jackfruit

The growers of jackfruit are found to be very ignorant in relation to their problem. They are mostly incapable of identifying their problems as up to 60% of the growers of Mymensingh and Gazipur districts do not know their constraints. However, lack of fund, storage and training are observed to be the major constraints in jackfruit production in Mymensingh and Gazipur districts. At the 'Bepari' level, 80-90% of the 'Bepari' have problem with lack of adequate transport facility. The transport problems are concerned with unavailability, high price and the hegemony of the local transport brokers. The wholesalers also have problems in relation to the lack of storage.

6.6 Papaya

Lack of fund and high prevalence of insect pests and diseases are observed to be the principal constraints of the papaya growers in the Ishurdi region of Pabna district. Inadequate and faulty transportation and lack of short and long-term storage facilities are the major constraints of the 'Bepari' and wholesalers of papaya.

6.7 Orange

The orange growers of the Moulvibazar are facing the challenge of irrigation crisis to grow orange. Water is very scarce over there, especially at the top of the hills. They also have no other improved irrigation systems like drip or trickle irrigation suitable for uneven topography. However, the growers apply different types of mulching materials, especially straw to conserve moisture in the soil. Insects and diseases are also found as important problems in orange growing region. Lack of transport and storage facilities are again the principal constrains in carrying out orange business as experienced by the intermediaries.

6.8 Tomato

For the tomato growers, the predominant problem is the high level of infection by viral diseases, especially the tomato mosaic virus. Problems are also concerned with insect and irrigation. Lack of storage and inadequate transportation are observed to be the constraints of the tomato 'Bepari' and wholesalers. The retailers of tomato also have problems with lack of storage and transport facilities.

6.9 Cauliflower

The growers experience mainly the problems related to insect damage and over maturity or discolouration of the curd. Over maturity, curd discolouration (red rot due to boron deficiency), and lack of storage, transportation and fund are observed to be the major constraints of the intermediaries engaged in the cauliflower supply chain.

6.10 Okra

At the growers' level, insect pests and diseases are observed to be the major problems. Apart from pests and diseases, other problems are related to seeds, water and fertilizers. As okra pods are very tender and highly perishable, numerous problems are faced by the intermediaries. Among the problems, lack of proper transport system is the main concern of the 'Bepari'. As a result, huge loss occurs, especially when the produce could not be delivered to the destination markets at the right time. In that situation, the 'Bepari' are compelled to sell their produce at throw-away prices, and often the produce becomes unsaleable, i.e. cent percent loss occurs. Other problems are quality deterioration of okra pods by rots and discolouration due to absence of proper storage facility. At the wholesalers' level, the problems are related to storage and pod maturity (increased fibreness). Over maturity of the pods is an important problem of the okra retailers, which results in lower prices since the consumers prefer to buy young tender okra pods. Pod discolouration is also a problem at the retailers' levels. At this last step of supply chain, the okra pods loss its attractive green colour and freshness due to longer duration after harvest and the repeated handling in the supply chain.

6.11 Brinjal

At the growers levels, the pests and diseases are found to be the main concerns. Otherwise, there is very little other problem. The intermediaries have problems with transportation and storage. Fruit separation from the stalk is the major problem of the retailers. Generally, the consumers prefer to buy brinjal with calyx and peduncle attached with the fruit.

6.12 Cucumber

The growers' problems are related to insect pests, diseases and lack of other inputs. Most of the wholesalers have no proper knowledge on storage and transportation of cucumbers. A considerable proportion of the retailers have problems in relation to quality deterioration due to water loss and subsequent shrinkage that render the cucumber unsaleable.

In conclusion, numerous challenges are faced by the growers and intermediaries involved in fruits and vegetables supply chain. In a nutshell, the growers have problems related to the availability of agricultural inputs like seeds, fertilizers and pesticides. Prevalence of insect pests and diseases is also major constraint of the growers for most fruits and vegetables. Lack of irrigation remains a big challenge for many crops, especially orange. Some growers also underscore the needs for training on production and management technologies for some crops. For the intermediaries, the predominant constraints are related to the adequate transportation and storage facilities. Lack of funds is also mentioned by some intermediaries. Intervention is crucial in the transport and storage sectors. The interventions should include the introduction of refrigerated vehicles and establishment of low temperature storage facilities at the vicinity of production areas of particular commodities. The improvement and refinement of the conventional transport systems are also crucial.

Chapter 7

Postharvest handling of fruits and vegetables

7.1 Postharvest supply chain

Postharvest handling operations mainly include: sorting, grading, cleaning and sanitation, packaging, transportation and storage. The harvested produces are firstly dumped in a place, and from where other operational steps are sequentially started (Fig 7.1).

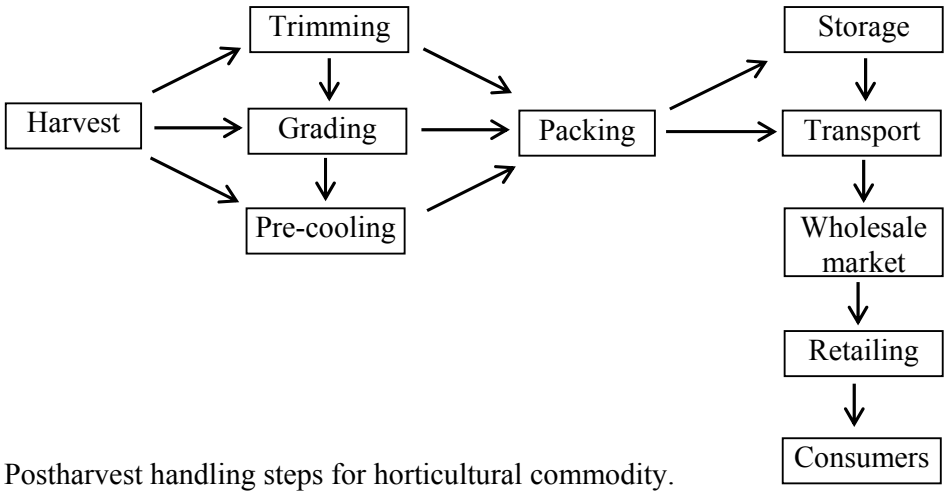

Fig 7.1 Postharvest handling steps for horticultural commodity.

7.2 Marketing of fruits and vegetables

The changing demand in domestic and international markets for high-value product creates challenges and opportunities. Majority of the horticultural commodities like fruits and vegetables are produced by small and marginal holders, but due to weak and fragmented value-chain, only a small percentage of the produce reaches the urban market (Minten *et al*. 2010). Appropriate marketing infrastructure is crucial for efficient marketing of fruits and vegetables. Adequate transportation and product handling are also important for the trade of agricultural products and important factors in assuring good prices and poverty alleviation (Khandaker *et al.* 2009). Investment is required for improved maintenance of road and port infrastructures. In addition to infrastructure development, modification of policies and management are also needed to improve appropriate and timely shipping of perishables (World Bank 2005).

7.2.1 Present horticultural marketing channel in Bangladesh

The present marketing channel of fruits and vegetables in Bangladesh is quite outdated and there is no sign of improved systems in operation as seen in many of the developed and developing countries. The growers generally sell their produce either to the 'Faria' in their own field or to the 'Bepari' in the nearby rural assemble markets. In the assemble markets, the 'Bepari' pays a certain percent of commission (≈5%) to the local commission agent. The produce is then loaded onto the transport vehicle and carried to the different wholesale markets in the big cities including Dhaka, Rajshahi, Chittagong, Khulna, Sylhet, Barisal, and also to other district towns based on demands. The 'Bepari' also pays a certain percentage of commission (≈5%) to the commission agent called 'Aratdars' in the

distant wholesale markets. In most cases, the wholesalers do nothing. They only take the commission in exchange of giving his place ('Arat') to be used by the 'Bepari' to keep their produce until sold to the 'retailers' or consumers. The retailers finally sell their produce to the consumers. An interesting observation is that the use of ripening chemicals is particularly concentrated in the rural assemble markets and wholesale markets for mango, banana, jackfruit and tomato. In contrast, the ripening chemicals are used by the growers in case of pineapple. The following marketing channel (Fig. 7.2) is observed for most of the horticultural commodities with some exception.

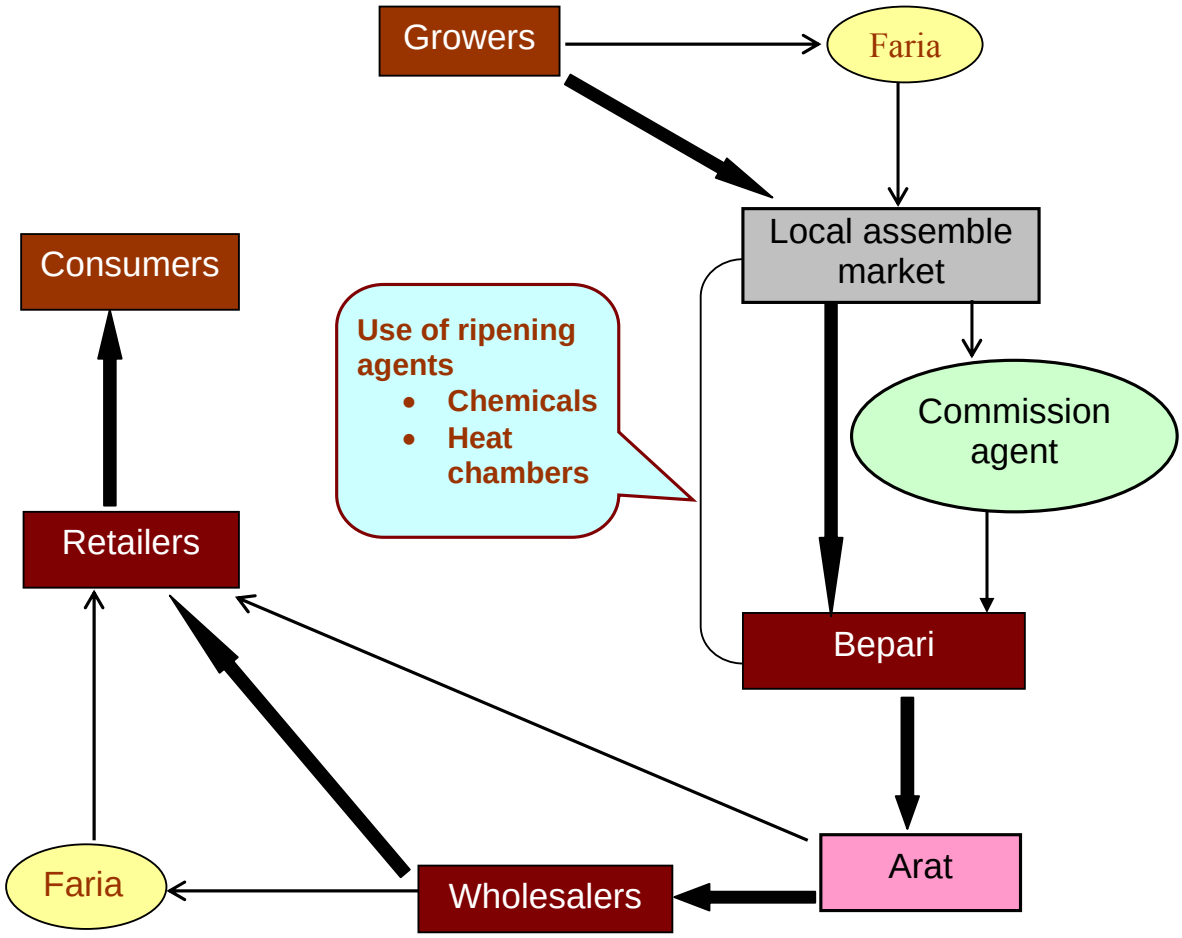

Fig 7.2 Marketing channel of fruits and vegetables in Bangladesh.

In the entire marketing channel, there is no facility for short and long term storage of perishables. Ideally, storage facilities should be located at each of the loading and unloading points, and in the wholesale markets. This is a critical problem in the present marketing system, especially for the perishables like fruits and vegetables. Introduction and establishment of cool chain is a must to reduce postharvest quantitative and nutritional losses, stabilize commodity price, reduce the negative engagement of the intermediaries, and ensure produce quality and safety. Similar observations were also mentioned by Minten *et al*. (2010), who reported that the infrastructures in the rural assemble, wholesale and retail markets are deficient and inadequate in Bangladesh. These markets are highly congested and lack basic facilities such as potable water, toilets, sewage systems, loading spaces and storage facilities. Poor market infrastructure contributes to huge losses of the high value produce.

7.2.2 Price variation of horticultural produce in supply chain

Price of commodity at different levels of supply chain is very important in Bangladesh, where the commodity price varies quite significantly due to the engagement of numerous intermediaries in the system. Generally speaking, the price of produce is pretty high at the retailers' level as compared to that of the growers' level. The price increase of produce ranged from 44.52% in mango to 252.35% in red amaranth in the marketing channels before the produce reaches the consumers (Table 7.1). High price increase of a particular commodity at the retail level is possibly attributed to the less market integration and vice-versa. More than 100% price increase is observed in pineapple, jackfruit and tomato. The levels of price increase in cucumber, banana, cauliflower and okra were 94, 90, 88 and 86%, respectively. The average increase in price of fruits and vegetables is 105% in the marketing channel before reaching the consumers. This may be because of the fact that the growers are not interested to sell their produce to the consumers. Sometimes, unnecessary hassles and inadequacy of transport facility encourage the growers to sell their produce either to the 'Faria' or to the 'Bepari' in the nearby assemble markets. In addition, strong trade organization of the intermediaries and no or weak organizations of the growers further compound the problems. However, government-assisted growers' society or similar society would greatly help the growers to receive reasonable price for their produce.

Table 7.1 Per cent increase in commodity price from harvest to retail sale

Produce	Harvest price	Retail price	Per cent increase
Mango	41.49 Tk/kg	59.96 Tk/kg	44.52
Banana	145.25 Tk/Bunch	275.00 Tk/Bunch	89.48
Jackfruit	26.57 Tk/Fruit	60.81 Tk/Fruit	128.87
Pineapple	10.94 Tk/Fruit	25.00 Tk/Fruit	128.52
Litchi	281.33 Tk/100 Fruit	481.57 Tk/100 Fruit	71.18
Papaya	16.04 Tk/Fruit	34.70 Tk/Fruit	116.33
Orange	5.8 Tk/Fruit	10.23 Tk/Fruit	76.38
Tomato	8.12 Tk/kg	17.9 Tk/kg	120.44
Okra	15.00 Tk/kg	27.96 Tk/kg	86.40
Cauliflower	7.58 Tk/kg	13.88 Tk/kg	88.13
Brinjal	18.95 Tk/kg	28.36 Tk/kg	49.66
Cucumber	9.14 Tk/kg	17.76 Tk/kg	94.31
Red amaranth	5.52 Tk/kg	19.65 Tk/kg	235.32
		Average increase	105.29

In conclusion, it is recognized that the intermediaries are also vital components of the today's business. So, they could not be excluded from the supply chain. Nevertheless, government intervention and monitoring should be strengthened in order to reduce the hegemony of the intermediaries in fruits and vegetables supply chain. This would ensure two-fold benefits, firstly, the growers would receive reasonable price of their produce, and secondly, the consumers would purchase produce at reasonably lower prices.

Chapter 8

Maturity standards of fruits and vegetables

Optimum maturity is of paramount importance to ensure good quality and longer shelf life of produce. For example, mangoes are generally harvested at physiologically-mature stage for optimum quality, otherwise fruit may not ripen, colour and flavour properly (Jha *et al*. 2006). Reid (2002a) defined maturity as "the stage of development at which a plant or plant part possesses the prerequisites for use by consumers for a particular purpose".

8.1 Types of maturity

Physiological maturity

Physiological maturity refers to the stage in development of an organ (eg. fruit) when maximum growth and maturation have occurred to be followed by ripening and senescence (Wills *et al.* 2004).

Horticultural maturity/commercial maturity

Horticultural maturity is the stage of development when the commodity attains the pre-requisites for marketing (Reid 2002a; Wills *et al*. 2004). Horticultural maturity can attain at any stage during development, maturation, ripening or senescence.

8.2 Determination of harvest maturity

Harvest maturity depends on the purpose of use and kind of produce. Maturity can be determined either by subjective or objective observations. According to Reid (2002a), the methods of determining harvest maturity are as follows:

Physical methods

Size, shape, colour, texture, etc.

Chemical methods

Total soluble solids (TSS), acidity, etc.

Physiological methods

Respiration and ethylene production.

Apart from the above measures, abscission, accumulated heat units, specific gravity, duration after flowering, firmness, dry matter, juice content, oil content, waxiness, tenderness, etc. can also be used to determine the optimum stage of harvest maturity. Some important measures of maturity of fruits and vegetables are described in the following.

Shape

The shape of mango fruit is an important index of maturity. The harvested mango fruits of 'Tommy Atkins' and 'Keitt' were categorised into three maturity groups, namely fully mature, half-mature and immature on the basis of shape (Medlicott *et al*. 1988). The fully mature or mature-green fruit had out-grown shoulders and cavity formation at the stem-end. The fruits also remained firm and green. The half-mature fruits were characterised by shoulders aligned with the stem-end, and the immature fruits had the shoulders below the point of stalk insertion or cavity.

Time after flowering

In mango, duration of fruit development is also considered as an index of maturity. Wang and Shiesh (1990) suggested that 90 days after anthesis seemed to be the most suitable stage for harvest maturity of 'Irwin' mango. After analysing a range of quality parameters including fruit weight, length, diameter, specific gravity, moisture, total soluble solids, acidity, vitamin C and β carotene contents, Tandon and Karla (1986) concluded that 'Langra' and 'Mallika' took 84 and 96 days after fruit set, respectively, to attain harvest maturity.

Specific gravity

The specific gravity of the fruit can be considered as an index for maturity grading of mango fruits. Water has a specific gravity of 1.00 and common salt solution (2.5% sodium chloride) has a specific gravity of 1.02, and both are used in the maturity grading of mango fruits (Kapse and Katrodia 1997). Immature, pre-mature and mature mango fruits had specific gravities of <1, >1 and <1.02, and >1.02, respectively.

Physical and chemical properties

After extensive study with 3 mango varieties, Jha *et al*. (2006) concluded that the properties of mango fruits for optimum ripening and storage quality include fruit size (70 mm diameter), colour (L = 42.31, a = -6.70, and b = 16.75) and firmness (30 N). Pulp dry matter content could be used as an index of maturity since it has strong relationship with ripe-stage eating quality (soluble sugar contents). Near infrared predicted dry matter and starch contents of hard-green mango, and ripe-stage eating quality in terms of soluble sugar contents, could be precisely determined (Sarangwong *et al*. 2004). Presently, pulp dry matter content at harvest is considered an important maturity index and is being used in Australia. Bally (2003) reported that the pulp dry matter content of 'Kensington Pride' mango should be at least 14% at harvest.

8.3 Effects of maturity on physico-chemical changes and ripening

Harvest maturity has a great influence on the postharvest quality of fruit. Fruits harvested at mature and half-mature stages produced good quality characteristics in the fruits when ripened at 25 ^{o}C (Medlicott *et al*. 1988). The mature fruits were observed to have a faster rate of ripening compared to the half-mature and immature fruits. The immature fruit only showed limited quality changes during ripening, and normal physico-chemical changes did not fully occur.

Chemical composition

Physico-chemical changes and respiration rates are often used in determining the maturity of mango fruit for harvest. Total soluble solids, starch, sugars, total carotenoid pigments and pH are correlated positively with fruit maturity, whereas moisture content, acidity, ascorbic acid and tannins are correlated negatively (Joshi and Roy 1988).

Rate of respiration

The rate of respiration varies with variety, stage of maturity and stage of ripening. Respiration attains at its maximum at the ripe stage compared to the unripe and senescent stages (Adaskaveg *et al*. 2002).

Ethylene production

In general, the rate of ethylene production remains lower in the preclimacteric phase and increases considerably in the climacteric phase (Cua and Lizada 1990; Lopez-Gomez and Gomez-Lim 1992; Gomez-Lim 1997). Mature and half-mature fruits showed higher rate of ethylene production, ripened normally and maintained acceptable flavour and aroma when compared with immature fruits. Ripening of the immature fruits was insufficient as revealed by low ethylene production, poor colour development, minor changes to fruit composition, insipid flavour, and poor aroma (Majeed and Brecht 2002). Cua and Lizada (1990) published an interesting result with regards to harvest maturity and ethylene production. Although the rate of ethylene production remained low during the later stages of maturation, a peak in ethylene production was observed about 10 days prior to harvest maturity.

Rate of ripening

Fruit ripening also depends on the stage of maturity at harvest. Ripening of mango fruits at low temperature (12^{o}C) was effectively retarded in the immature fruits compared with mature fruits of the variety 'Amelie'. In contrast, the variety 'Sensation' ripened rapidly, irrespective of harvest maturity (Seymour *et al.* 1990). Medlicott *et al*. (1990a) reported on the basis of ripening changes at 12^{o}C that immature fruits had superior storage capacity than those fruits harvested at more advanced stages of maturity. When the immature fruits were ripened at 25^{o}C, they failed to develop the characteristics of full ripeness. Exposure of mature and half-mature fruits to acetylene (1.6 mL/L) and ethylene (1.0 mL/L) for 8 hours resulted in the initiation of full ripening, whereas immature fruits failed to fully ripen (Medlicott *et al*. 1990b).

8.4 Maturity symptoms of selected fruits and vegetables

Harvesting horticultural produce at the optimum stage of maturity is the most important step to retain desired quality of the produce. Harvesting produce at premature or over mature stages is disadvantageous. For proper harvesting of produce, attention must be paid to maturity standard, harvesting practices, harvesting containers, harvesting tools, field packaging and transport to the packing house. Maturity symptoms for harvesting of some commercially important fruits and vegetables are briefed in the following.

Mango

- Characteristic varietal size and shape.
- Shoulder growth.
- Slight colour development on shoulder.
- One or two naturally ripe fruit fall from the tree.
- Specific gravity of fruit ranges from 1.01 to 1.02 (Kapse and Katrodia 1997).
- 90 to 120 days from the fruit set (Majumder *et al*. 2001).
- Pulp dry matter content should be at least 14% (Bally 2003).

