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Postharvest Quality Assurance of Fruits

Practical Approaches for Developing Countries

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ISBN 978-3-319-21196-1 ISBN 978-3-319-21197-8 (eBook)
DOI 10.1007/978-3-319-21197-8

Library of Congress Control Number: 2015946867

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

To our beloved parents this book is affectionately dedicated

Preface

Being perishable in nature, the annual postharvest loss in fruits considering quality and quantity is very high ranging from 30 to 40 % of the total production. Moreover, the absence of proper postharvest handling practices and value addition exaggerates the postharvest losses. This book entitled *Postharvest Quality Assurance of Fruits: Practical Approaches for Developing Countries* is written by the experienced authors; it contains 14 chapters related to postharvest quality descriptions, marketing, factors affecting quality of fruits during postharvest handling, quality testing procedure on commercial scale, harvesting season, etc.

The first chapter is introduction describing general modes of marketing, producer's share in consumer's rupee, changing scenario of fruit business, and quality for organized retailing. The second chapter describes major factors affecting the quality of fruits/fresh produce after harvesting until final consumption. The third chapter includes the factors that affect demand and market value of the crops. The fourth chapter deals with the growing belt and harvesting season of major and commercially important fruits. Fifth and sixth chapters describe overall quality prerequisites for domestic and international markets. Seventh chapter comprehensively discusses all the important operations in order to preserve the quality of fresh fruits during postharvest conditions. Chapter 8 is about packaging of fruits. This chapter describes objectives, and commercially used traditional and modern packaging systems including active, smart, and shrink packaging. Chapter 9 summarizes different types of storage systems starting from low cost on farm storage to most sophisticated Controlled Atmosphere (CA) storage. Chapter 10 describes almost all marketing channels prevailing in fruit business in developing countries including India, Pakistan, and Bangladesh. Chapter 11 nicely discusses about the supply chain and marketing channels of fruits. Similarly, Chap. 12 highlights and discusses different modes of transportation during supply chain of fresh fruits. Chapter 13 describes the testing procedure for quality assurance of fruits during postharvest storage and marketing. The last chapter, i.e., Chap. 14, summarizes the important nondestructive quality assessment methods along with some case studies including illustrations.

The authors are well confident that the book will be of great importance for the professionals and industries involved in the handling of fresh fruits worldwide. The book is also an important and useful venture for the graduate and doctorate students to have practical knowledge about the subject. The authors welcome the suggestions from the readers and professionals for the betterment and enrichment of the book.

Bihar, India

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Mohammed Wasim Siddiqui

Acknowledgements

First of all, we ascribe all glory to the Gracious "Almighty Allah" from whom all blessings come. We would like to thank Him for His blessings to write this book.

We, the authors, wish to appreciatively thank the Bihar Agricultural University, India, for providing us the opportunities and facilities to execute such an exciting book. We convey our special thanks to our colleagues and other research team members for their support and encouragement that helped us accomplish this venture.

Much appreciation is expressed to Prof. Kamlesh Prasad, Department of Food Engineering and Technology, S. L. I. E. T., Longowal, Punjab, India for contributing a very nice and informative chapter to this book. The information provided in his chapter on "Non-destructive Quality Analysis of Fruits" is the need of the hour that not only beautified the book but also increased the importance as well. We are heartily grateful to him.

We are thankful to *Shri Basant Nayak*, Head-Business Development, Adanni Agrifresh Ltd., India, *Shri Dinesh Bhagwat Rao Mankar*, CEO, M/S Satpuda Impex Pvt. Ltd., India, and *Dr. Pradyumna Raj Agrahari*, CEO, Indus Mega Food Park Pvt. Ltd., India, for providing related information, photographs, and valuable advice while writing the manuscript, which made this book useful at practical levels.

We also would like to express appreciation to Dr. Daniel Falatko, Associate Editor, Food Science and Jeffrey Taub, Project Coordinator, Book Production from Springer, NY, USA, who have offered considerable and valuable information that employed during preparation of book proposal and manuscript.

Our acknowledgement will not be complete without expressing our indebtedness to our beloved parents and family members for their infinitive love, cordial affection, incessant inspiration, and silent prayer to "Allah" for our well-being and confidence.