Jackfruit

- Fruits become ready to harvest in 90-110 days after appearance of the spike (Anon. 1975; Samaddar 2002).
- Watery latex at harvest maturity and concentrated white milky latex at immature stage.
- Metallic sound on striking the fruit with a finger indicates immature stage, whereas dull sound indicates maturity.
- More spaces between protuberances.

Pineapple

- Characteristic varietal shape and size of the fruit.
- The lowermost eyelets show orange yellow colour. The eye gets flattened in the centre and bulge on the sides (Sen and Mitra 2001).
- Harvesting for local markets should be done at full ripe stage and for distant market at 75-80 per cent maturity (Sen and Mitra 2001).

Banana

- The ridges on the surface changes from angular to round.
- Requires 11-14 months and 14-16 months after planting for dwarf and tall varieties, respectively (Chattopadhyay *et al*. 2001).
- Fruits generally mature 90-120 days after the appearance of inflorescence (Chattopadhyay *et al*. 2001).
- Floral remnants at the fruit tips dry out.

Litchi

- Generally takes 55 days after fruit set for reaching optimum maturity (Gaur and Bajpai 1977).
- Flatness of tubercles and smoothness of epicarp (Maity and Mitra 2001).
- Fruit colour changes from green to pink on maturity.
- At optimum maturity stage, the fruits should have 18.1 %Brix TSS, 0.24% acid and 1.00 specific gravity (Biswas and Roy 1985).
- Fruits should not be harvested immediately after rain to reduce rot.

Papaya

- Mature-green fruits should be harvested.
- Peel colour changes from green to yellowish-green.
- Latex of the fruit becomes watery (Shetty 1953).
- The first fruits would be harvested 12-14 months after transplanting (Muthukrishnan and Irulappan 2001). However, it depends on agroclimates and variety.

Okra

- Desirable size of the pods attained.
- The tips of the pods can easily be snapped.
- The tender young fruits of 7-10 cm long should be harvested every alternate day.
- The pods of okra become ready for harvest from the 6^{th} day of flowering. Pods harvested on or after the 8^{th} day of flowering become fibrous (Hazarika *et al*. 1997).

Brinjal (Eggplant)

- Desirable size and colour attained.
- The fruits should be tender at harvest. Over mature fruits have dull colour and hard seeds.
- The surface of the fruit should not loose its bright and glossy appearance.
- At harvest, the calyx and the peduncle should remain attached with the fruit (Som and Maity 2002).

Tomato

- Tomatoes should be harvested at mature-green stage (fully-grown fruit with light green colour at the blossom end and seeds are surrounded by jelly-like substances; Tiwari *et al*. 2002).
- Tomatoes can also be harvested at turning pink ($1/4^{th}$ of the surface at the blossom end shown pink; Wills *et al*. 2004).

Cauliflower

- Desirable size attained.
- Cauliflower should be harvested at the stage when the curd is compact.
- Over-mature curd becomes loosened with elongated flower clusters.

Red amaranth

- Amaranth should be harvested at 25-30 days after seed sowing when the plants remain tender (Vijaykumar 1980).

8.5 Methods of harvesting

To maintain optimum quality, good harvesting practices should be followed. Fruits and vegetables should be harvested at their optimum stages of maturity, and appropriate

harvesting containers and harvesting tools should be used to make sure that the harvested produce are not damaged. There are some vegetables like potato, cassava and yams which require curing at high temperature and high humidity to create a protective layer to check water loss and protect produce from fungal infections. For example, potatoes are cured immediately after harvest at 15-20^{o}C and 90-95% relative humidity for 5-10 days (Kitinoja and Kader 2003).

8.6 Points to be considered during harvesting of horticultural crops

- Produce should be handled with care to avoid injury and damage.
- Market demands in terms of size and stage of maturity should be considered.
- Containers and harvesting tools should be clean and free from rough edges.
- Stackable and nestable plastic crates could be used as field containers during harvest. Plastic crates are durable, reusable and can easily be cleaned.
- The harvesters should be properly trained on harvesting methods and proper stages of maturity.
- Produce that has fallen or touched the ground should not be harvested.
- Shade should be provided over the harvested produce to prevent heat and sun damage and reduce nutritional degradation.
- Suitable time of harvesting horticultural produce is the early morning.
- The harvesting tools and equipments should be disinfected with chlorine water.

Chapter 9

Sorting, grading, washing and packaging of fruits and vegetables

9.1 Sorting

In Bangladesh, sorting is practiced for most of the fruits and vegetables to remove damaged, diseased and insect infested produce on the basis of visual observation. However, in the advanced countries different types of sorters are used. The commonly-used sorting equipments are belt conveyor, push-bar conveyor and roller conveyor (Kitinoja and Kader 2003).

9.2 Washing

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. Chlorination of wash water is very important in postharvest handling. Chlorine can reduce the spread of contamination form one item to another during the washing stage. The pH of the wash water should be maintained at 6.5 to 7.5 for best results. Typically 1 to 2 mL of chlorine bleach per liter of clean water provides 100 to 150 ppm total Cl (Kitinoja and Kader 2003).

9.3 Grading

Grading is one of the important postharvest operations. In Bangladesh, grading is practiced in limited scale based on size, especially for mango, banana, pineapple, papaya and jackfruit. Otherwise, no grading standard is found available for most of the fruits and vegetables. In case of banana, the 'Bepari' prefers to purchase well-shaped and well-developed bananas. They usually purchase bananas on the basis of flatness of angularity of the fingers. They grade bananas based on bunch size into large, medium and small. Brinjal and cucumber are not properly graded by the growers. Regarding the grading of okra, the 'Bepari' prefers to purchase well-shaped okra pods. They rely on the visual/external quality parameters of okra pods like tenderness (by tip pinching), color, size and shape of the pods. However, tenderness is found to be the common means of judging the quality of the okra pods prior to taking decision on whether the produce to be purchased or not. There are no scientific methods of grading or grade standards of fruits and vegetables in Bangladesh. In this regard, the introduction of UREPGAP (common standards for agricultural farm management practices in the European countries) in the 1990s in Europe would be worth mentioning. Therefore, emphasis must be given to develop GAP (Good Agricultural Practices) for the horticultural produce in Bangladesh not only for export but also for domestic market development in order to ensure quality and safety in the horticultural supply chain. Sizing rings are used based on the size and shape of commodity to manually grade horticultural produce (FAO 1989). Automatic grading of fruits is also a common practice in the developed countries. Automatic rotary cylinder sizer is used to grade fruits in the developed countries (Reyes 1988). However, the advanced practice of grading fruits and vegetables in Bangladesh seems quite remote to be introduced right

now. But, in the future, these sophisticated technologies should be introduced, optimized and disseminated for the promotion of fruits and vegetables industries in the country.

9.4 Packaging

Packaging is an important postharvest handling step for long-distance transportation and storage of fruits and vegetables. Different types of bags, crates, baskets, cartons and bins are commonly-used packaging materials for perishables. Packaging is used to assemble the produce in convenient units for transportation, marketing and distribution. Good packages must cope with long distance transportation, multiple handling, and changed conditions of storage, transport and marketing. The present packaging systems for perishables in Bangladesh is unscientific. Use of traditional forms of packaging like bamboo baskets, especially at the growers' level, is still predominant. Other packages at the growers' levels include polystyrene and jute sacks. Use of corrugated fibreboard packages is also very limited. For bulk transportation, still the intermediaries rely on large packages made of local materials like bamboo basket, jute sacks, jute ropes, leaves and vines. Often, the packages are unhygienic and lack adequate aeration facility. These packages are also unsuitable in relation to convenience, handling and stocking. Recently, plastic crates have been introduced for some valuable horticultural produces like mango and tomato. The present status of packaging of horticultural produce is discussed in the present chapter.

9.4.1 Mango

Different types of packaging materials are used during transportation of mango, especially bamboo baskets and plastic crates (Plate 9.1). Nowadays, the mango 'Bepari' are interested to use the plastic crates through which the postharvest loss is minimized. This is also economic and reusable as compared to those of the presently-practiced bamboo baskets.

9.4.2 Banana

Usually, bananas are not packaged for long distance transportation in Bangladesh. However, use of corrugated fibreboard cartons with foam-made sleep sheets inside for banana hands is common in many of the industrialized countries.

9.4.3 Litchi

Litchi fruits are packaged in bamboo baskets and covered with gunny sacks (Plate 9.2). Large volumes of litchi leaves are placed inside the package (Plate 9.3). When litchi leaves becomes unavailable, the leaves of mast tree (*Polyalthia longifolia*) and Mahogany (*Swietenia mahogani*) are also used (Plate 9.3B). These leaves are thought to have impacts as padding materials during long-distance transportation. Another important possible role of these leaves would be the elevation of CO_2 and reduction of O_2 concentrations inside the package which create a modified atmosphere suitable for storage of fruits.

Plate 9.1 Conventional packaging of mango fruits (A & B) and plastic crates (C&D).

Plate 9.2 Conventional packaging of litchi fruit for long distance transportation (A); and small bamboo-made customer pack (B).

Plate 9.3 Litchi fruits are temporarily stacked and covered by litchi leaves (A); leaves of mast tree (B) are also used in case of scarcity of litchi leaves.

9.4.4 Jackfruit and pineapple

Packaging is not practiced in case of jackfruit and pineapple. However, layers of green leaves, vines and straw are used as padding materials to reduce vibration damage during transportation.

9.4.5 Papaya

In the case of papaya, individual fruits are wrapped with newspaper. Otherwise, no improved packaging is used for these fruits. Foam nets would be suitable packaging for papaya in Bangladesh.

9.4.6 Brinjal and cucumber

Conventional packaging i.e. jute sacks are mainly used by 'Bepari' of brinjal and cucumber trades. Some 'Bepari' use plastic sacks as packaging materials for brinjal and cucumber marketing.

9.4.7 Okra

The usual means of packaging okra are plastic sacks and gunny bags (Plate 9.4). Improved packaging is not usually practiced in okra trading by the 'Bepari'. However, some 'Bepari' use more improved and recently introduced plastic crates for okra packaging for long distance transportation. Plastic crates are durable and reusable. It also helps reduce transport damage and thereby extend shelf life of produce.

Plate 9.4 Packaging of okra by gunny sack for long distance transportation.

9.4.8 Points to be considered for packaging of fruits and vegetables

Although packaging of perishables is not quite satisfactory in Bangladesh but there are ample scopes to introduce and expand the use of improved packaging to reduce postharvest loss and maintain quality. The following points should be considered during packaging of fruits and vegetables.

- Improved packaging such as plastic crates (stackable and nestable), woven plastic sacks, plastic net bags, and corrugated fibreboard cartons should be used instead of the conventional bamboo made packages, which cause substantial damage to the produce during handling. The use of plastic crates in increasing, especially for high value produce like mango and tomato.
- Packages should be strong so as to withstand repeated postharvest handling.
- Packages should not be very large or voluminous. In Bangladesh, the 'Bepari' very often use large and extra large packages (made of bamboo and jute sacks) with capacity varies from approximately 300-600 kg per package, and there is high risk of damage to the produce during transportation and subsequent handling.
- The packages should not be overloaded and the produce should not be held too tightly or too loosely to minimize damage during transportation and handling.
- Packages should have ventilation holes to allow aeration (5% of the surface area per side, Kitinoja and Kader 2003).
- Different types of packaging accessories like cups, wraps, foam nets, liners and cushioning (shredded papers, leaves, vines, etc.) should be used to protect the produce during transportation and handling.
- The packages should have label with farm logo and other relevant information for value addition and enhanced marketing.

Chapter 10

Transportation of fruits and vegetables

Transportation is an important postharvest operation immediately after harvest. The harvested produces are transported from the farm in two phases. Firstly, the produces are transported from the place of harvest to packaging house, where the produce are subjected to different postharvest operations like cleaning, sorting, grading and different postharvest treatments for shelf life extension. Then the produces are packaged. Secondly, the packaged produces are transported to different destinations like distribution centre, wholesalers, supermarkets and the retailers. Refrigerated vehicle should be used for transportation of perishable horticultural produce to check transport damage during which recommended temperatures and relative humidity should be maintained. Modified atmosphere packaging should be employed to ensure safety of the commodities during transport. Initial wrapping of produce in perforated or non-perforated plastic bags depending on nature of produce prior to packaging would be used.

Ethylene scavenging compounds like potassium permanganate inside the package would further help improving produce quality during transport. Produce mix should be avoided as the liberated gas (ethylene) from one group of produce may badly affect the quality of another group of produce. Temperature management is critical during long distance transport, so loads must be stacked to enable proper air circulation to carry away heat from the produce itself as well as incoming heat from the atmosphere and off the road (Kitinoja and Kader 2003). Transport vehicles should be well insulated to maintain cool environments for commodities and well ventilated to allow air movement through the produce.

10.1 Status of transportation of fruits and vegetables in Bangladesh

The mode of transportation presently in practice in fruits and vegetables marketing in Bangladesh are discussed in the following.

Mango

Mangoes are transported from the growers' field to the local assemble markets by rickshaw, van and bicycle and to the distant markets by truck (Plate 10.1). Truck is found to be the main transport vehicle to carry mango from the place of purchase to the distant markets. No 'Bepari' is found to use refrigerated vehicle to carry perishables despite the fact that refrigerated vehicle is used to carry perishables in developed countries as part of cool chain management. The retailers mainly use van to carry mangoes from the wholesale to retail markets. A large proportion of the retailers also use truck to carry mango from the wholesale to the distant retail markets. The destination markets of the mangoes produced in Chapai Nowabgonj and Rajshahi districts are spread all over Bangladesh. However, the overwhelming majority of the produced mango from Chapai Nowbgonj and Rajshahi is delivered to different wholesale markets of Dhaka.

Banana

Van and truck are mainly used for transportation of banana from growers' field to the local and distant markets. Maximum 'Bepari' comes from big cities, especially from Dhaka. They supply bananas to the destination markets located in the big cities.

Litchi

Van and trucks are mainly used as transport vehicles for litchi by the 'Bepari' to the local and distant wholesale markets.

Pineapple

A variety of transport systems are found available in pineapple transportation from the growers field to the assemble markets, which include bicycle, van, buffalo cart, etc. (Plate 10.2). As usual, trucks are found to be the major transport vehicle for pineapple by the 'Bepari'.

Plate 10.1 Transportation of mango fruits to the assemble markets by the growers using van and bicycle (A & B), and to the distant wholesale markets by the 'Bepari' using truck (C).

Plate 10.2 Transportation vehicle used by growers for carrying pineapples to the assemble markets.

Jackfruit

A wide variety of transport systems are found available in jackfruit transportation from the growers' field to the assemble markets. The mode of transportation includes head load, shoulder load, rickshaw, van, push cart, engine-driven cart and many more (Plate 10.3). Again, open truck is found to be the only vehicle for long distance transportation of jackfruit as used by the 'Bepari' (Plate 10.4). The retailers, however, rely on van and head load.

Plate 10.3 Transportation of jackfruit by shoulder load (A), van without padding (B), van with banana pseudostem padding (C), rickshaw (D), tempo (E), and pull cart (F). These are especially used by the growers to carry jackfruits to the assemble markets.

Plate 10.4 Mixed truck load of jackfruit and pineapple.

Brinjal and cucumber

Van and trucks are mainly used for transportation of brinjal from the growers' field to the local assemble markets (Plate 10.5). Retailers mainly use van and rickshaw for transportation of brinjal to the respective retail markets. Similar nature of transport vehicles are also in operation for cucumber.

Plate 10.5 Van transportation of brinjal to the assemble markets by growers.

Okra

Vans are mainly used for transportation of okra from the growers' field to the local assemble markets. Trucks and bus (mix loads) are the principal methods of transportation of okra from the assemble markets to the wholesale markets. Retailers carry okra by means of head loads to the respective retail markets. Some retailers also carry okra by rickshaw.

Tomato and cauliflower

Tomato is transported by growers using different local carriers like bicycle, rickshaw, vans, push cart, etc. Trucks and vans are mostly used for tomato transportation from the assemble markets to the destination wholesale markets (Plate 10.6A). Similar systems of transportation are also practiced for cauliflower (Plate 10.6B).

Plate 10.6 Van transportation of tomato (A) and cauliflower (B) by the growers to carry their produce from the field to the assemble markets.

In a nutshell, the problems in transporting fruits and vegetables are manifold. The most important problem is due to the absence of refrigerated vehicle in the supply chain. Initiatives should be taken to introduce refrigerated transport vehicles into the existing marketing channel in Bangladesh to reduce postharvest loss and maintain quality of perishables. The Hortex Foundation of Bangladesh recently introduced few such refrigerated vehicles (REFER Truck with temperature range +15 to –25^{o}C) to carry fruits and vegetables (Anon. 2010). However, profitability assessment should be carefully carried out prior to the introduction of any such sophisticated technology into the existing marketing channel of Bangladesh. Another important problem is the serious involvement of truck brokers and different transport federations. Extortion also causes unnecessary financial loss during transportation. In addition, there are no ideal storage facilities for fruits and vegetable in the assemble and wholesale markets in Bangladesh. To resolve these problems, government agencies and private enterprises should come forward to improve the present transport system in Bangladesh.

10.2 Points to be considered for transporting fruits and vegetables

- The transport vehicle should not be overloaded.
- Strong and durable packages should be used.
- Rough handling during loading and unloading should be avoided.
- Containers should be aligned properly.
- Vibration damage would be reduced by using plastic crates, liners and padding.
- Ventilation should be ensured to prevent heat generation during transportation.
- The packages should be loaded in uniform stacks and braced securely.
- Workers should not stand upon the produce during loading and unloading.
- The entire load should be covered with a silver or light-colored canvas.

Chapter 11

Storage of fruits and vegetables

Short and long-term storage are the most important postharvest operations in fruits and vegetables supply chain. In the developed countries, variety of storage facilities are available at different levels of marketing from growers to the retail shops. Cool chain management is ensured to maintain produce quality. Moreover, the growers use suitable postharvest treatments to prolong shelf life of produce. The usually-practiced storage methods include low temperature storage, controlled atmosphere (CA) storage and modified atmosphere (MA) storage. The commonly-practiced postharvest treatments are: recommended fungicidal dips, ethylene scavenging chemicals like potassium permanganate and 1-methyl cyclopropene and edible coating like chitosan. The improved postharvest technologies ensure high quality and long marketing life of the produce.

The perishability of fruirs and vegetables greatly vary with their types. Kitinoja and Kader (2003) categorized fruits and vegetables into 4 in decreasing order of perishablity as: 'Very High' (potential storage life less than 2 weeks; examples tomato, cauliflower, broccoli, spinach and mushroom) > 'High' (potential storage life 2-4 weeks; examples are banana, grapes, guava, mandarin orange, mango, papaya, cabbage, brinjal and okra) > 'Moderate' (potential storage duration 4-8 weeks; examples are apple, pomegranate, carrot, radish and potato) > 'Low' (potential storage life 8-16 weeks; examples are potato, dry onion, garlic, pumpkin, taro and yam). Therefore, more emphasis should be given to those fruits and vegetables belonging to 'Very High' and 'High' levels of perishablity.

11.1 Status of storage of horticultural commodities in Bangladesh

Modern storage of fruits and vegetables is virtually absent in Bangladesh. Cold storage facility is only available for potato. However, there are a very few multi-chambered and privately-owned low temperature storage facilities in Badamtali, Dhaka (Plate 11.1) where the wholesalers keep high-value fruits, particularly the imported apples, orange, dates, pears and grapes. Very few growers and intermediaries adopt any technologies to prolong shelf life of fruits and vegetables.

Plate 11.1 Multi-chambered refrigerated facility for storing fruits (Badamtali, Dhaka).

Hence, appropriate and pragmatic interventions are crucial to reduce loss and maintain quality and safety of fruits and vegetables in Bangladesh for the promotion of the concerned industries in the country.

11.2 Improved storage practices

Horticultural produce is highly perishable mainly because of its high water content. Proper storage of produce is one of the most important aspects. In Bangladesh, commercial-scale low temperature storage facilities are absent except cold storage for potatoes, and therefore, huge amounts of the harvested produces are lost or sold at less price. Some improved methods of storage of perishable horticultural commodities are described in the following.

Low temperature storage

Low temperature storage is the most widely used technology for perishables throughout the world. Low temperature storage can be of different types including air-cooled stores, ice-refrigeration and commercial cold storage. Commercial cold stores are in operation in most of the industrialized countries for the storage and preservation of perishable produce. This generally utilizes the mechanical refrigeration to reduce storage temperature. Recommended temperature and relative humidity (Table 11.1) should be maintained to safely store produce.

Table 11.1 Temperature, relative humidity and approximate storage life of important fruits and vegetables (Kitinoja and Kader 2003)

Product	Temperature (^{o}C)	Relative humidity (%)	Approximate storage life
Fruits			
Bananas (Green)	13-14	90-95	1-4 weeks
Jackfruit	13	85-90	2-6 weeks
Litchi	1.5	90-95	3-5 weeks
Mango	13	85-90	2-3 weeks
Orange	3-9	85-90	3-8 weeks
Papaya	7-13	85-90	1-3 weeks
Pineapple	7-13	85-90	2-4 weeks
Mandarin orange	4	90-95	2-4 weeks
Vegetables			
Amaranth	0-2	95-100	10-14 days
Cauliflower	0	95-98	3-4 weeks
Cucumber	10-13	95	10-14 days
Eggplant	12	90-95	1 week
Tomato			
Okra	7-10	90-95	7-10 days
Potatoes	4.5-13	90-95	5-10 months

Temperature influences vital physiological processes, namely respiration and ethylene production. Sommer (1985) mentioned that low temperature not only slowed down fungal development but also maximised postharvest life. According to Kader (2002), mature-green mangoes should be stored at 13^{o}C, while the partially-ripened mango should be stored at 10^{o}C. Several other authors also demonstrated the extension of mango storage life by applying low temperature (Farooqi *et al*. 1985; McLaughlan and Wells 1994). Though low temperature storage significantly extended storage life of mangoes, temperatures as low as 8^{o}C caused considerable damage due to chilling injury, which is

characterised by uneven ripening, poor colour and flavour, surface pitting, grey scald-like skin discolouration, and increased susceptibility to decay and flesh browning (Medlicott *et al*. 1990b; Kader 2002).

Controlled atmosphere (CA) storage

Controlled atmospheres maintain a low concentration of oxygen and high concentration of carbon dioxide in the storage atmosphere that ultimately reduce the rates of respiration, ethylene production and other metabolic processes. The carbon dioxide-enriched atmosphere also inhibits the action of ethylene (Kader 2002). Gaseous composition of 2-5% oxygen and 2-5% carbon dioxide have been reported to be suitable for banana storage at 12-15^{o}C (Kitinoja and Kader 2003).

Modified atmosphere (MA) storage

The basic principle of MAP technology is that once produce is placed in a package and sealed, an environment different from ambient conditions will be established as the produce continues to respire. Modified atmosphere (sealed packaging with or without ethylene inhibiting compounds) may improve postharvest quality by reducing water loss (Wills *et al*. 1998; Hassan 2000), rates of respiration and ethylene production (Wills *et al*. 1998; Jiang *et al*. 1999; Lalel *et al*. 2005), chilling injury (Pesis *et al*. 2000), and microbial activity (El-Goorani and Sommer 1981; Wills *et al*. 1998). MA has been reported to be suitable for the extension of shelf life of banana (Hassan *et al*. 2004; Hassan and Shipton 2006; Hassan and Shipton 2006a) and litchi (Hassan *et al*. 2009a). Packaging in plastic films can modify the atmosphere surrounding the produce. Modified atmosphere packaging generally restricts air movement, allowing the product's normal respiration processes to reduce oxygen content and increase carbon dioxide content of the air inside the package. An additional major benefit of the use of plastic films is the reduction of water loss. Low density polyethylene (LDPE), and polyvinyl chloride (PVC) are the commonly used films. The limitations of MAP include risk of microbial safety, appearance of brown spots and injuries due to high CO_2 concentration, and environmental hazards for the plastic bags/films/liners.

Heat treatments

Postharvest application of heat has been found suitable for shelf life extension of fruits and vegetables. Generally, there are three methods of heat treatment, namely vapour heat treatment, forced-hot air treatment and hot water treatment (Jacobi *et al.* 2001). Hot water treatment is extensively used in the postharvest handling of mango (Wills *et al*. 1998; Ledger 2004) and banana (Hassan *et al*. 2004) mainly to control fungal infection and shelf life extension. In Bangladesh, BARI has developed an automated hot water treatment facility particularly for mango for the extension of shelf life. The mango fruits are treated with hot water at 52-57^{o}C for 5-7 minutes at a capacity of 1080 kg/hr (Alam *et al*. 2008). Application of heat (30^{o}C air) reduced spore germination and decay development in lemon when inoculated with *Penicillium digitatum*, and the level of the antifungal compound, scoparone, was higher in the heat-treated fruits (Kim *et al*. 1991).

Ethylene scavengers

Since ethylene is considered the only gaseous hormone to trigger fruit ripening, emphasis must be given on the inhibition of ethylene production to ensure safe and long postharvest

life of climacteric fruits. Anti-ethylene compounds have been used for long time in the extension of postharvest life of horticultural commodities. Silver thiosulphate greatly extends the vase-life of ethylene-sensitive flowers (Kader 2002), but it is not a viable treatment for edible fruits. Ethylene can be removed by a number of chemical processes (Reid 2002b). $KMnO_4$ oxidizes ethylene to CO_2 and H_2O. Porous materials are used as $KMnO_4$ absorbers which include vermiculite, pumice and brick, and Purafil® is one of the commercial products containing $KMnO_4$ is available. Ultraviolet light produces ozone, which is thought to be the active ethylene-removing agent. The ethylene oxidising bacterial strain RD-4 was reported to use ethylene as a substrate and thus remove it from the atmosphere (Elsgaard and Andersen 1998).

Ethylene inhibiting compounds

Recently, 1-MCP (1-methylcyclopropene) has been shown to be very effective in inhibiting ethylene action in fruits (Sisler and Serek 1997; Blankenship and Dole 2003). It is thought that 1-MCP occupies the ethylene receptors, and as a result, ethylene cannot bind and elicit its action. When mango fruits were exposed to 1-MCP at a concentration of 100 μL/L for 14 h at 20^{o}C, the shelf-life of mango fruits was extended (Jiang and Joyce 2000). In an experiment conducted by Hofman *et al*. (2001), mango fruits were gassed with 25 μL/L 1-MCP for 14 h at 20^{o}C followed by treatment with 100 μL/L ethylene for 24 h, and the fruits were allowed to ripen at 20^{o}C. Results revealed that ethylene treatment alone halved the number of days for mango fruit to reach the ripe stage compared with the untreated fruit, whereas 1-MCP treatment increased the number of days to reach the ripe stage by 5.1 days. Macnish *et al*. (2000) reported that 1-MCP gas could be used to prevent ethylene perception and response in banana.

Earthen cooling pot

Earthen cooling pot may be used for storage of perishables. Bhattacharjee *et al*. (2007) reported that earthen cooling pot was suitable for storage of pointed gourds and other vegetables. We also examined the efficacy of the use of earthen cooling pot and other modified atmosphere technologies to store okra. Fresh okra pods have extremely short shelf life due mainly to higher rates of respiration and water loss. High temperature and water loss cause reduction in quality of okra pods showing shriveling and toughening of tissues that cause okra unmarketable. Modified atmosphere exerted significant effects in extending shelf life of okra. The longest shelf life (12 days) was observed in okra pods held in plastic box followed by earthen cooling pot (11 days) at ambient temperature (Fig 11.1). Combined effects of low temperature and modified atmosphere on shelf life extension are also shown in Fig 11.2. The unwrapped pods lost quality earlier than those held in plastic box and earthen cooling pot, and both the treatments appeared to be suitable for extending the shelf life as well as maintaining other postharvest quality of okra pods.

In conclusion, at all storage temperatures, the unwrapped okra pod lost its freshness quickly as compared to other modified atmosphere treatments. Okra pod retained its acceptable freshness up to 9 days when held in plastic box. Earthen cooling pot also performed well at all storage temperatures. Earthen cooling pot is cheap and environmentally-friendly, and would be used as the poor peoples' fridge for short-term storage of vegetables.

Plate 11.2 Earthen cooling pot is suitable for low-cost and small-scale storage of fruits and vegetables, especially for those areas where electricity and refrigeration facilities are lacking [Adapted from IND FAO Pilot Project on Prevention and Elimination of Micronutrient Malnutrition in Dharmapuri District, Tamil Nadu, India (2000-2002) and FAO/DAE/UNDP Integrated Horticulture and Nutrition Development Project, Bangladesh (2000-2006)].

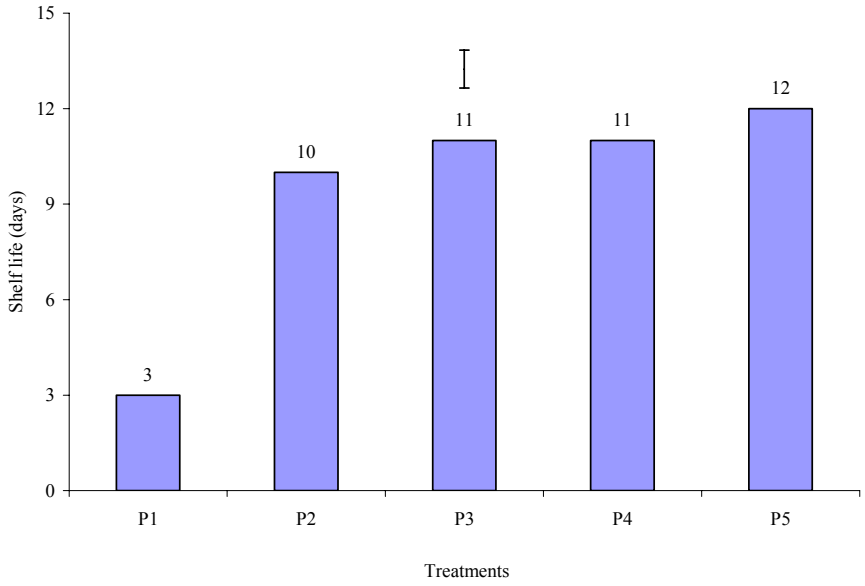

Fig 11.1 Main effect of MAP on shelf life of okra. The vertical bar represents LSD at the 5% level of significance. P_1: Okra pods kept unwrapped (control), P_2: Okra pods wrapped in perforated LDPE plastic bag (4 perforations), P_3: Okra pods wrapped in non-perforated LDPE plastic bag, P_4: Okra pods held in earthen cooling pot, and P_5: Okra pods held in plastic box.

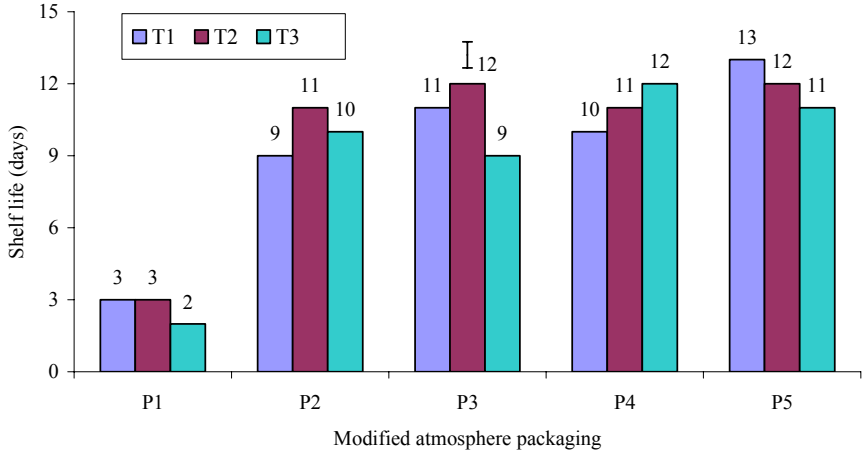

Fig 11.2 Combined effects of low temperature and modified atmosphere storage on shelf life of okra. The vertical bar represents LSD at the 5% level of significance. P_1: Okra pods kept unwrapped (control), P_2: Okra pods wrapped in perforated LDPE plastic bag, P_3: Okra pods wrapped in non-perforated LDPE plastic bag, P_4: Okra pods held in earthen cooling pot, P_5: Okra pods held in plastic box.

Use of chemical fungicides

Chemicals are extensively used in the pre- and postharvest operations of fruits and vegetables. Ogawa and Manji (1984) provided a list of about 30 chemicals registered in the USA for controlling postharvest decay of fruits, including benomyl, calcium hypochlorite, captan, imazalil, and sulphur-dioxide. In Australia, the currently-registered fungicides for postharvest treatment of mango include carbedazim and prochloraz to

control anthracnose (Ledger 2004). The systemic fungicide Amistar® has been recently included to control anthracnose in the field. Amistar® is a synthetic analogue of a naturally-occurring fungal metabolite (strobilurin) found in wild mushroom (*Strobilurus tenacellus*). This fungicide has been reported to be quite safe and regarded as 'environmentally benign' (Willingham 2001). However, the residues of Amistar® (azoxystrobin) was found highly persistent, and preharvest application of Amistar® greatly contributed to the reduction of postharvest anthracnose severity (Hassan 2006). In Bangladesh, so far, no fungicides have been registered for postharvest use. Any postharvest application of fungicides requires thorough research and government permission prior to introduction into the existing system of Bangladesh.

Varietal resistance

Use of resistant varieties and exploitation of natural resistance to postharvest spoilage would be alternatives to chemicals. Despite the beneficial role of chemical fungicides in reducing spoilage, the general public has become more concerned with chemical residues in their food, and scientists are aware of fungicide resistance in target pathogens. Consumers are reluctant to buy chemically-treated fruits because of perceived harmful effects of the chemical residues on health. The future viability of the postharvest use of pesticides is highly uncertain as many of the fungicides have already been banned or withdrawn from different countries of the world. Therefore, use of tolerant varieties would be a viable option. Although similar findings are not available in Bangladesh but such disease management options need to be exhaustively examined. A mango called 'Keitt' was reported to be tolerant to postharvest anthracnose (Hassan *et al.* 2007; and Hassan *et al.* 2009). The levels of tolerance of some mango varieties are summarized in Table 12.2.

Table 11.2 Levels of resistance of mango varieties to anthracnose disease

Levels of resistance	Variety	Reference
Resistant	Keitt	Droby *et al*. (1986); Hassan *et al*. (2007)
Moderately resistant	Kensington Pride	Peterson (1986); Hassan *et al*. (2007).
Susceptible	Nam Doc Mai	Dinh *et al*. (2003); Hassan *et al*. (2007)
Highly susceptible	Kent	Kernot *et al*. (1999); Bally (2003)

Biotechnological approaches to improve postharvest life

Biotechnology is emerging as a powerful tool to address many of the postharvest problems in horticulture. Several biotechnological approaches have been implemented on model crops like tomato, especially in the delay of ripening. Since ethylene is one of the major factors contributing to the spoilage of fruits, considerable efforts have been directed towards the inhibition of ethylene action. Genes that encode ACC synthase (a key enzyme in the biosynthesis of ethylene) and ETR-1 (ethylene binding site), can be used to modify the biosynthesis of ethylene in plants (Kader 2002). This technology has been found successful in tomato with regards to the extension of shelf-life (Kader 2002). Molecular modification could be applied to fruits and vegetables to reduce or inhibit ethylene biosynthesis and thereby extend shelf life of commodities.

11.3 Important points to be considered for storage of perishables

- Produce to be stored should be harvested at proper stage of maturity.
- Recommended temperature and relative humidity should be maintained.
- Root, tuber and bulb crops should be cured at high temperature and high humidity.
- The storage room should not be overloaded.
- Adequate ventilation in storage rooms should be ensured.
- The storage room should always be kept clean.
- Onions and garlic should not be stored at high humidity environments.
- Potatoes should be stored in dark room to avoid solanine production.
- Ethylene sensitive commodities should not be held with ethylene liberating ones.
- Produce should regularly be inspected to sort out damaged produce.

Chapter 12

Fruit ripening and safety standard

Food safety is presently a global concern. The present food safety issues are mainly concerned with food-borne illness, safe use of pesticides and ripening chemicals, and detection and assessment of food adulteration. Research and development of practical testing kits to identify chemicals, pesticides, additives, preservatives and toxic elements at the production, processing, distribution and consumption levels is essential. Currently, in Bangladesh, there is public outcry regarding the indiscriminate use of chemicals in fruits and vegetables production system. To go along with the increasingly important food safety requirements for high-value products, investments are needed in laboratory and testing infrastructure to make them compatible with international standards. This will require modern equipment, skilled manpower, and enforcement of HACCP (Hazard Analysis and Critical Control Points) in order to control food contamination during the entire supply chain. This is also suggested by the Plan of Action of the National Food Policy (2008-2015) of the Government of Bangladesh, where food safety and quality issues have been given due importance (NFP 2008).

Quality control is also very important in both domestic and international trades. Care must be taken to maintain the quality of foods at all levels of marketing (assembling, cleaning, sorting, processing and packaging). Capacity strengthening of grades and standards of food products, investment in packing and packaging, storage, and develop and enforce appropriate regulatory mechanism to control indiscriminate use of harmful additives, preservatives and toxic elements in production and in the marketing chain of food stuff are required (NFP 2006). As high-value product value chain is more demanding in food safety and quality standards, greater attention is required for certification and quality enforcement.

Bangladesh is facing a typical problem of using synthetic chemicals in accelerating ripening of climacteric fruits like mango, banana, papaya, tomato and jackfruit. Some non-climacteric fruit like pineapple are also being exposed to ripening chemicals. For commercial agriculture, accelerated fruit ripening is recommended all over the world for uniform ripening, taste and quality. In the developed country, ethylene gas is used to accelerate ripening of climacteric fruits. This is healthy, and it does not pose any threat to human health. By contrast, in Bangladesh, different types of liquid plant growth regulators containing ethephon as active ingredient are sprayed on the fruits or the fruits are dipped into the solution of ripening chemicals. Although there are opinions in favour of using the chemicals (Islam 2008), vast majority of the people of the country are opposing to the use of ripening chemicals (Shajal 2008). Accordingly, the Government of Bangladesh have imposed ban on using calcium carbide as ripening agent. The law enforcing agencies of Bangladesh are also in regular vigilance to nab and fine the peoples who are involved in such kinds of activities. At the same time, they are destroying hundreds of thousands of fruits that were subjected to chemical spray (Anon. 2009; Anon.2009a; Anon. 2010a; Anon. 2010b). Considering the forgoing problem, the present section describes the results of an extensive survey which attempted to collect information on the present status of using fruit ripening activities in Bangladesh.

12.1 Methods of fruit ripening

Both conventional and chemical ripening methods are used in Bangladesh. Synthetic chemicals are especially used for large scale and commercial fruit ripening. Immature and premature fruits are the main targets for enhanced ripening to obtain early price.

12.1.1 Conventional methods of fruit ripening

Conventional methods of fruit ripening include: (i) Application of heat (Banana and papaya; Plate 12.1), (ii) Polyethylene covering and application of heat by lighting candles (Banana), (iii) Fruit piercing through enlarged fleshy peduncle (Jackfruit; Plate 12.5), (iv) Home fruit ripening by incorporating high concentration ethylene-liberating fruits like banana and apples in enclosed container of climacteric fruits (mango, banana and papaya) to be ripened.

Plate 12.1 Heat chamber is used for accelerated banana ripening (Karwan Bazar, Dhaka).

12.1.2 Chemical methods of fruit ripening

Usually, ethylene (CH_2=CH_2), a natural gaseous hormone, is used for fruit ripening. Application of ethylene gas at recommended concentration is the worldwide-used method for large-scale and commercial fruit ripening. Application of ethylene gas at a concentration of 0.1-1.0 μL/L for 24 h is sufficient to hasten full ripening of climacteric fruits (Wills *et al.* 2004).

12.1.3 Fruit-ripening chemicals in Bangladesh

In Bangladesh, plant growth regulators and calcium carbide (banned) are used in fruit ripening. Different types of synthetic formulations (Ripen-15, Harvest, Profit and Promote) containing ethephon (2-chloroethylphosphonic acid) as active ingredient are available in the market (Plate 12.2). Ethephon penetrates into the fruit and decomposes to ethylene, which accelerates ripening.

Plate 12.2 Ripening chemical called 'Promote' is on sale in retail shop (Bogra).

12.1.4 Chemical properties of active ingredients of ripening agents

1. Active ingredient: Ethephon

Other names: **Chlorethephon**

Chemical name: 2-Chloroethylphosphonic Acid

Potential health hazard (MSDS, Material Safety Data Sheet)

- Eye irritation
- Skin irritation
- Ingestion: Gastrointestinal irritation with nausea, vomiting and diarrhea, cardiac disturbances, central nervous system depression
- Inhalation: cardiac abnormalities, high concentration causes CNS depression
- Toxicological information: Oral, rat: LD_{50} = 3400 mg/kg

2. Calcium carbide: Properties and mode of action

Calcium carbide produces acetylene gas after absorbing moisture. Acetylene is an analogue of ethylene, the ripening hormone. Calcium carbide poses dangers of explosion and carries toxic materials to the consumers.

$$CaC_2 + H_2O > CaCO_3 + CH{\equiv}CH$$
(Acetylene)

Chemical name

- Acetylenogen/Calcium acetylide

Physical properties

- Grey-brown solid (rock-like) with garlic odour

Potential health hazard (MSDS, Material Safety Data Sheet):

- Swallowed: Gastrointestinal tract burns
- Eye: Severe eye burns, blindness
- Skin: Irritation and skin burns
- Inhaled: Severe irritation of the respiratory tract and possible burns
- Toxicological information: LD_{50}: Not available

More detailed information on the presently-used fruit ripening chemicals in Bangladesh is also furnished in Appendices I, II.

12.2 Status of the use of accelerated fruit ripening in Bangladesh

12.2.1 Banana

Climacteric fruits like bananas are subjected to chemical treatments for uniform ripening. Growers adopt different methods to accelerate banana ripening, and they mostly follow conventional methods of ripening. The 'Bepari' and wholesalers in the banana supply chain are mostly involved in artificial fruit ripening. All 'Bepari' are involved in banana ripening either by using conventional or chemical methods. The conventional ripening methods include application of heat and piling of fruits followed by covering with polyethylene sheet. With regard to chemical use, the maximum 'Bepari' use Harvest to accelerate banana ripening (Appendix I, Plate 12.3). Other ripening chemicals include Profit, Tomtom, Ripen 15, and Harvest (Appendix I, II). In a survey, Hassan (2010) observed that 60-70% of the wholesalers were involved in accelerated banana ripening. Among them, 36% were engaged in chemical fruit ripening, and among the chemicals, Harvest was the mostly used followed by Ripen-15 and Tomtom. The present findings are in support of those of Bhuiyan *et al*. (2009) who reported that three-fourth of the banana wholesalers were involved in the use of different types of ripening agents. In contrast with Bhuiyan *et al*. (2009), Hassan (2010) did not find any use of calcium carbide and formalin in banana ripening and preservation, respectively. Most strikingly, the immature and premature bananas are mainly sprayed with chemical ripening agents (Plate 12.3).

Plate 12.3 Immature banana ripening in the assemble market of Madhupur, Tangail.

12.2.2 Mango

Hassan (2010) reported that 4-16% of the growers were involved in ripening of mango using chemicals. Calcium carbide was used by 4-20% mango growers followed by Ripen-15 (0-12%). Results also showed that 4-32% growers used straw for enhancing ripening, and they (60-92%) mainly sold unripe mature-hard mangoes. It was found that 8-20% of the 'Bepari' was involved in chemical fruit ripening (Plate 13.4), whereas the value was 6-8% in case of the wholesalers.