Contents

About the Authors

Mohammad Shamsher Ahmad, Assistant Professor-cum-Scientist, Department of Food Science and Post-Harvest Technology, Bihar Agricultural University (BAU), Sabour, Bhagalpur, Bihar, acquired bachelor's degree in Agriculture from Sam Higginbottom Institute of Agriculture, Technology and Sciences (SHIATS), Deemed University (Formerly Allahabad Agricultural Institute, Allahabad), Allahabad, Uttar Pradesh, India, and master's degree in Horticulture with specialization in postharvest technology from Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India.

Before joining BAU, Sabour, Mr. Ahmad had been working with Adani group (Adani Agrifresh Ltd.) as an executive looking over the postharvest quality control of fresh fruits and vegetables. He also worked as a postharvest consultant at Fritolay (Pepsico India Holdings Pvt. Ltd.). Besides these renowned companies, he also worked with Litchica International, Mumbai, and COCO Food Products (I) Pvt. Ltd., Delhi, as a Quality Control (QC) officer. Mr. Ahmad has about 13 years of experience in the field of postharvest handling, marketing and quality maintenance of fresh produce, and more than 3 years experience in teaching, research, and extension in the field of postharvest technology of horticultural crops. He is handling several projects as a PI and CO-PI including one mega project under ASIDE scheme, Government of India, namely Food Development Centre, being the Nodal Officer of the centre. Mr. Ahmad published several articles in the journals of national and international repute, and eight book chapters. He is also having two practical manuals to his credit, which are on postharvest and value addition of fresh produce.

Mohammed Wasim Siddiqui, Ph.D. is an Assistant Professor and Scientist in the Department of Food Science and Post-Harvest Technology at Bihar Agricultural University in Sabour, India, and is the author or co-author of 30 peer-reviewed journal articles, 18 book chapters, and 18 conference papers. He has four edited and one authored books to his credit, published by CRC Press, USA; Springer, USA; and Apple Academic Press, USA. He is a co-author of two manuals and co-editor of three annual reports. Dr. Siddiqui has established an international peer-reviewed journals, *Journal of Postharvest Technology*. He has been honored to accept the

position of Editor-in-Chief of a book series entitled *Postharvest Biology and Technology*, being published by Apple Academic Press (AAP), USA. Dr. Siddiqui is also an Acquisitions Editor for Horticultural Science for AAP. He is also an active editorial board member and reviewer of several journals of international and national reputes.

Recently, Dr. Siddiqui has received the Achiever Award 2014 for outstanding research work by the Society for Advancement of Human and Nature (SADHNA), Nauni, Himachal Pradesh, India, where he is also an Honorary Board Member. He has been an active member of the organizing committees of several national and international seminars, conferences, and summits.

Dr. Siddiqui acquired a B.Sc. (Agriculture) degree from Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India, and received M.Sc. (Horticulture) and Ph.D. (Horticulture) degrees from Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, India, with specialization in postharvest technology. He was awarded a Maulana Azad National Fellowship Award from the University Grants Commission, New Delhi, India. He is a member of the Core Research Group at Bihar Agricultural University (BAU), where he helps with providing appropriate direction and assisting with prioritizing the research. He has received several grants from various funding agencies to carry out his research projects. Dr. Siddiqui has been associated with postharvest technology and processing aspects of horticultural crops, and he is dynamically involved in teaching (graduate and doctorate students) and research. His contribution as an academician, scientist, and editor in postharvest biology and technology has been well recognized by the world.

Chapter 1
Introduction

Fruit business in most of the developing countries is highly unorganized and controlled by traders, commission agents, and intermediate people. These intermediate people not only control the market, but also share the major part of the sale price, without any or little value addition. This is the reason that farmer's share of consumer's rupee is highly disappointing (Siddiqui et al. 2014). The farmer's share of consumer's rupee is studied by many workers and organizations. According to Anantia (2008), the share of producer in consumer's price depends upon the types of marketing channels. On an average, the share of producer varies between 33 and 75 % in case of fruits. Another survey by Government of India (2001) reported that the farmer receives only one rupee out of every Rs. 3.50 paid by the consumers. Whereas the retailer receives Rs. 0.75, the wholesaler Rs. 0.50, and rest of the amount Rs. 1.25 goes to commission agents and traders. Not only farmers get very less share out of consumer's price, but also restricted unofficially in many markets to dispose their produce directly to the consumers. Jaitath (2008) also reported that in India, many producers face barriers to effective participation in markets for sale of fruits and vegetables.