Plate 12.4 Mango fruits spread on the floor and ready to receive chemical spray for accelerated ripening (A) and mango fruits were subjected to chemical spray for accelerated ripening (B) (mango assemble market of Kansat, Shibgobj, Chapai Nowabgonj).

12.2.3 Jackfruit

In the case of jackfruit, both conventional and chemical ripening methods are used. Conventional methods include piling of fruits and covering with thick polyethylene sheet (Plate 12.5). Another method is fruit piercing using iron stick through the large fleshy peduncle (Plate 12.6). These methods are harmless if no additional chemicals are applied. In terms of chemical ripening, Ripen-15 is mainly sprayed over jackfruits, especially by the 'Bepari' and wholesalers. Sometimes, chemicals are sprayed after piercing the fruit through the fleshy peduncle. As a result, the chemicals directly penetrate into the fruit that ripen at a faster rate but pose great danger of leaving chemical residues higher than maximum residue levels (MRLs) and ultimately affect consumers' health.

Plate 12.5 Jackfruits that received chemical spray were covered by polyethylene sheet and leaves to raise temperature and accelerate ripening.

Plate 12.6 Jackfruit piercer gets 25 paisa per fruit pierced. Everyday 2000 jackfruits are pierced by each piercer (Bhaluka, Mymensingh).

Sometimes jackfruits are sprayed with ripening chemicals followed by covering with thick polyethylene sheet and leaves (Plate 12.6). The shelf life of the chemically-ripened jackfruits is very short due to faster rate of rot as compared to those fruits ripened following conventional methods. As a consequence, postharvest loss of jackfruit in the marketing channel has been found to be very high.

13.2.4 Pineapple

Pineapple is one of the very important fruits of Bangladesh, and the production is mainly concentrated in Tangail, Chittagong Hill Tracts and Sylhet. Pineapple is a non-climacteric fruits (Wills *et al.* 2004), and should be harvested when the fruits are fully mature and ripe in the plants for proper taste, flavour and quality. Strangely, a number of plant growth

regulators are currently being used by the pineapple growers for accelerated ripening while the fruits are still attached with the plants (Plate 12.7). They generally sell the immature or premature fruits to catch the early market and obtain more profit. Hassan (2010) in a survey found that only the growers were involved in the use of ripening chemicals for pineapple, and this finding contrasts those of other fruits like mango, banana, jackfruit, papaya and tomato. It was observed that 80-90% of the growers were involved in spraying ripening chemical called Ripen-15. The actual figure may be more since many of the growers do not reveal the actual practice owing to fear of police harassment and related problems. The recommended dose of use as per the company suggestion is 10 mL/16 L of water, but in many cases they use 50 mL/water (i.e. full bottle in 16 L water).

The ripening chemical has two-fold negative effects on pineapple fruit quality in particular. Firstly, pineapple is non-climacteric fruit, and ripening rate (rates of respiration and ethylene production) remains mostly unchanged even though ripening agents are exogenously sprayed on the fruits. The chemicals only contribute to change in the fruit peel colour from green to yellow resembling complete fruit ripening, since the active ingredient, ethephon, is a degreening agent and has senescence properties. Secondly, the consumers are deprived from obtaining the optimum taste, quality and flavour of this delicious fruit. Many of the growers admitted that these chemicals are harmful and should not be used. They also mentioned that these fruits lack taste and flavour, and the consumers purchase fruit once would not purchase pineapple again. Interestingly, the growers themselves do not consume the fruits that were subjected to chemical spray. The growers, and other stakeholders of the pineapple supply chain also speculated that the heritage of pineapple in Tangail would be irreversibly lost if measures are not taken immediately.

Plate 12.7 Immature pineapple being sprayed for degreening (Madhupur, Tangail).

12.2.5 Papaya

For papaya ripening, heating is used by the wholesalers (Plate 12.8). No chemicals were found to apply to accelerate fruit ripening.

Plate 12.8 Papaya fruit ripening using traditional method of piling paper-wrapped fruits (A) followed by placing heat source (B) and covered by thick polyethylene sheet (Sham Bazar, Dhaka).

12.2.5 Tomato

Use of ethylene gas is a recommended practice worldwide for uniform ripening, especially for commercial purposes. Tomatoes are generally harvested at mature-green or breaker or turning pink stage and exposed to ethylene. The fruits are uniformly ripened and quality is not affected. However, the practice of using ripening agent in Bangladesh is different. Here the fruits are harvested at immature conditions at the same time and held in the growers' house where the fruits receive chemical spray. The fruits ripen with beautiful red colour, but the actual taste, flavour and quality are lacking due to the premature harvesting (Plate 12.9). The advantage from the intermediaries' perspective is that the labour cost is minimized due to the same time harvest of all fruits, ripe fruits remain firm for quite a long period of time, and the loss is minimal. Unfortunately, these benefits are at the cost of quality and consumers' satisfaction.

The study found that, the 'Bepari' of Bogra used more chemicals than those in Jessore. In Bogra, 20% of the 'Bepari' was found to use ripening chemicals. Again the value would be much more since some 'Bepari' are scared of telling the truth. The 'Bepari' also mentioned that tomatoes harvested at right stage of maturity do not require chemical spray for ripening. Fruits harvested at immature stage require chemicals. This is again a sub-optimal and poor postharvest practice, and intervention is urgent to stop the immature fruit harvesting. Immature harvest also contributes to lower bioavailability of lycopene, an important anticancer micronutrient found in tomato. Nevertheless, some good postharvest practices are also adopted by our growers. For example, the growers of summer tomato in Jessore have strong and collective commitment not to use any harmful and illegal ripening agents in their products. Summer tomatoes are harvested at turning pink stage and not ripened by chemicals.

Plate 12.9 Immature tomato ripening in Bogra. Fruits, ripened chemically, are simply recognized by observing uniform and bright red peel colour development.

Form the above discussion, it can be inferred that use of ripening agent is absolutely required for horticultural produce marketing in commercial purposes. Uniformity in fruit colour, taste and flavour is prerequisite for commercial purpose. However, we must be careful not to misuse the technology. So far, the government of Bangladesh has not given registration to any chemicals for absolute use for fruit ripening purposes. Some of the chemicals, for example ethephon, might have been given registration for early flowering or other purposes. But these chemicals are being misused. Therefore, the government should take appropriate initiatives to introduce ethylene-induced ripening technology, optimize to the local socio-economic conditions and extend it to the relevant stakeholders. This would help to safeguard and prevent exposure to hazardous chemicals and enable consumers to enjoy the real taste and flavour of the delicious local fruits.

12.3 Recommended fruit ripening methods

Accelerated fruit ripening is an integral part of the today's commercial horticulture. Ripening chamber should be constructed in which ethylene gas of desired concentration would be inserted at recommended rate depending on fruit type. Ethylene, applied at a concentration of 0.1-1.0 μL/L for 24 h is normally sufficient to hasten full ripening of climacteric fruits (Wills *et al*. 2004). This is healthy and recommended method. This technology is urgently required in Bangladesh since people are seriously scared of consuming chemically-treated fruits. Some recommended and safe fruit ripening methods are described in the following:

13.2.1 Ripening chamber

This is commercial ripening technology. Ripening chamber is constructed and ethylene gas is applied inside the ripening room. The recommended doses of ethylene gas for fruit ripening or degreening are summarized in Table 12.1.

Table 12.1 Recommended doses of ethylene with exposure time and ripening temperatures (Kitinoja and Kader 2003)

Commodity	Ethylene concentration (ppm)	Exposure time (h)	Ripening temperature (^{o}C)
Mango	100-150	12-24	20-22
Banana	100-150	24	15-18
Orange (degreening)	1-10	24-72	20-22
Tomato	100-150	24-48	20-25

12.3.2 Ripening bins/cartons

For small-scale wholesalers and retailers, fruits can be ripened in bins or cartons by placing a small quantity of ethylene-generating produce such as ripe banana or any other high ethylene-generating products.

12.3.3 Ripening bowls/bags

For safe and home fruit ripening, high ethylene-liberating fruit such as apple or banana is placed in a transparent ripening bowl containing the climacteric fruits (mango, banana, tomato, etc.) to be ripened. There should have some ventilation holes at the top. It would take only 1-4 days for complete ripening. Home fruit ripening is also possible using very cheap and low cost technology such as by placing pieces of ripe fruits into paper bags containing the climacteric fruits to be ripened.

Chapter 13

Consumers' perception on quality and safety in fruits and vegetables consumption

Consumers are the end users of the fruits and vegetables carried through a number of handling steps. The perception of the consumers is important in considering the introduction of improved interventions in the present marketing systems. The present section describes the results of an extensive consumers' survey in relation to their awareness regarding produce quality and safety. The study also investigates the degree of willingness of the consumers to pay more if they want high quality and safe produce.

Results revealed that 84% of the consumers of both Dhaka and Mymensingh regions are conscious about the deleterious effects of chemicals on human health. Hundred percent of the consumers were interested in purchasing safe fruits and vegetables (Table 13.1). Only 56-64% of the consumers were willing to pay more for obtaining safe and chemical-free fruits and vegetables. Results also revealed that 64.8 and 33.8% of the consumers possessed refrigerator to store fruits and vegetables in surveyed areas of Dhaka and Mymensingh, respectively (Table 13.1).

Table 13.1 Consumers' perception on marketing and quality of fruits and vegetables

Consumers' perception on:	% of respondents	
	Dhaka (N=500)	Mymensingh (N=500)
Awareness about chemical hazards	84.4	83.8
Have knowledge on names of chemicals	83.8	96.2
Interested to buy safe produce	100	500
Ready to pay more for safe produce	75.4	63.6
Methods of storage (refrigerator)	64.8	33.8

It was noticed that considerable proportion of the consumers knew the names of some chemicals used to fruits and vegetables for long-term preservation and forced ripening. It was observed that 58.8 and 26.4% of the consumers knew about calcium carbide in Dhaka and Mymensingh, respectively (Table 13.2). Quite significant percentage of consumers also knew the name of formalin (Table 13.2).

Table 13.2 Consumers' knowledge on the specific names of chemicals used to fruits and vegetables

Knowledge on specific names of chemicals	% of respondents	
	Dhaka (N=500)	Mymensingh (N=500)
Formalin	32.6	35.4
Calcium carbide	58.8	26.4
Ethylene	16.8	12

The consumers had good knowledge on the specific use of chemicals. According to 62-65% and 62-78% of the consumers, chemicals are particularly used for preservation and ripening purposes (Fig 13.1). These results suggest that the consumers are gaining

awareness gradually in relation to the importance of quality and safety in fruits and vegetables consumption.

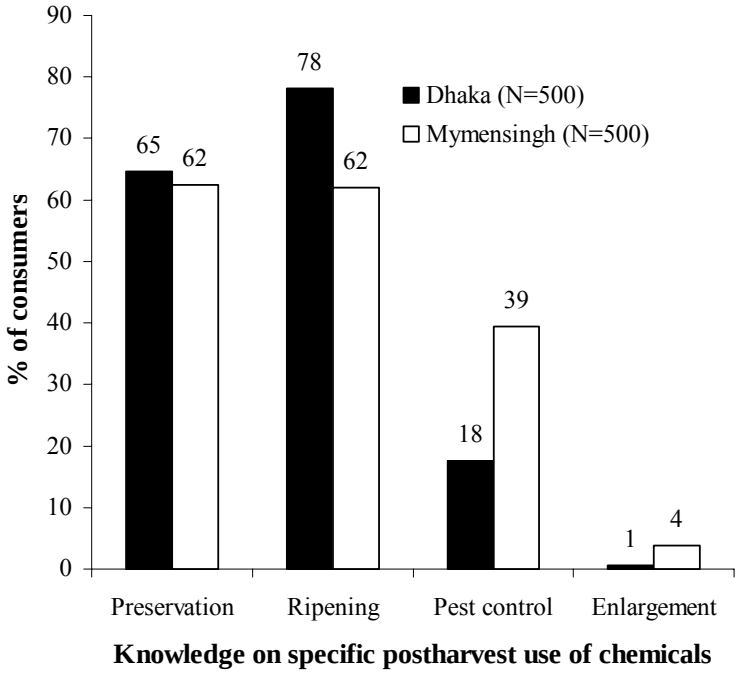

Fig 13.1 Consumers' knowledge on the specific use of chemicals in the harvested fruits and vegetables.

The consumers are aware about the harmful effects of postharvest chemical use, and they suggested that government monitoring and building public awareness would greatly resolve the problem (Table 13.3).

Table 13.3 Consumers' suggestion to reduce/stop the use of harmful chemicals to the harvested fruits and vegetables

Suggestions to improve the situation	% of respondents	
	Dhaka (N=500)	Mymensingh (N=500)
Government monitoring	79.2	79.8
Awareness building	62.0	64.4
Strengthening local market management	22.8	20.2

Furthermore, the consumers were found ready to pay up to 20% more (6 and 15% of the consumers in Mymensingh and Dhaka, respectively) as compared to the usual payment for the safe fruits and vegetables. However, they refused to pay more than 20% for safe food (Fig 13.2). A considerable proportion of the consumers (34 and 37% in Dhaka and Mymensingh, respectively) were found willing to pay 10% more for safe food.

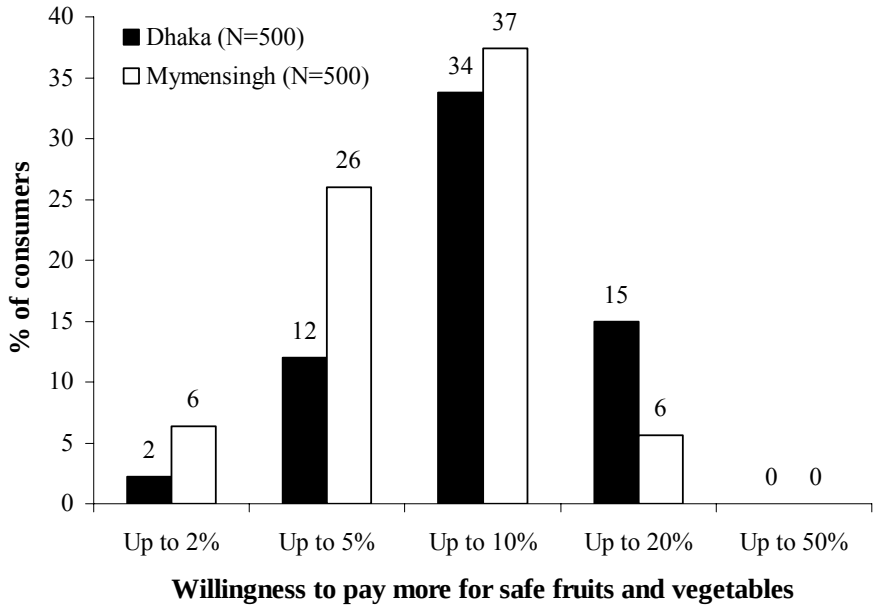

Fig 13.2 Consumers' willingness to pay more for purchasing safe fruits and vegetables.

The results would have important implications in making decision with regards to the marketing of quality and safe produce. As majority of consumers want to pay up to 10% for safe food, a programme of safe food production involving 10% more cost would be effective.

Chapter 14

Nutrient composition of fruits and vegetables

The number of people in the world suffering from hunger and poverty has risen to more than one billion (IFPRI 2010), and in Bangladesh the situation needs no elaboration. The food security status of Bangladesh is very fragile despite some progress that has been made with reference to grain production. For instance, the food security index has improved in Bangladesh and moved from 'extremely alarming' to an 'alarming' level of hunger from 1990 to 2010 (IFPRI, 2010). However, the levels of child stunting, underweight, wasting and childhood anemia, and maternal energy deficiency and anemia are very high in Bangladesh (BDHS 2009). The importance of better quality and high-value horticultural commodities like fruits and vegetables in the food consumption basket needs to be increased. The role of horticulture is extremely important for improving food and nutritional security in Bangladesh. The field of horticulture is also a major source of employment and livelihoods of the people of Bangladesh.

Presently, food security is the most important concern in Bangladesh. The food security situation was very critical due the recent natural disasters, AILA and SIDR, when the Government of Bangladesh faced problems to purchase foods despite having money. Furthermore, a significant proportion of Bangladeshi population is food insecure due to poor diet quality. The diet is heavily dependent on rice and most of the energy in the diet is contributed by cereals. Hence, there is high prevalence of micronutrient deficiency in the country. Conceptually, the solution lies in the increased consumption of high quality micronutrient-rich foods such as fruits and vegetables. The food consumption patterns in Bangladesh have very little diversity. Rice accounted for 71% of total calorie consumption in 1995-96 as compared to that of 68% in 2005 (Yusuf *et al.* 2009). Consequently, even though rice is a poor source of protein but it constitutes about half of total protein consumption in Bangladesh diet.

14.1 Micronutrient malnutrition situation in Bangladesh

Malnutrition that includes macro and micronutrient deficiencies is the major concern in addition to dietary excesses among the emerging affluent section of the population in Bangladesh. Forty three percent of the children under the age of five years are stunted due to chronic malnutrition, 17% are wasted due to acute malnutrition and 41% are underweight. Among the rural women of reproductive age, 33% have critical food insecurity with a BMI of less than 18.5. By contrast, the prevalence of overweight (12.5%) with BMI 25 or higher among women has increased by 10% between 2004 and 2007 indicating the existence of double burden of malnutrition in Bangladesh (BDHS 2009; Yusuf *et al*. 2009). The present consumption and demand for food of the people of Bangladesh are furnished in Appendix III.

14.2 Options to reduce micronutrient deficiency

Fruits and vegetables are highly valued in the human diet mainly for vitamins and minerals. However, the present consumption rate of fruits and vegetables in Bangladesh is 126 g/day/capita, which is far below the minimum average requirement of 400 g/day/capita (FAO/WHO 2003). So, higher intake of micronutrient-rich and safe fruits and vegetbales can greatly improve the severe micronutrient deficiency in Bangladesh.

The government of Bangladesh has been promoting food-based stratregies through the agriculture and related sectors to enhance production and consumption of micronutrient-rich foods as a sustainable means to address micronutriernt malnutrition in the country (Bhattacherjee *et al*. 2007).

14.3 Composition and loss of nutrients in fruits and vegetables

Nutrient composition of fruits and vegetables vary with preharvest production conditions, stages of maturity at harvest, duration after harvest, variety, storage conditions and methods of preparations and cooking. Therefore, to prepare national food composition table, the above factors need to be considered. The present study investigated the pattern of changes and degradation of important micronutrients including vitamin C, β-carotene and lycopene.

14.3.1 Vitamin C

Vitamin C (L-ascorbic acid) is essential for collagen formation. It helps maintain the integrity of connective tissue, bone and dentin. Vitamin C increases the body's absorption of calcium (essential minerals for strong bones and teeth) and iron from other foods. It is worth mentioning that low iron intake can lead to anemia, a serious nutrition-related disorder affecting about 2 billion people worldwide (Nandi and Bhattercherjee 2005). Severe vitamin C deficiency results in scurvy, which is characterised by haemorrhages and abnormal bone and teeth formation. Vitamin C is an important antioxidant that can protect cells from cancer causing agents (Nandi and Bhattacherjee 2005). The incidence of vitamin C deficiency peaks in children aged 6-12 months who are fed a diet deficient in citrus fruits or vegetables. Incidence also peaks in the elderly. Vitamin C is found in a wide variety of fruit and vegetables (Appendix IV). Good sources of vitamin C include citrus, litchi, mango, pineapple, tomatoes, cauliflower and okra. The pattern of changes or the loss of vitamin C as determined by visual titration method (Plummer 1971) in important fruits and vegetables are described below.

14.3.1.1 Loss of vitamin C in litchi

Vitamin C content in litchi fruit shrpaly declined with the progress of storage duration after harvest (Fig 14.1). The freshly harvested China 3 litchi contained 48 mg/100 g vitamin C, which sharply declined to 31 mg/100 g at 96 h after harvest. Results also showed that vitamin C contents of China 3 and Bombai varieties of litchi were reduced by 18 and 21% at 96 h after harvest, respectively (Table 14.1). Similar pattern of vitamin C loss was also observed in the variety Bombai. Vitamin C contents of 31 and 49 mg/100 g were reported by Maity and Mitra (2001) and Darnton-Hill *et al*. (1988), respectively. However, none of the reports clearly mentioned the name of the variety used and the stage of maturity at which the fruit were harvested, and which we found very important in explicitely determining the nutrient composition of any fruits or vegetables. Otherwise, the values would very often be misleading.

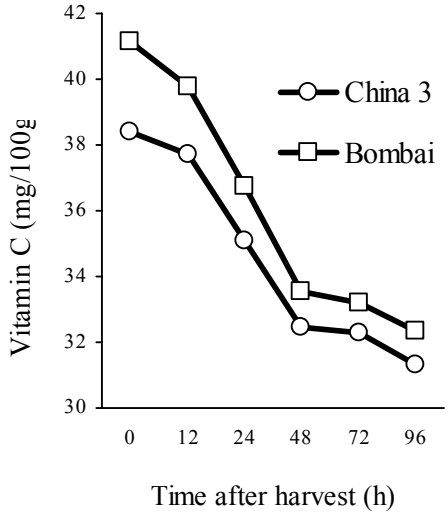

Fig 14.1 Loss of vitamin C in litchi fruit with the progress of storage duration.

Table 14.1 Degree of vitamin C loss in litchi fruits over time

Variety	Loss of Vitamin C (%)		
	Time (hours after harvest)		
	12	48	96
China 3	9	16	18
Bombai	11	18	21

14.3.1.2 Loss of vitamin C in mango

Vitamin C content in the pulp of Fazli variety of mango sharply declined from 51.48 mg/100g at farm fresh (mature-hard) level to 17 mg/100g at 8 days after harvest (Fig 14.2). However, for Bombai variety the values were 36.4 and 17.0 mg/100 g, respectively. The magnitude of loss of vitamin C in Fazli and Langra varieties were 39 and 46%, respectively (Table 14.3). Levels of vitamin C in mango were also reported by several authors as 6.8-38.8 mg/100 g (Majumder *et al*. 2001); 16 mg/100g (Gopalan *et al.* 1981) and 41 mg/100 g (Darnton-Hill *et al.* 1988), and those reports are in agreement with the findings of the present study.

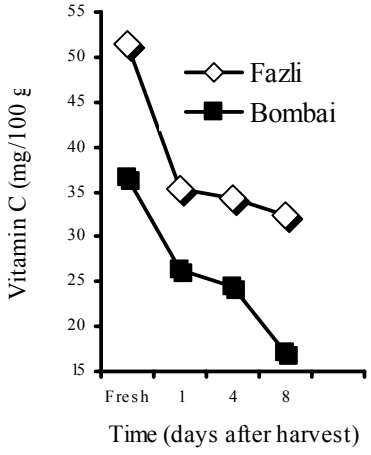

Fig 14.2 Loss of vitamin C in mango fruit with the progress of storage duration.

Table 14.2 Degree of loss of vitamin C in mango over time

Variety	Loss of Vitamin C (%)		
	Time (days after storage)		
	1	4	12
Fazli	32	34	39
Bombai	28	33	46

14.3.1.3 Loss of vitamin C in jackfruit

Jackfruit, the national fruit of Bangladesh, contains lower amount of vitamin C as compared to those in litchi and mango (Fig 14.3A). Vitamin C contents of jackfruit pulps of mature hard, eating ripe and overripe stages were 5.2, 4.8 and 4.0 mg/100 g, respectively indicating a gradual decrease in vitamin C content with the progress of ripening (Fig 14.3A). Gopalan *et al*. (1981) also reported that jackfruit is relatively poor source of vitamin C (7 mg/100 g). However, Darnton-Hill *et al*. (1988) reported that jackfruit contained 21 mg/100 g vitamin C. So, there are variations in vitamin C content as reported by different authors. Therefore, a comprehensive and updated nutrient composition table for the fruits and vegetables of Bangladesh is a need of the time.

15.3.1.4 Loss of vitamin C in tomato

Tomato was observed to be a moderate source of vitamin C. An experiment was carried out to investigate the levels of vitamin C contents of tomato under different storage conditions, namely control, low temperature (10 and 15^{o}C), hot water treatment, earthen cooling pot and plastic wrap. Irrespective of storage treatments, vitamin C contents declined with duration of storage. It was observed that the vitamin C contents of tomato declined from 25.29 mg/100 g in farm fresh sample to 12.16 mg/100 at day 8, manifesting a total of 51.91% loss of vitamin C (Fig 14.3B).

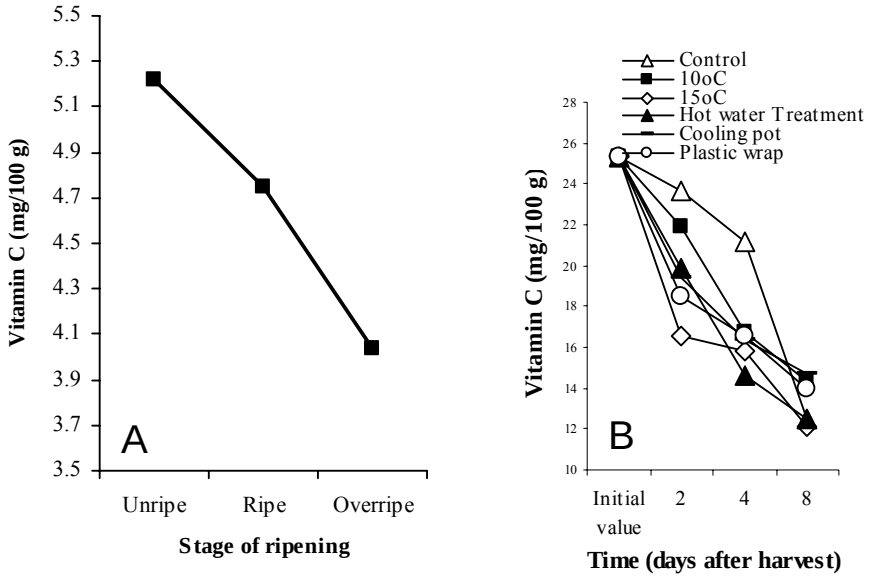

Fig 14.3 Loss of vitamin C in jackfruit (A) and tomatoes (B) during storage and ripening.

14.3.1.5 Vitamin C loss in okra

Vitamin C content of okra pods declined with time after harvest. Vitamin C content was always found to be higher in okra pods that were held at lower storage temperatures (10 and 15^{o}C) than those held at ambient conditions (Fig 14.4A). For example, at the 2nd day of storage, the highest level of vitamin C (17.51 mg/100 g) was found in okra pods stored at 15^{o}C temperature. Thereafter, it starts declining, and at day 3, it was 12.43 mg/100 g at the same storage temperature. Modified atmosphere storage also influenced vitamin C content of okra pods (Fig 14.4B). At the 2nd day of storage, the highest vitamin C (14.64 mg/100 g) was found in okra pods which were held in earthen cooling pot (Fig 14.4B). Vitamin C contents of okra pods were reported to be 10 and 13 mg/100 g (Darnton-Hill *et al*. 1988 and Gopalan *et al*. 1981, respectively). The result actually suggests that storage in lower temperature and in earthen cooling pot help to preserve vitamin C in okra during the first two days after harvest. Relatively lower temperature inside the earthen cooling pot possibly contributed to maintain higher levels of vitamin C content, especially at the early part of storage. Magnitude of vitamin C loss of okra pods are also shown in Tables 14.3 and 14.4.

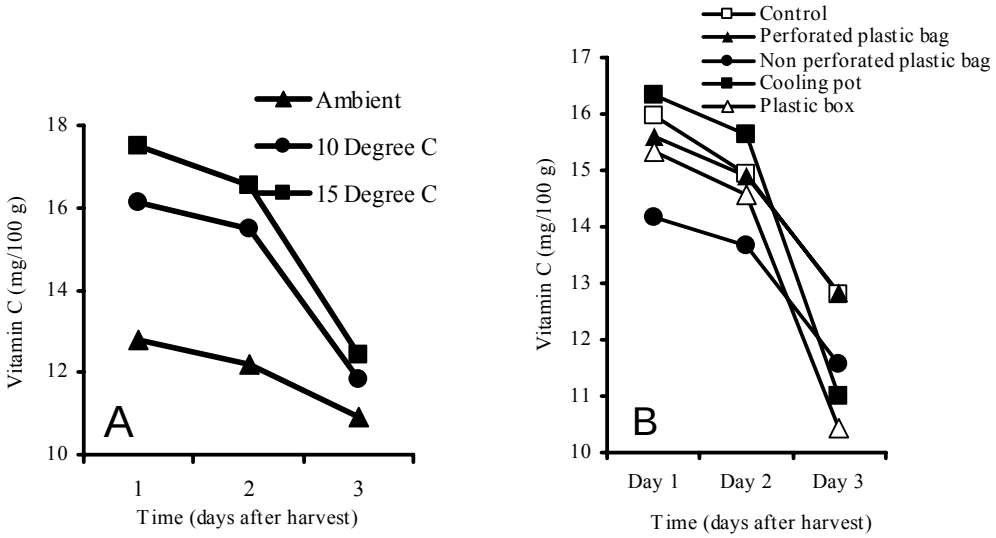

Fig 14.4 Effects of storage temperature (A) and modified atmosphere (B) on the retention of vitamin C content in okra pods.

Table 14.3 Degree of vitamin C loss in okra pods with time as influenced by storage temperatures

Storage temperature	Loss of Vitamin C (%)	
	Time (days after storage)	
	2	3
Ambient	5	15
10^{o}C	4	27
15^{o}C	6	29

Table 14.4 Degree of vitamin C loss in okra pods with time as influenced by modified atmosphere storage

Modified atmosphere storage	Loss of Vitamin C (%)	
	Time (days after storage)	
	2	3
Control	7	20
Plastic bag (perforated)	5	18
Plastic bag (non-perforated)	4	18
Earthen cooling pot	4	33
Plastic box	5	32

14.3.1.6 Vitamin C loss in cauliflower

The results of the present study suggest that cauliflower is a rich source of vitamin C, and the freshly harvested cauliflower contains 53.69 mg/100 vitamin C. The degradation of vitamin C in cauliflower is slower unlike other fruits and vegetables reported here (Fig 14.5). In cauliflower, a trend of elevation in vitamin C content was observed in the early part of storage and subsequently start declining.

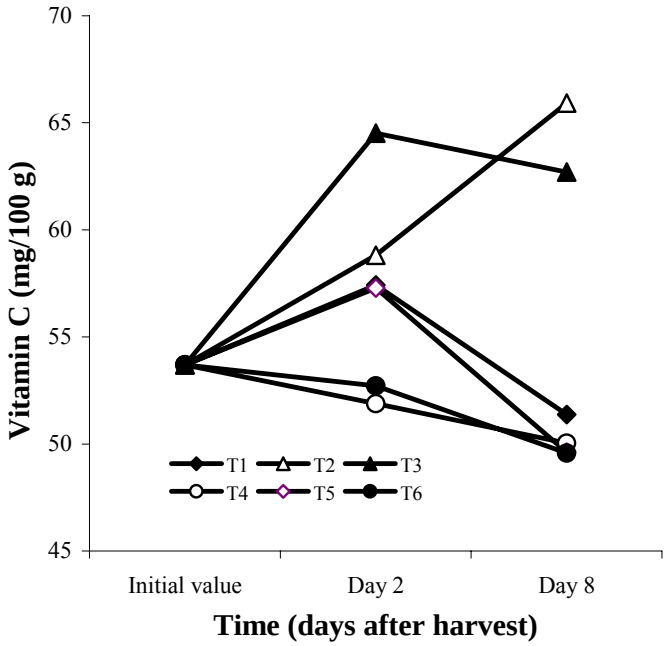

Fig 14.5 Loss of vitamin C in cauliflower under different postharvest treatments (T1: Control; T2: Storage at 10^{o}C; T3: Storage at 15^{o}C; T4: Plastic film wrap; T5: Paper wrap; and T6: Cooling at 5^{o}C for 30 min).

14.3.2 β-carotene

Fruits and vegetables are also rich sources of β carotene, the precursor of vitamin A. Vitamin A is a vital part of balance diet, and it maintains eye health and body's immunity to infectious diseases (Nandi and Bhattacharjee 2005). Vitamin A deficiency (VAD) is the leading cause of blindness among children and women in the developing world. It is also associated with increased risk of morbidity and mortality. Several nutrition surveys and

focused studies during the last four decades indicate that though the situation has improved, VAD continues to be a public health problem in Bangladesh. Prevalence of severe VAD, based on night blindness, in preschool children has decreased from 3.7% in 1982-83 to 0.2% in 2002. However, sub clinical VAD is still present in preschool children. Bitot's spots and night blindness are still problems in the school age children and non-pregnant women (HKI/IPHN 2006). Treatment options are food fortification for improving vitamin A deficiency. A variety of oily and dry forms of the retinol esters, retinyl acetates and retinyl palmitate are available for food fortification of vitamin A. Another option could be the increase of consumption of β-carotene rich fruits and vegetables. The present study investigates the levels of β carotene as determined by column chromatography (AOAC 1965) in mango and jackfruit at different stages of ripening and described below.

15.3.2.1 β carotene in mango

The present study revealed that β-carotene (precursor of vitamin A) of mango pulp vary with variety and stages of ripening (Fig 14.6A). β-carotene of mango pulp at mature-green and eating ripe conditions of the varieties Fazli and Bombai were 190.53 and 219.13 and 1086.61 and 2868.49 µg/100g, respectively, indicating that the variety Bombai contained much higher concentration of β-carotene than in variety Fazli (Fig 14.6A). Gopalan *et al*. (1981) also reported that ripe mango contained 2743 µg/100g carotene. The present results suggest that β-carotene and other major micronutrients of available fruit and vegetable cultivars at different postharvest stages should be determined in order to prepare a meaningful national food composition table.

14.3.2.2 β carotene in jackfruit

Jackfruit was found to be a moderate source of β-carotene. Considerable amount of β-carotene is also present in jackfruit, but the amount is much lower than that of mango (Fig 14.6B). Results showed that β-carotene content in jackfruit pulp of mature hard fruit was only 66.75 µg/100g, which rapidly increased to 194.92 µg/100g at eating ripe stage and then declined as the ripening advanced (Fig 14.6B). Similar value for carotene in jackfruit (174 µg/100g) was also reported by Gopalan *et al*. (1981). The agricultural practices and climate have remarkably changed over the last few decades, and hence analyses of nutrients of the available cultivars of fruits and vegetables are the need of the time.

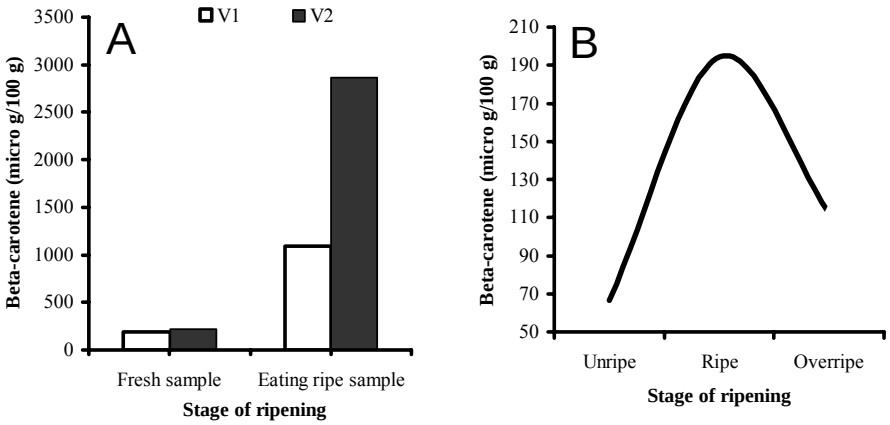

Fig 14.6 β-carotene contents of mango (A; V1: Fazli and V2: Langra) and jackfruit (B) at different stages of ripening.

14.3.3 Lycopene

Tomato is an excellent source of valuable antioxidant called lycopene (Saxelby 2002; Plate 14.1; Fig 14.7). Antioxidant is a molecule capable of slowing or preventing the oxidation of other molecules. Antioxidants terminate chain reactions by removing free radical intermediates. Lycopene is found primarily in tomato and tomato products. High intake of lycopene may play a role in reducing the risk of prostate cancer (Lister 2003). Lycopene is a part of carotenoids and is fat-soluble. Unlike vitamin C, lycopene content does not decrease during processing (Appendix V). Processing increases lycopene content due to concentration operations. Lycopene is insoluble in water and tightly bound to vegetable fiber, therefore bioavailability of lycopene is increased by processing. Lycopene in tomato paste is four times more bioavailable than in fresh tomatoes. Thus processed tomato products such as tomato juice, soup, sauce and ketchup contain higher concentrations of bioavailable lycopene.

Hassan (2010) investigated the pattern of change of lycopene in Tomato of variety BARI Hybrid 4 following the method of Sadasivam and Manickam (2004). Results of the present study suggested that lycopene content of tomato fruit increased with time. Lycopene level in tomato varied from 0.92 to 7.42 mg/100 g (Fig 14.7). Rate of lycopene conversion was observed to be slower at low temperature conditions (10^{o}C) as compared to those fruits held at higher temperature. This was attributed to the higher rate of conversion of bioavailable lycopene at higher temperature.

Although tomato is an excellent source lycopene, but unfortunately, a considerable portion of the harvested tomatoes never reach the consumers because of lack of proper postharvest handling facilities, especially low temperature storage facility in Bangladesh. During the year, 2009-2010, the loss of tomatoes was found enormous as shown earlier in Chapter 4 (Plate 4.4). Therefore, postharvest management of tomato should be strengthened, transport facilities should be improved, refrigerated vehicles should be introduced and low temperature storage facilities should be constructed to reduce damage, extend shelf life and maintain quality of tomato. At the same time, the wholesale markets and growers should be well-linked with the processing plant, so that the produce could be immediately transferred to the processing unit at the time of risk of damage. This private-public partnership would greatly save huge losses and contribute nutritional security of the people of the country. Simply, this high-value produce should not be allowed to get spoiled as very often happened in Bangladesh.

Plate 14.1 The author in hybrid tomato field visit in Jessore (A) and highly nutritious and lycopene-rich tomato fruits (B).

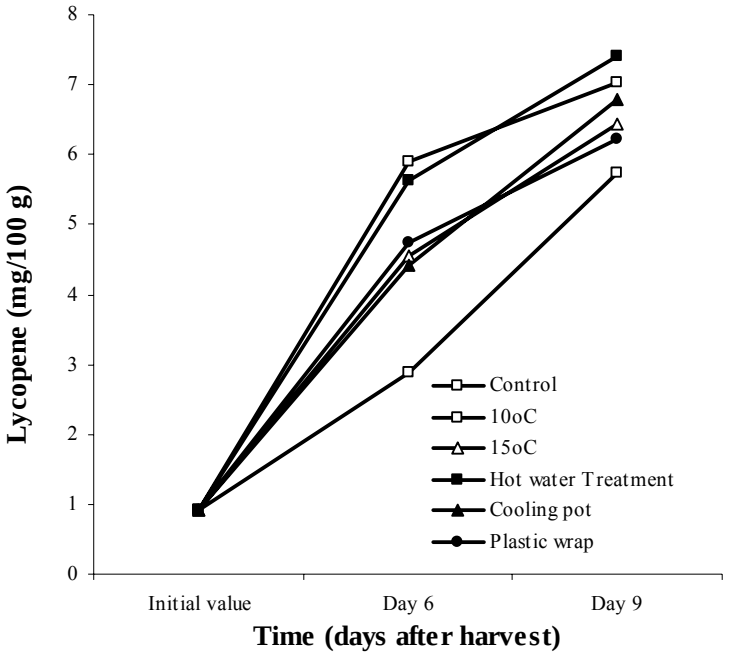

Fig 14.7 Lycopene content of tomato held at different storage conditions.

So, micronutrients including vitamins and minerals are needed for good health. Fruits and vegetables are rich sources of micronutrients including calcium, iron, β-carotene (precursor of vitamin A), vitamin C and antioxidants. Therefore, dietary diversification through fruit and vegetables consumption and nutrition education would be a sustainable approach to fight micronutrient malnutrition in Bangladesh. HKI Bangladesh has been working through its home gardening and nutrition education programmes to increase year round availability and consumption of micronutrient rich foods for the past 15 years. One of its projects, *Jibon-O-Jibika* has been emphasizing improved food production and utilization as well as improved marketing practices. There is need to enhance and upgrade the skills of the rural women and farmers in processing, marketing and help to enhance their income which may result in better use of household resources, improved caring practices and better nutrition for the household (HKI 2007). FAO in collaboration with DAE implemented a project on integrated horticulture and nutrition development which resulted in improving both the production and productivity of rural farmers and also improved their consumption of fruits and vegetables for better nutrition (Bhattacharjee *et al.* 2007). Nutrition education is of paramount importance to ensure nutritional security in the country. The degradation and pattern of changes of nutrients in fruits and vegetables need to be properly investigated to take full advantage of fruits and vegetables consumption. Fruits and vegetables require proper handling, preparation and storage to maintain nutritional quality.

Results of the present study showed that vitamin C is unstable, and it degrades sharply due to oxidation with the progress of time after harvest. So, a shorter time period between harvest and consumption would ensure vitamin C security to the people. Soaking fruits and vegetables after cutting should also be avoided since water can dissolve a number of key nutrient elements including vitamin C (Nandi and Bhattacherjee 2005). Therefore, steaming and stir fry are desirable cooking practices for increasing micronutrient bioavailability in the vegetables based preparations, and these practices should be promoted. Addition of appropriate quantity of oil and fat are required to prepare fruits and

vegetables based preparations that are rich in β-carotene in order to increase their absorption. Similarly, lycopene in tomato becomes more bioavalable after processing. From the foregoing discussion, it can be inferred that important issues like updated nutrient composition of indigenous and exotic fruits and vegetables, postharvest nutrient loss, and appropriate methods of food preparations and cooking need to be included into the existing course curricula, researched and practiced in the real life in order to reduce the severe micronutrient malnutrition in Bangladesh.

Chapter 15

Summer tomato: An example of improved pre- and postharvest practices in Bangladesh

15.1 Variety

The cultivation of summer tomato has been started in Bagharpara of Dadpur, Jessore during the year 1995. Different heat-tolerant varieties like BARI Hybrid 3 and BARI Hybrid 4 are cultivated in the summer. However, the BARI Hybrid 4 is the most popular variety in the region. Different types of improved cultural practices are used in growing summer tomato. The most important cultural practices are the use of polytunnel to protect the plants from rain and application of plant growth regulator for fruit set.

15.2 Planting

The growing season of summer tomato is June to November. The same plant continues to grow in the winter without application of growth regulator. The sources of seeds are BARI and Lal Teer, but the seeds from BARI are the best as mentioned by the growers. The plants are grown in raised beds (Fig 15.1).

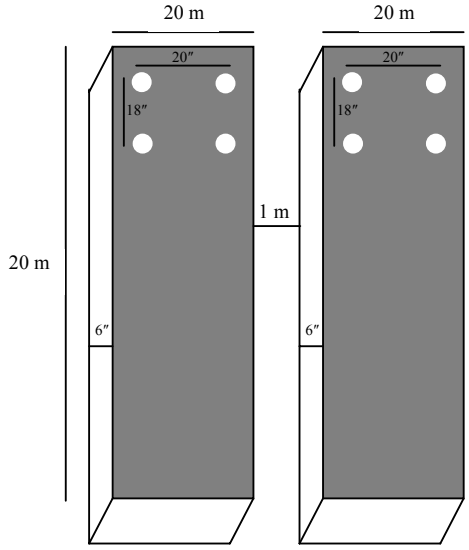

Fig 15.1 Measurements of raised beds used for planting the seedlings of summer tomato.

15.3 Use of plant growth regulators

The most important operation in summer tomato production is the application of growth regulators on the fully-open flowers by using hand gun (Plates 15.1, Plate 15.2A). The available plant growth regulators (PGRs) are Tomatotone (BARI), Bumper Falan (Lal Teer), Joar (Gurpukur) and Surprise (Agrovet). The active ingredient of the PGRs is 4-CPA (4-chlorophenoxy acetic acid). The rate of application is 25 mL/10 L and sprayed 3-4 times in the entire growth period. Fruits become ready to harvest within 31 days of spray of PGR, which increases fruit set and fruit size. The number of flowers and fruits are much

less if the flowers are not sprayed with PGR. The same plant can grow up to the winter season and give flowers and fruits without the use of PGR. Summer tomatoes are seedless or have only the rudimentary seeds. In contrast, the fruits of the same plants during winter possess seeds.

15.4 Intercultural operations

After seedling planting, polytunnel is constructed over each bed (Plate 15.2B). Mulching is an important practice to conserve moisture in the soil. Irrigation is provided when required. Netting is practiced to get rid of the birds. Manures and fertilizers are applied as per the following rates during land preparation (Table 15.1). The same rates are followed for 4-5 times during whole growing season.

Table 15.1 Rate and methods of application of manures and fertilizers in summer tomato

Name of manures and fertilizers	Amount/bed (1 decimal) during land preparation
Well rotten cowdung	10 kg
Compost	5 kg
TSP	1 kg
MoP	1 kg
Urea	250 g

15.5 Insect pests and diseases

A number of insects have been found to cause damage. The important insects were aphids, white fly and leaf miners. The growers usually apply Agromethrin 10EC (Cypermethrin group) and Admire 200SL (Emidachlorpid group) at a rate of 1 mL/10 L water. The important diseases were foot rot, wilting and tomato mosaic virus in the standing crop and black spots on the fruits. The fungicides used were Score 250EC (Diphenochonazole group) and Ridomil Gold MZ 68WP (Metalexil L+Mencozeb group) at a rate of 1-2 mL/10 L water. Roguing was also practiced by the growers to control virus attack.

15.6 Harvesting

Fruits are harvested during the month of August-September. The maturity is judged by observing the skin colour of the fruits. The fruits are usually harvested at mature-green or turning or half-ripe stage. Most growers harvest the fruits manually by hand when 50% of the fruit skin showed color (Plate 15.3).

15.7 Postharvest handling

Improved postharvest operations are also practiced in summer tomato business. The small-sized, disease infected and insect infested fruits are sorted out. Then the fruits are graded on the basis of size, shape and colour (Plate 15.3). The fruits are then packed in plastic creates (22 kg fruits/crate) (Plate 15.3). Very negligible loss occurs at the growers' level as mentioned earlier (Chapter 5; Fig 5.1).

Plate 15.1 Plant growth regulators, namely Tomatotone (A) and Joar (B) are used for fruit set of summer tomato.

Plate 15.2 Use of plant growth regulators (A) and polytunnel (B) to grow summer tomato.

Plate 15.3 Stage of harvest (A), and postharvest operations, namely sorting (B), grading (C) and packaging (D).

15.8 Marketing of summer tomatoes

The harvested tomatoes are brought to the nearby assemble market where the produce are sold to the 'Bepari', who came from different distant markets. Generally, the summer tomatoes are sold to the 'Bepari' of Karwan Bazar and Jatrabari of Dhaka, Chapai Nowabgonj, Chittagong and Biani Bazar of Sylhet. There is a Growers' Cooperative Society elected by the tomato growers. There is no dominance of the intermediaries in the summer tomato marketing. The 'Bepari' pay 1% commission to the Growers Cooperative Society. The average prices of summer tomato in different month are 75 Tk/kg (Summer, July-August), 45-50 Tk/kg (Late summer, September-November), and 5-20 Tk/kg (winter, December-January).

15.9 Constraints in summer tomato business

The major constraints as faced by the growers are:

- Competition with poor quality imported tomatoes.
- Inadequate supply of quality seeds from BARI.
- The seeds supplied from other sources are often poor in quality.
- Farmers' training should be restarted which was stopped in 2000.
- Government assistance reduced.
- Lack of fund.

Chapter 16

Processing of fruits and vegetables

Fruits and vegetables are highly perishable. Huge amounts of fruits and vegetables are spoiled in Bangladesh every year due to lack of proper postharvest management facilities. However, the situation can significantly be improved if the public-private partnership is strengthened and small and large-scale processing facilities are established. When fruits and vegetables cannot be marketed immediately due to unfavourable conditions (less demands, low prices and lack of proper storage facilities), fruits and vegetables can be processed using simple technologies and preserved for long time. Postharvest handling, transport and marketing of processed products are simpler and less costly than for fresh products since expensive refrigeration facility is not essential here. This chapter describes the methods of preparing some important products from the selected fruits and vegetables.

16.1 Methods of processing

Fruits and vegetables are processed by physical (refrigeration, freezing, pasteurization, drying and irradiation), chemical (pickling, preparation of preserves, jams, jellies and marmalades) and fermentation (preparation of wine and cider) methods (Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers). According to Kitinoja and Kader (2003), the processing methods for small-scale entrepreneurs would be drying, fermenting, canning, freezing, preserving and juicing. The important methods of processing of fruits and vegetables are described below.

Drying

Drying is the most common and cheap method of processing fruits and vegetables. In drying, fruits and vegetables are often treated with sulfur by dipping in 1% potassium metabisulfite solution for 1 minute to prevent darkening and loss of flavor and vitamin C, and to retain original colour (Kitinoja and Kader 2003). Fruits and vegetables can be dried using direct or indirect solar radiation. Generally, fruits are sliced or quartered and vegetables are thinly sliced, chopped or diced before drying. Drying of fruits and vegetables takes 2-3 and 1-2 days, respectively. The simplest method for solar drying is to place the cut pieces/slices fruits and vegetables on flat black surface and allow them to dry.

Canning

Canning is a commonly-used processing method for most fruits and vegetables. For canning, fruits and vegetables are peeled, sliced and cooked. Then the hot slices are taken in cans, heated to boiling point and capped. Then the cans are sterilized, labeled and stored. Two types of canners (water bath canner and pressure canner) are commonly used for small-scale canning of fruits and vegetables. Acidic foods such as fruits, tomatoes and pickles, and high sugar foods such as jams, jellies, syrups and marmalades are processed and canned using a boiling water bath (Kitinoja and Kader 2003).

Juicing

Juicing is also commonly practiced processing method. To prepare juice, fruits are simmered in water in a stainless steel or glass pots. When the fruits become tender, they

are cut into pieces and pressed through a food mill or several layers of cheesecloth. Sugar and lemon juice can be added to improve taste. The juice is packed and then either frozen or canned for storage. Most fruit juices are canned in a boiling water bath for 20 minutes. Detailed information and recipe for variety of juices are provided by Kabir (2008) and Ferdows (2008).

Freezing

Where refrigeration facility is available, freezing is used to preserve fruits and vegetables. Most fruits and vegetables are blanched before freezing to prevent loss of flavor and color during storage. The best freezing temperature ranges from -21 to -18 °C. The best packaging materials for freezing should be moisture and vapor proof. Examples of suitable packaging materials for freezing are heavy plastic bags, heavy aluminum foil, glass freezer jars and waxed freezer cartons (Kitinoja and Kader 2003).

Jams, jellies and marmalade

Jams, jellies and marmalades are high-sugar products prepared from a balance mixture of fruit (pulp and juice), acid, pectin and sugar. Pectin is required to solidify the products. Underripe fruits contain more pectin than ripe fruits. Apple juice is also a good source of natural pectin (Kitinoja and Kader 2003). For making jam and jelly, fruits are cooked in medium heat until the mixture sheets from a spoon. Overcooking should be avoided because it reduces the jelling capacity of the mixture. The mixture is poured into cans and sealed. For jam and jelly, fruit pulp and fruit juice are used, respectively. Therefore, jams are non-transparent and jellies are transparent. The method of preparation of marmalade is similar to that of jam and jelly except that thin slices of orange peels are embedded into the pulp in case of marmalade. More information and recipe on jams, jellies and marmalade are provided by Kitinoja and Kader (2003), Kabir (2008) and Ferdows (2008).

Fermentation

Fermentation is an important processing method, especially for manufacturing wines. In this process, lactic acid bacteria convert carbohydrates to lactic acid, and the resulted lower pH help preserve the food for longer period of time. The most common examples of fermented products are Sauerkraut from cabbage and wines from grapes. More information and recipes are described in books namely ‘Rural Processing and Preserving Techniques for Fruits and Vegetables’ (published by FAO) and ‘Fruits and Vegetables Processing Handbook’ (published by EIRI Board of Consultants and Engineers, Engineers India Research Institute, India).

Acidification

Pickling is a simple processing method used for fruits and vegetables preservation. Brine solution (9 parts white vinegar, 1 part non-iodized salt, 9 parts water, plus flavorings and spices) is poured over the product into glass jars leaving ½ inch headspace (Kitinoja and Kader 2003). The bottled pickles are sealed and left at ambient temperature for three or more weeks, while fresh pack pickles are processed in boiling water bath for 10 minutes. More information and recipes are described in books namely ‘Rural Processing and Preserving Techniques for Fruits and Vegetables’ (published by FAO) and ‘Fruits and Vegetables Processing Handbook’ (published by EIRI Board of Consultants and Engineers,

Engineers India Research Institute, India). Detailed descriptions on variety of pickles are also provided by provided by Kabir (2008) and Ferdows (2008).

16.2 Basic steps of processing of fruits and vegetables

Steps of processing actually depend of the nature and kind of products to be manufactured. However, some very basic steps of processing of fruits and vegetables are described in the following.

Collection of raw materials

The raw materials (fruits and vegetables) to be used for processing should be harvested at the proper stage of maturity (ripe or unripe) depending on the nature of the products. The raw materials should be of good quality and free from insect pest, diseases, defects and disorders.

Washing

Washing is the first step of processing, which greatly determines the quality of the final products. Fruits and vegetables should be properly washed before processing to remove undesirable adherences including soils, dirt, fungal structures, stones, gravels and other foreign materials that may adversely affect product quality. Generally, fruits and vegetables are washed using cold running water or chlorinated water.

Sorting

The purpose of sorting is to separate the undesirable fruits and vegetables from the lot. Damaged, bruised, malformed, under or oversized and under or overripe fruits or vegetables should be sorted out. Sorting is also practiced to separate the ripe fruits from the underripe fruits. During sorting, partly damaged fruits or vegetables are also removed to maintain optimal quality of the processed product. For small-scale processing, sorting is done manually based on visual observation. However, for large-scale processing computer aided automated system is used for sorting operation.

Peeling and cutting

Peeling and cutting or slicing are very important operations in fruits and vegetables processing. Peeling facilitates the operation of cutting the raw materials into pieces or into slices before processing. In most cases, fruits are peeled and cut into pieces or slices before processing. However, for the preparation of some products like mango pickle, fruits are sliced but not always peeled. For olive pickle, whole fruits are used. So, these operations depend on the nature of the raw materials and kind of the final products. Generally, stainless steel knives are used for peeling and cutting.

Blanching and sulphiting

Blanching and sulphiting are very important operations in fruits and vegetables processing. These treatments improve the quality and keeping properties of the products. These also help preserve the natural colour of the processed products, especially in the dried products. Both the treatments may be carried out simultaneously. A solution is prepared with water and potassium or sodium metabisulphite. The prepared raw materials

are placed in a piece of cloth or basket, and then plunged for 3 minutes into the boiling solution containing potassium or sodium metabisulphite.

Sterilization

Sterilization is an important operation in fruits and vegetables processing to destroy microorganisms to make the products preservable for longer period of time. All the materials required for processing operations like jars, lid, containers, spoons, etc. should be sterilized. Cooking in boiling water or heating or autoclaving or steaming or washing with chlorinated water are the commonly-practiced methods of sterilization.

Packing

Proper packaging is a pre-requisite for maintaining optimal quality of the processed products in the shelf and for creating customer appeal. Dried products should be packaged in air-tight containers. For example, cellophane is used to wrap and to bag the finished dried products. Products processed by heat (juice, syrup, jams, jellies and marmalade) are packed in bottles and jars to achieve a good seal. The container should have proper label with information on name of products, ingredients, net weight, origin, date of production, approximate storage life and date of expiry.

Storing

Processed products should be stored properly in order to achieve their potential shelf life of up to one year. Generally, the dried products, and the canned or bottled products are best stored in cool and dark place (Kitinoja and Kader 2003). Refrigerated stores are not essential for processed products. However, for minimally processed products or for fresh juice, refrigerated storage facilities are required.

16.3 Small-scale processing of fruits and vegetables

Processing of fruits and vegetables is an important enterprise throughout the world. Although, the consumption of processed fruits and vegetables is still low in Bangladesh but is gradually gaining popularity, especially in the affluent section of the society. By this time, dozen of large-scale processing industries have been established in the country. In this regard, PRAN-RFL Group is in the forefront, and is presently exporting their products to different countries across the globe. On the other hand, the pace of emergence of small-scale processing plants is rather slow. Therefore, to reduce enormous postharvest loss of perishable horticultural commodities, more emphasis should be given for the rapid expansion of small-scale processing facilities in the country. In this chapter an attempt has been made to provide simplified methods of preparing some popular and potential processed products from selected fruits and vegetables, especially for small-scale business.

16.3.1 Mango

Mango is one of most popular and commercial fruits in Bangladesh. Presently, 828 thousand metric tons of mangoes are produced from 31 thousand hectares of land (BBS 2009). The major mango producing districts in Bangladesh are Rajshahi, Chapai Nowabgonj, Nowgaon, Jessore, Kushtia and Chittagong Hill Tracts. However, due to seasonal gluts, and lack of proper storage and transport facilities, an appreciable proportion of the produced mangoes are spoiled every year. Hence, processing (small or

large-scale) would greatly help reduce the postharvest loss and save crores of taka every year. The processing methods of some mango products are given below.

Product 1: Mango Bar

Ingredients

- Ripe mango fruits
- Sugar (10-15% of the weight of the pulp)
- Lemon juice (2 spoons per kg of pulp)
- Potassium metabisulphite (2 g per kg of pulp)

Steps of preparation

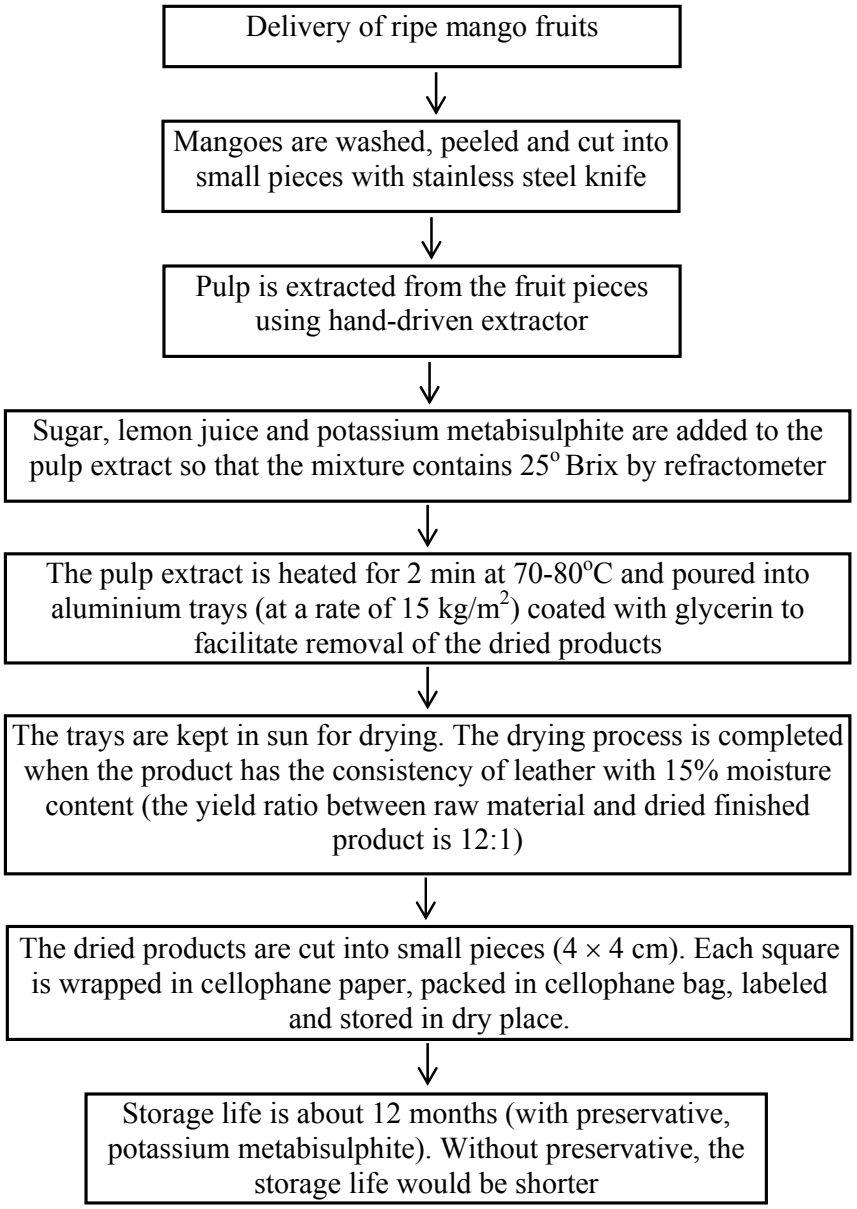

Fig 16.1 Flow chart showing the steps of preparation of mango bar (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

Product 2: Mango Juice

Ingredients

- Fully ripe mango fruits
- Boiling water (1 L per kg of pulp)
- Sugar (200 g per kg of pulp)
- Lemon juice (2 spoons per kg of pulp)

Steps of preparation

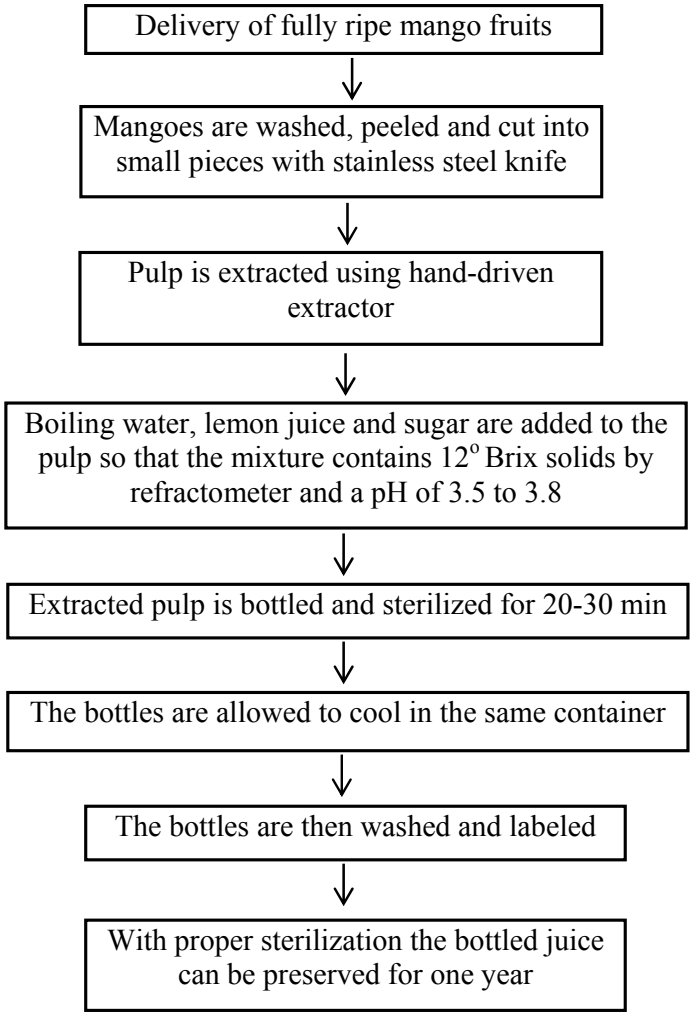

Fig 16.2 Flow chart showing the steps of preparation of mango juice (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

Product 3: Mango Jam

Ingredients

- Both ripe and unripe mango fruits
- Sugar (60% of the weight of mango pulp)
- Lemon juice (4 spoons per kg of mango pulp)

Steps of preparation

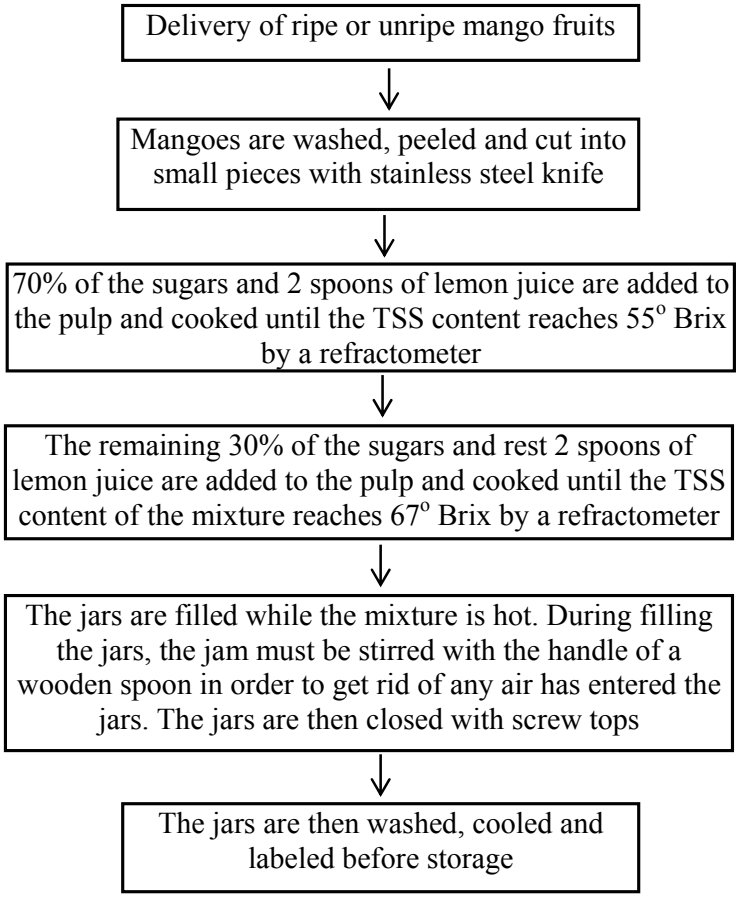

Fig 16.3 Flow chart showing the steps of preparation of mango jam (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

Product 4: Mango Pickles

Ingredients

- Green but fully developed mango fruits
- Oils (mustard or rapeseed)
- Brine solution (2-3% strength)
- Spices and condiments

Recipe

Components	Amounts
Mango slices	0.9 kg
Common salt (powdered)	2.26 g
Fenugreek (coarsely ground)	113 g
Nigella (coarsely ground)	28 g
Turmeric powder	28 g
Red chilli powder	28 g
Black pepper	28 g
Fennel or aniseed	28 g

Steps of preparation

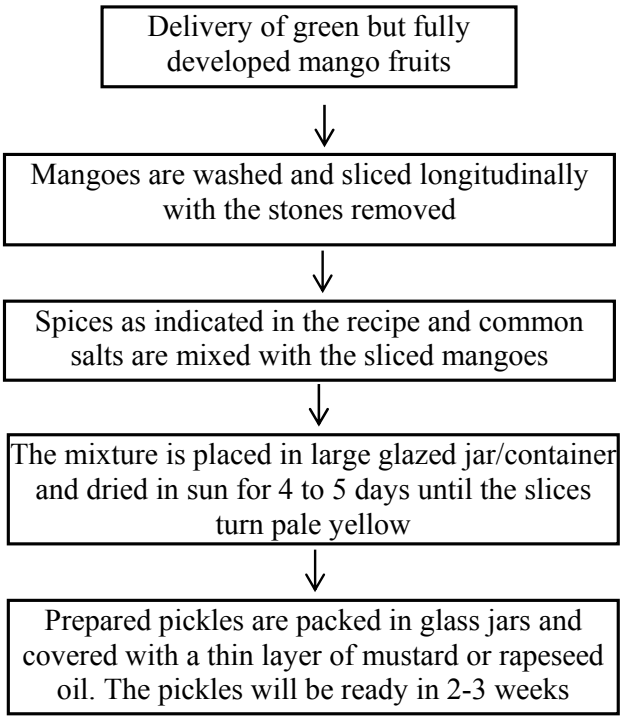

Fig 16.4 Flow chart showing the steps of preparation of tomato sauce (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

16.3.2 Banana

Banana is a top-ranking major fruit in Bangladesh. Presently, 836 thousand metric tons of bananas are produced from 53 thousand hectares of land (BBS 2009). Bananas are produced almost all over the country. However, the major banana producing districts include Tangail, Kushtia, Chuadanga, Bogra, Rangpur and Jessore. Due to lack of adequate transport and storage facility, an appreciable proportion of the produced bananas are spoiled every year. Hence, processing option would greatly help reduce postharvest loss and save crores of taka every year. Products produced from bananas are dried banana, canned banana and banana chips. In Bangladesh, not many banana products are available in the market. However, the processing method of one potential banana product is given below.

Product 5: Canned Banana

Ingredients

- Fully ripe banana fruits
- Sugar syrup (25-30^{o} Brix)
- Citric acid (0.2%)

Steps of preparation

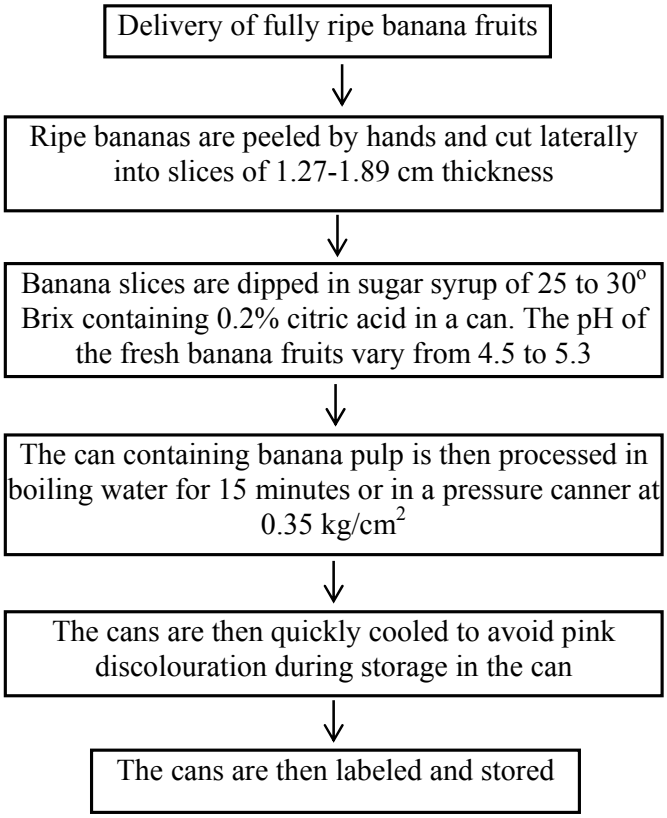

Fig 16.5 Flow chart showing the steps of preparation of canned bananas (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

16.3.3 Papaya

Papaya is a highly nutritious and major fruit crop in Bangladesh. Presently in Bangladesh, 104 thousand metric tons of papayas are produced annually (BBS 2009). Papaya is grown almost all over the country, especially in the homesteads. However, some commercial and large-scale production is in place in some places of Pabna and Gazipur. Papaya is a highly perishable and postharvest loss is very high (Paull 1993; Hassan 2010). Hence, processing would greatly help reduce the huge postharvest loss of this highly perishable fruit. Products produced from papaya include papaya juice and canned papaya. In Bangladesh, processed papaya products are not found available in the market. However, canned papaya is very popular in many of the overseas countries including India and Thailand. The method of processing canned papaya is given below.

Product 6: Canned Papaya

Ingredients

- Fully ripe papaya fruits
- Sugar syrup
- Citric acid (0.5%)

Steps of preparation

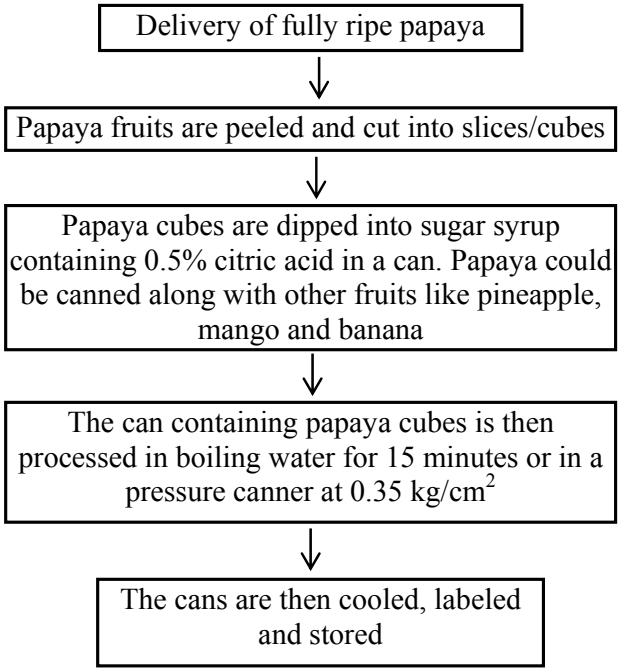

Fig 16.6 Flow chart showing the steps of preparation of canned papaya (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

16.3.4 Pineapples

Pineapple is one of the major and popular fruit crops in Bangladesh. Presently, 228 thousand metric tons of pineapples are produced from 16 thousand hectares of land (BBS 2009). The major pineapple producing areas include Madhupur of Tangail, Gorashal of Norshingdi, Sylhet and Chittagong. Again, due to seasonal gluts, and lack of proper storage facilities, an appreciable proportion of the produced pineapples are lost every year. Hence, promotion of small-scale processing facilities in the production catchments would greatly reduce the postharvest loss and contribute to the improvement of national fruit consumption. The common processed products from pineapples include pineapple juice and canned pineapples. The processing method of one pineapple product is given below.

Product 7: Pineapple Juice

Ingredients

- Fully ripe pineapples

Steps of preparation

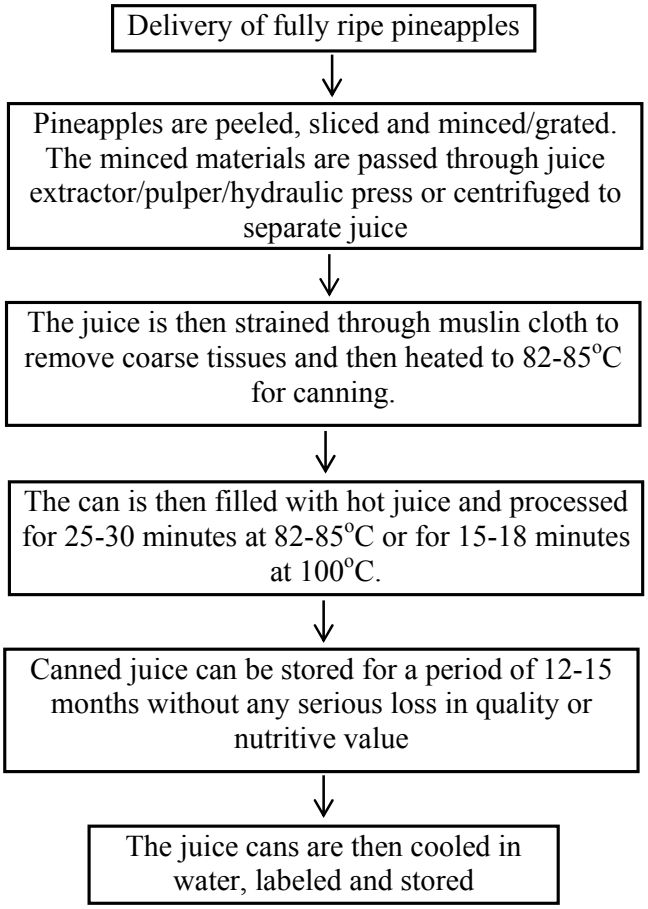

Fig 16.7 Flow chart showing the steps of preparation of pineapple juice (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

16.3.5 Jackfruit

Jackfruit is the national fruit of Bangladesh. Presently, 975 thousand metric tons of jackfruits are produced from 9 thousand hectares of land (BBS 2009). Although jackfruit is grown all over the country, but the major jackfruit producing districts are Gazipur, Sreepur, Mymensingh and Chittagong. Postharvest loss of jackfruit is enormous due mainly to the seasonal gluts, and lack of proper transport and storage facilities. Hence, promotion of small to large scale processing facilities at the vicinity of the production areas would greatly reduce the postharvest loss. The common processed products from jackfruit include juice, chips, jams, jellies and leather. The processing method of a jackfruit product is given below.

Product 8: Canned Jackfruit

Ingredients

- Fully ripe jackfruits
- Sugar syrup (50^{o} Brix)
- Citric acid (0.5-0.75%)

Steps of preparation

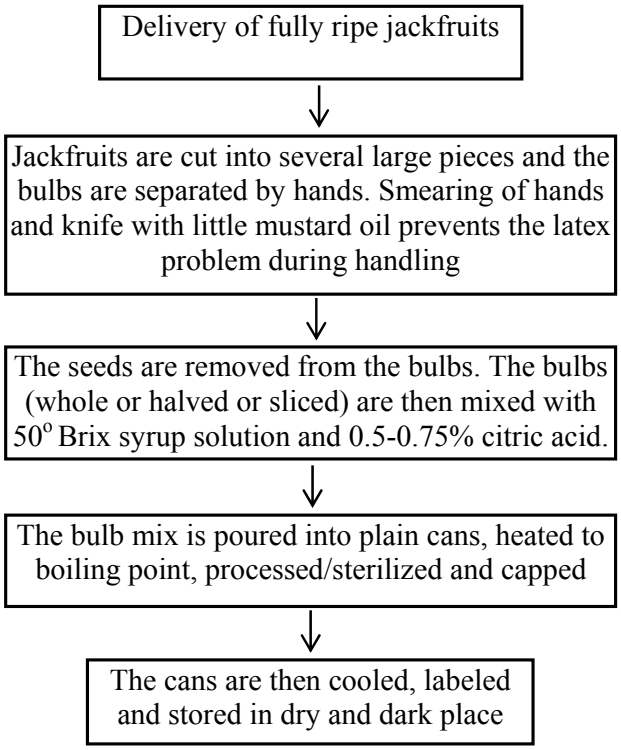

Fig 16.8 Flow chart showing the steps of preparation of canned jackfruit (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

16.3.6 Litchi

Litchi is an important commercial fruit of Bangladesh. Litchi is highly perishable and period of availability is very short. Presently, 55 thousand metric tons of litchis are produced from 2 thousand hectares of land (BBS 2009). The major litchi-producing areas are Dinajpur, Rajshahi, Pabna, Kushtia, Jessore and Mymensingh. Postharvest loss of litchi is very high due mainly to the seasonal gluts, high perishability and lack of proper storage facilities. Hence, promotion of small-scale processing facilities in the production areas would greatly reduce the postharvest loss of this expensive and delicious fruit item. The common processed products from litchi are canned products. The processing method of canned litchi is given below.

Product 9: Canned Litchi

Ingredients

- Fully ripe litchi fruits
- Sugar syrup (40^{o} Brix)
- Citric acid (0.5%)

Steps of preparation

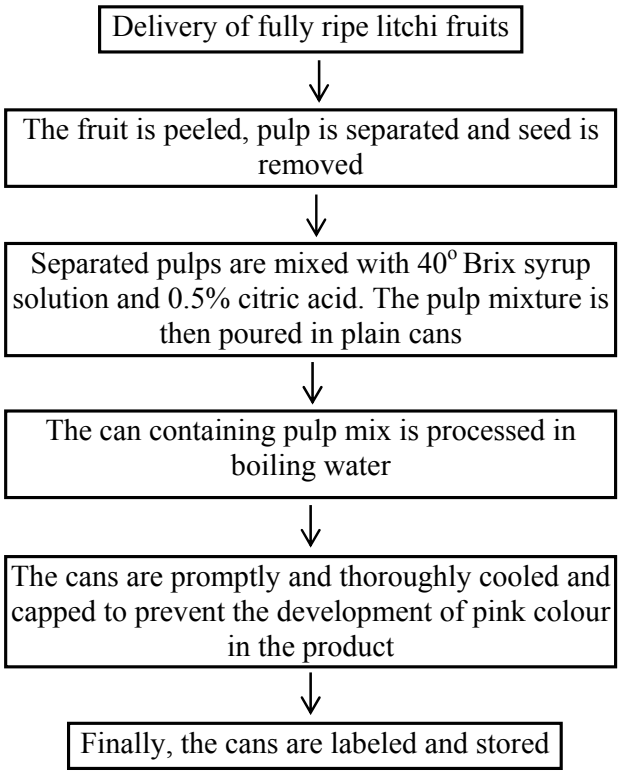

Fig 16.9 Flow chart showing the steps of preparation of canned litchi (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

16.3.7 Orange

Mandarin orange is grown mainly the Sylhet and Moulvibazar. Presently, only 2 thousand metric tons of orange is produced from 0.4 thousand hectares of land (BBS 2009). Numerous processed products could be prepared from orange. The common processed products from orange include juice, squash, pulps, jams, jellies and marmalade. The method of preparation of an orange product is given in the following.

Product 10: Orange Juice

Ingredients

- Fully ripe orange fruits
- Sugar (5% of of extract)

Steps of preparation

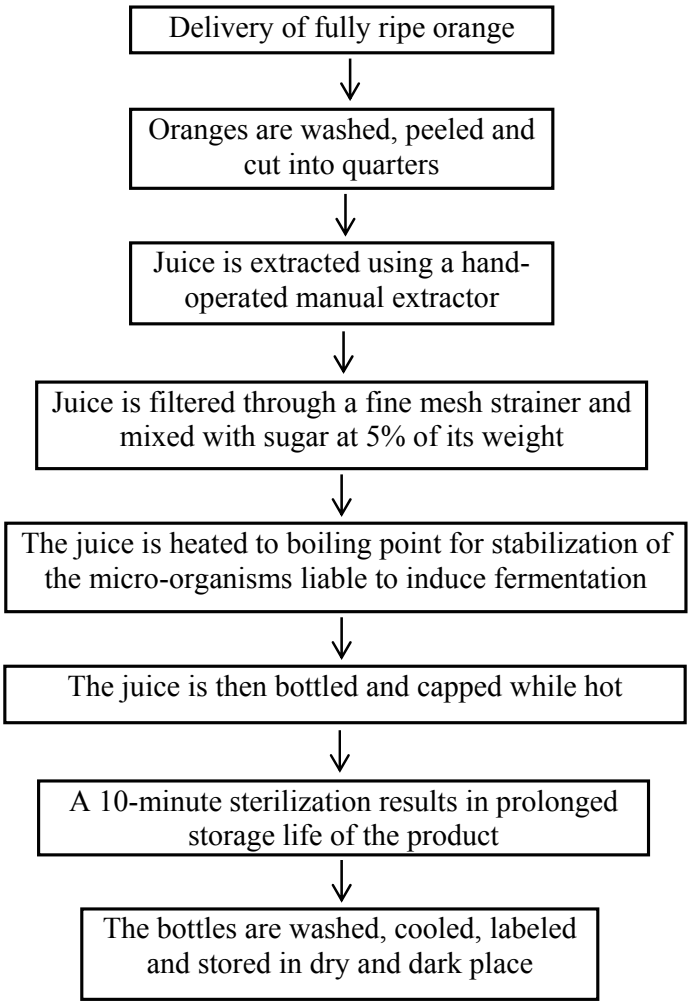

Fig 16.10 Flow chart showing the steps of preparation of orange juice (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

16.3.8 Tomato

Tomato is an important winter vegetable crop in Bangladesh. Nowadays, summer tomato production is also gaining popularity. Presently, 151 thousand metric tons of tomatoes are produced from 20 thousand hectares of land (BBS 2009). Tomatoes are sporadically grown all over the country. However, commercial production is concentrated in Rangpur, Rajshahi, Bogra, Comilla, Chittagong, Norshingdi and Jessore. The postharvest loss of tomato is very high due to high perishability, seasonal gluts, and lack of adequate transport and storage facilities. Hence, promotion of small-scale processing facilities in the production areas would greatly reduce the postharvest loss and contribute to the improvement of nutrition security in the country. In addition, processing increases the bioavailability of lycopene, an antioxidant and anticancer compound, found in tomato and tomato products. The common processed products from tomatoes are tomato juice, dried tomatoes, tomato pickles, tomato pulp, tomato sauce and tomato ketchup. The methods of processing few potential tomato products are given below.

Product 11: Tomato Pulp

Ingredients

- Fully ripe tomatoes

Steps of preparation

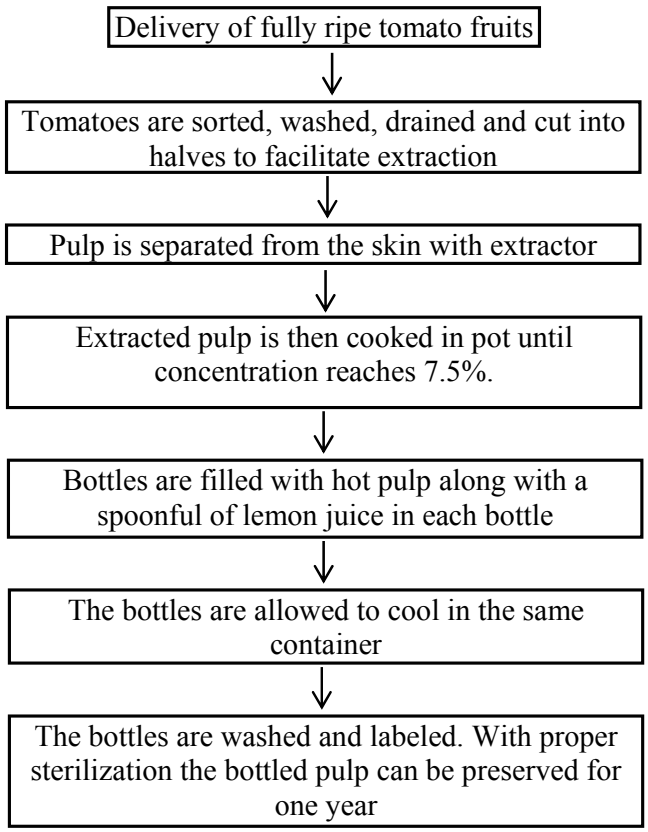

Fig 16.11 Flow chart showing the steps of preparation of tomato pulp (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

Product 12: Dried Tomato

Ingredients

- Fully ripe tomatoes

Steps of preparation

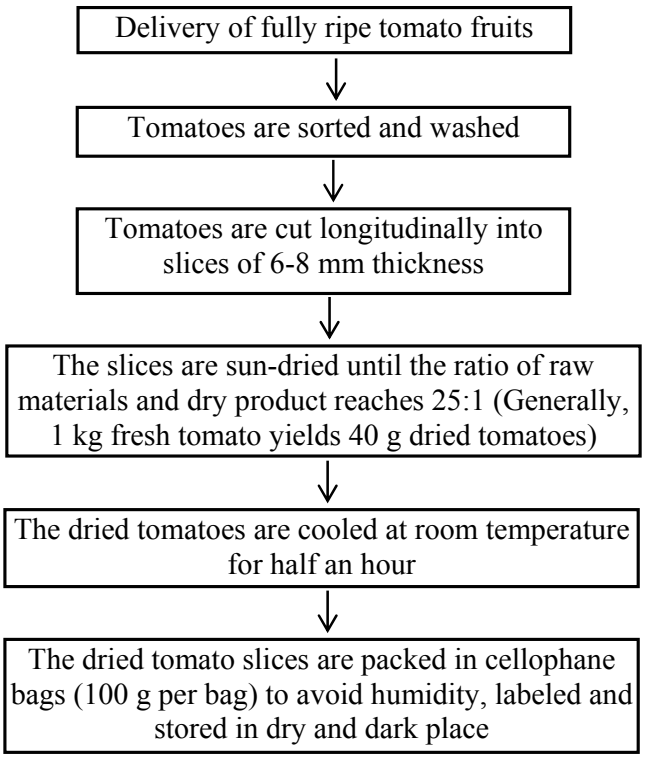

Fig 16.12 Flow chart showing the steps of preparation of dried tomato (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

Product 13: Tomato Sauce

Ingredients

- Fully ripe tomatoes
- Thickening agents (apple pulp or starches of maize, potato, arrow root, sago, rye)
- Spices and condiments

Recipe

Components	Amounts
Tomato pulp (6% soluble solids)	29.25 g
Cardamom	8.5 g
Pepper	8.5 g
Cumin	8.5 g
Cinnamon	8.5 g
Cloves	5.7 g
Mace/Nutmeg	5.7 g
Salt	5.7 g
Chopped onions	154 g
Ground garlic	18 g
Sugar	2.14 kg
White vinegar	580 mL
Red chilli powder	15 g

Steps of preparation

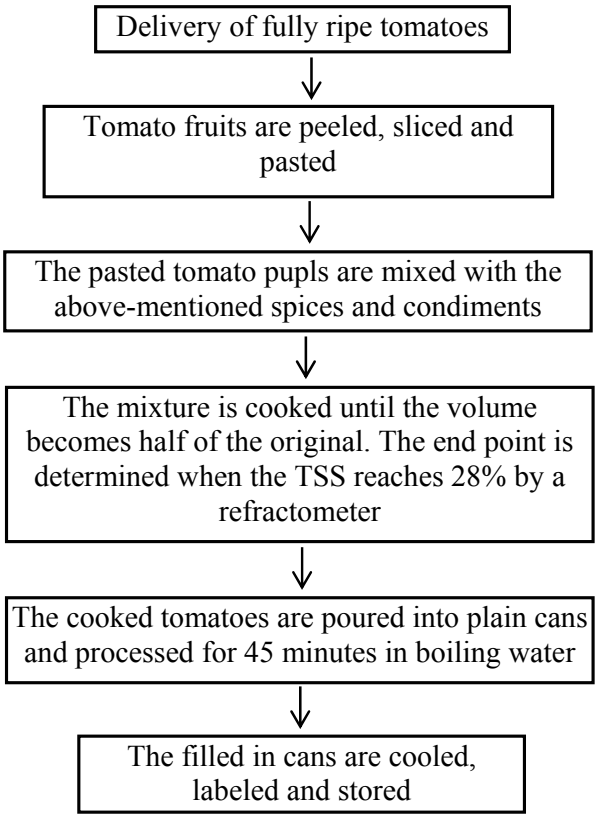

Fig 16.13 Flow chart showing the steps of preparation of tomato sauce (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

16.3.9 Okra

Product 14: Dried Okra

Okra is an important summer vegetable crop in Bangladesh. Presently, 40 thousand metric tons of okra pods are produced from 10 thousand hectares of land (BBS 2009). Okra is grown all over the country. However, commercial production is concentrated in major vegetable-growing areas including Rangpur, Rajshahi, Bogra, Comilla, Chittagong, Norshingdi and Jessore. Appereciable proportion of okra pods are also spoiled due to high perishability, seasonal gluts, and lack of proper transport and storage facilities. In Bangladesh, processed okra products are unavailable in market. The common processed products from okra are okra pickles and dried okra. The method of preparation of dried okra is given below.

Ingredients

- Okra pods harvested at commercial maturity
- Salt (50 g salt/L of water)
- Potassium metabisulphite (3 g/L of water)

Steps of preparation

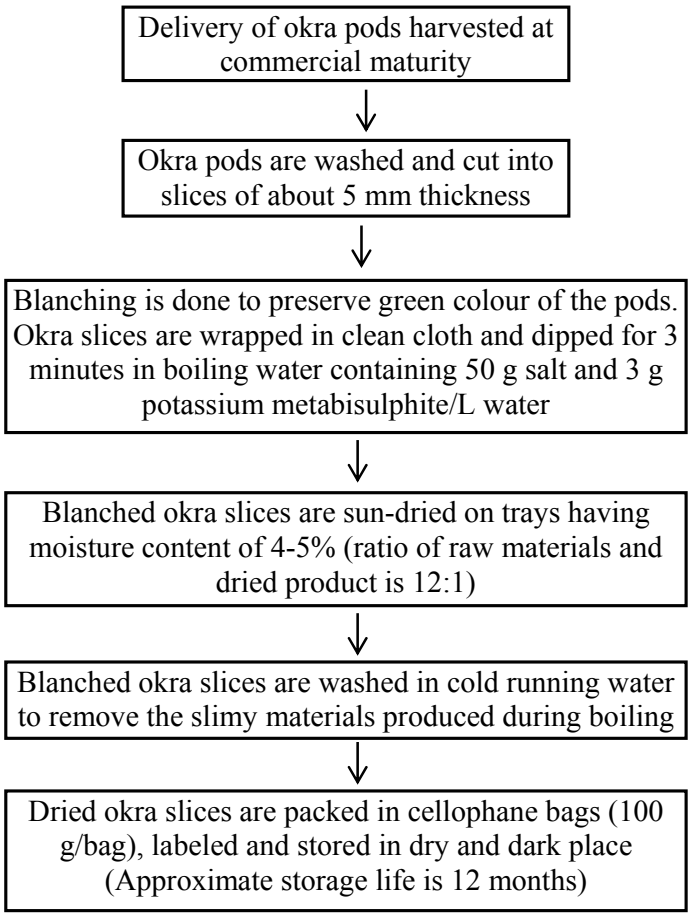

Fig 16.14 Flow chart showing the steps of preparation of dried okra (Source: Rural Processing and Preserving Techniques for Fruits and Vegetables, FAO).

16.3.10 Cauliflower

Cauliflower is one of the important winter vegetables in Bangladesh. Presently, 153 thousand metric tons of cauliflower curds are produced from 16 thousand hectares of land (BBS 2009). Cauliflower is grown all over the country. However, commercial production is concentrated in major vegetable-growing areas including Rangpur, Rajshahi, Bogra, Comilla, Chittagong, Norshingdi and Jessore. Appreciable proportion of cauliflower is also spoiled due to high perishability, seasonal gluts, and lack of proper transport and storage facilities. In Bangladesh, processed cauliflower is not available. However, the common processed products from cauliflower are cauliflower pickle and minimally-processed mixed vegetables for stir fry. The method of preparation of cauliflower pickle is given below.

Product 15: Cauliflower Pickle

Ingredients

- Freshly harvested cauliflower curds
- Oil (mustard or rapeseed)
- Spices and condiments

Recipe

Components	Amounts
Prepared cauliflower	20 kg
Common salt	1.25 kg
Chilli powder	0.75 kg
Cumin	2 oz
Cloves	2 oz
Cardamom	1 oz
Cinnamon	2 oz
Ginger green	2 oz
Chopped onion	0.75 kg
Mustard seeds	0.75 kg
Rape seeds	2.25 kg

Steps of preparation

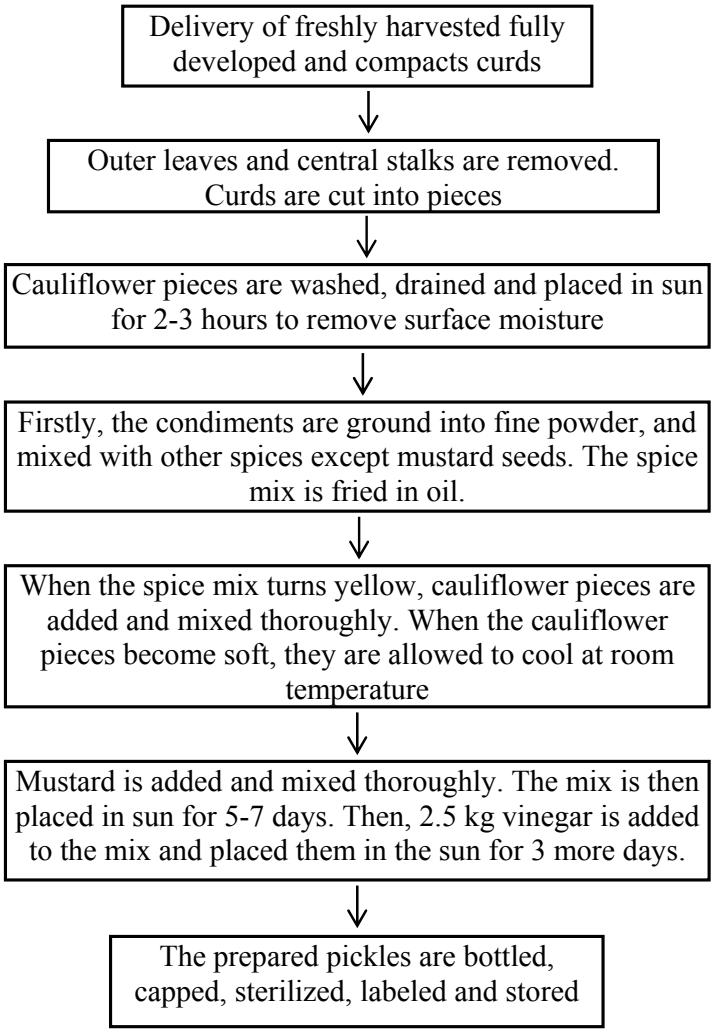

Fig 16.15 Flow chart showing the steps of preparation of cauliflower pickle (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

16.3.11 Brinjal

Brinjal is an important vegetable found available round the year in Bangladesh. Presently, 214 thousand metric tons of brinjal are produced from 28 thousand hectares of land (BBS 2009). Brinjal is grown all over the country. However, commercial production is concentrated in major vegetable-growing areas including Rangpur, Rajshahi, Bogra, Comilla, Chittagong, Norshingdi, Mymensingh and Jessore. Appereciable proportion of brinjal is spoiled due to seasonal gluts, and lack of proper transport and storage facilities. In Bangladesh, processed brinjal is not found available in the markets. However, the common processed products from brinjal are canned brinjal, pickled brinjal and dried brinjal. The method of preparation of brinjal pickle is given below.

Product 17: Brinjal Pickle

Ingredients

- Freshly harvested brinjal
- Brine solution (10% salt or 40 ^{o}Salometer)

Recipe

Components	Amounts
Prepared brinjal (1 cm cubes)	2 brinjal (800 g each)
Garlic	4 cloves
Fresh chopped ginger	50 g
Chopped red chillis	2 Chillis
Mustard oil	Half cup
Chopped onion	1 onion
Ground cumin	1 table spoon
Fennel seeds	1 table spoon
Ground coriander	1 table spoon
Ground turmeric	½ table spoon
White vinegar	1 cup
Sugar	Two-third of a cup

Steps of preparation

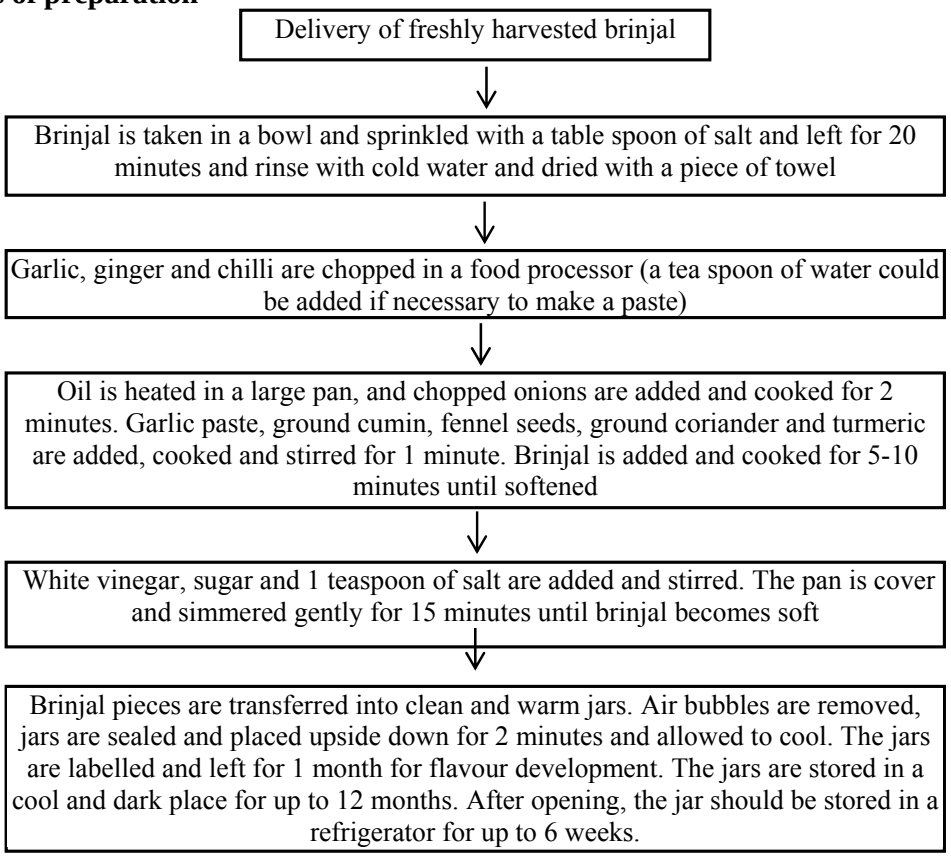

Fig 16.16 Flow chart showing the steps of preparation of brinjal pickle (Better Homes and Garden 2011).

16.3.12 Cucumber

Cucumber is an important salad crop in Bangladesh. Presently, 21 thousand metric tons of cucumber is produced from 6 thousand hectares of land (BBS 2009). Commercial production is concentrated in major vegetable-growing areas including Bogra, Comilla, Chittagong, Norshingdi and Jessore. Appreciable proportion of cucumber is spoiled due to high perishability, seasonal gluts, and lack of proper transport and storage facilities. In Bangladesh, processed cucumber is not available. However, the common processed products from cucumber are canned cucumber and pickled cucumber. The method of preparation of cucumber pickle is given below.

Product 18: Cucumber Pickle (with salt and with vinegar)

Ingredients

- Freshly harvested firm cucumbers of small sizes
- Brine solution (10% salt or 40^{o} Salometer)

Steps of preparation

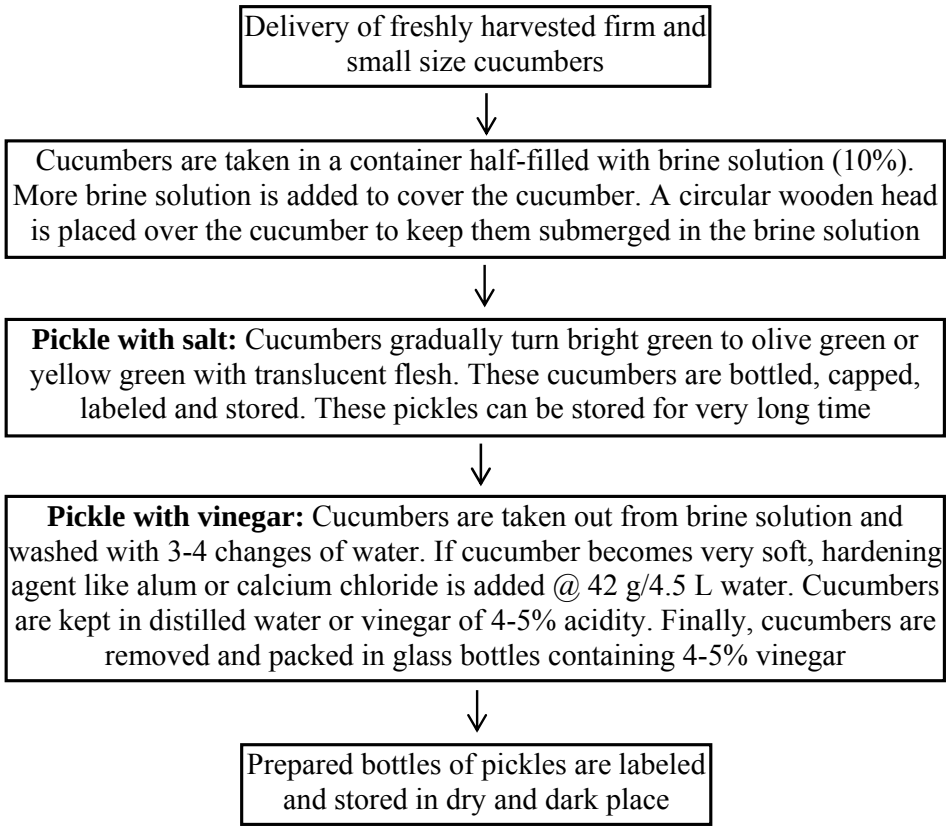

Fig 16.17 Flow chart showing the steps of preparation of cauliflower pickle (Source: Fruits and Vegetables Processing Handbook, EIRI Board of Consultants and Engineers, Engineers India Research Institute, Delhi, India).

In conclusion, there is ample scope to foster the establishment of small-scale processing plants in Bangladesh, especially in major production areas. This chapter only attempted to provide some primary information in relation to manufacture of processed products from

selected fruits and vegetables. However, methods of preparation of numerous products have been described by Kitinoja and Kader (2003), Ferdows (2008), Kabir (2008) and James and Ngarmask (2010). Also detailed methods and recipe are reported in 'Fruits and Vegetables Processing Handbook' (EIRI Board of Consultants and Engineers, Engineers India Research Institute, India) and in 'Rural Processing and Preserving Techniques for Fruits and Vegetables' (FAO).

Chapter 17

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Chapter 18

Appendices

Appendix I: Chemical properties and other relevant information on fruit ripening chemicals in Bangladesh, Ripen 15 (A) and Harvest (B).

RIPEN-15

- PGR (Ethephon 80%)
- National AgriCare Import & Export Ltd., Bangladesh
- DAE Reg. No. IMP 44
- Recommended for use in fruit crops, pea nut, coffee, cotton, bitter gourd, cucumber, maize, etc.
- No clear recommendation for fruit ripening
- Indiscriminately being used in ripening mango, tomato, banana, jackfruit, pineapple, etc.

HARVEST

- PGR (Ethephon 48 SL)
- Blessing Agrovet Ind. Ltd., Bangladesh
- DAE Reg. No. IMP 190
- Recommended for use in fruit crops, namely pineapple, tomato, banana, mango, papaya, citrus, water melon, onion, sugarcane and cucurbits
- Early flowering, uniform fruit ripening, fruit enlargement

Appendix II: Chemical properties and other relevant information on fruit ripening chemicals in Bangladesh, Profit (A) and Promote (B).

PROFIT

- PGR (Ethephon 40 SL; 400 g ethephon/L)
- Global Agrovet Ltd., Bangladesh
- DAE Reg. No. IMP 245
- Recommended for use in tomato, banana and mango for uniform fruit ripening and bright skin colour
- Flower growth and development- pineapple
- Fruit enlargement and uniform growth- papaya

PROMOTE

- PGR (480 g Ethephon/L)
- Shark, Bangladesh
- DAE Reg. No. IMP 251
- Recommended for use in tomato, banana, mango, papaya, citrus, water melon, onion and cucurbits
- Bright and attractive skin colour
- Fruit enlargement and uniform growth
- No clear recommended for fruit ripening

Appendix III Present consumption and demand of food items for people of Bangladesh.

Nutrients	Present daily intake (g)	Present daily requirement (g)	Deficit (-) /surplus (+)
Cereal	492	375	117 (+)
Rice	442	315	127 (+)
Wheat	50	60	10 (-)
Pulse	14	60	46 (-)
Animal protein	96	180	84 (-)
Fish	38	55	17 (-)
Meat	20	48	28 (-)
Egg	15	27	12 (-)
Milk	23	50	27 (-)
Fruits	34	100	66 (-)
Vegetables	97	200	103 (-)
Potato	53	60	7 (-)
Oil	16	40	24 (-)
Sugar	20	28	8 (-)
Spice	18	20	2 (-)
Total	840	1063	223 (-)
Total energy (kcal)	1950	2350	400 (-)

Source: BAN-HRD 2007. Bangladesh Applied Nutrition and Human Resource Development Board. Dhaka, Bangladesh.

Appendix IV Micronutrient rich fruits in Bangladesh.

Nutrients	Name of fruits
Carbohydrates	Tamarind, banana, jujube, mango, coconut, bullock's heart, custard apple, bael, litchi, pomegranate and hog plum.
Vitamin A (β-carotene)	Mango, papaya, jackfruit, pineapple, guava, shaddock and blackberry.
Vitamin B	Elephant apple, shaddock, guava, tamarind, bullock's heart, banana, pineapple, jackfruit and mango.
Vitamin C	Aonla, guava, tamarind, shaddock, lemon, hog plum, carambola, orange, malta, lime, papaya, jujube and mango.
Calcium	Ripe tamarind, lime, elephant apple, hog plum, coconut, lemon, shaddock and bael.
Iron	Water melon, blackberry, hog plum, orange, phalsha, bangi, olive, aonla, bullock's heart, tamarind, coconut, lemon, guava and mango.
Protein	Coconut, jujube, bael, pummelo, custard apple, papaya, pomegranate, bullock's heart, custard apple, jackfruit and mango.
Fat	Coconut, banana, carambola, blackberry, mango, lime and phalsha.
Fibre	Coconut, elephant apple, guava, Bedana, ripe tamarind, bael, blackberry, bullock's heart, custard apple, pomegranate, aonla and lemon.
Energy (K Cal)	Coconut, ripe tamarind, banana, jujubee, mango, bael, bullock's heart, custard apple, pomegranate, palmyra palm, phalsha, olive, hog plum and guava.

Source: Haque, M.A. 2010. Role of Indigenous Fruits in Food and Nutritional Security in Bangladesh, Keynote speech presented at the National Workshop, BARC, Dhaka, Bangladesh, 16 June 2010.

Appendix V Lycopene content in fresh and processed tomatoes.

Tomato/tomato products	Lycopene (mg/100 g)
Raw tomato (red)	2.6
Tomato juice	9.0
Tomato soup	10.9
Tomato paste	28.8
Tomato powder	46.3

Source: USDA. 2005. National Nutrient Database for Standard Reference, Release 2005.