From the last 10–15 years, national and global markets for fresh produce, especially fruits, have registered many changes. These changes are observed in all marketing-related operations such as in harvesting, assembling, packaging, distribution patterns, quality control, and consumption patterns. In all unit operations, there are up-gradation and improvements; all these up-gradation and improvements are consumer-friendly and business oriented. Now fresh produce marketing, especially fruits, has been transformed into a multimillion dollar business. Without reaching to the actual site of production and sale, one can purchase any quantity of fruits and sale the same. Improved communication systems, as well as uniform grading and packing standards, well-managed transportation collectively allowed wholesale purchasers and buyers to shop in various regions nationally and internationally. More and more retailers, semi-wholesaler, and wholesalers are also joining to fresh produce section of trade and marketing. Large wholesale markets at national level are connected with small wholesale markets at state levels and district levels.

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DOI 10.1007/978-3-319-21197-8_1

Large retail chains (Organized retails) are also connected with different wholesale markets of the country.

Marketing of fresh produce, especially fruits, differs from state to state and from country to country. These differences are due to several reasons starting from socio-economic conditions to consumption pattern. One typical example is marketing of apple from J&K and Himachal Pradesh, two important apple growing states of India. In J&K, harvesting season of apple starts in the middle of August, 1 month later than Himachal Pradesh and the season ends in the last week of October or first week of November. Most of the farmers store their produce in the orchards itself in loose packing in wooden boxes or as a heap. A small house in the orchard is constructed for this purpose to save the produce from rain and direct sun. Few of them transport their apple to their village and store in the house. Once harvesting is completed, farmers of J&K start packing and sending to different markets of their contact. This practice continued up to March next year, i.e., for 4 months. They took the advantage of natural cold conditions in the months of November to March. The situation in Himachal Pradesh is totally different from J&K. Here on farm and home, storage is totally absent. Farmers harvest their produce, pack it in the orchard, and send to the markets. In few cases, they keep their produce in the cold store and sale in off-season.

At present, India is the second largest producer of fruits with a production level of nearly 81.25 million MT (National Horticulture Board 2012–2013). Out of total production, nearly 75 % produce reaches nearby mandis and sold through commission agents to wholesalers, sub-wholesalers, and retailers. Few wholesalers, sub-wholesalers, and commission agents, after purchasing in local mandis at wholesale rate send to other wholesalers or sub-wholesalers or commission agents after adding his forwarding charge and labor cost. All reputed and big fruit traders send few trained person to growing areas and local mandis for purchasing and price information. They do re-sorting, grading, and packing by experienced packers before sending to other commission agents of other states. Mostly untrained labors are employed for handling practices in the farm as well as in the mandi. There is little or no facilities in the form of infrastructure for the welfare of farmers available at the wholesale markets such as packing, grading, sorting, and cold storages. Only limited cold storage facilities are available in few selected mandis, but the capacity is far below than required. There is also massive wastage and deterioration in quality by physical and pathological means resulting in large amount of wastage (30–40 %) in developing countries, including India.

Indian farmers are dependent heavily on traders and middlemen for marketing their produce. Most of the risk in supply chain before sale is also borne by the growers. The whole supply chain is dominated by commission agents, traders, and other middle men. Another disappointing factor is lack of transparency in pricing of farmer's produce at wholesale marketing. Here price is fixed between buyers and traders under a piece of cloth secretly. In majority of the cases, true sale price is not paid to the growers. Consumer also faces problems in fruits and vegetables market on weighing, bargaining, and quality.

Now the fruit marketing scenarios are changing with the entry of organized retails in almost all developing countries. The concept of organized retail has been existing in India since early 1980s with the existence of players like Mother Dairy covering Delhi NCR only. In recent years, companies like Reliance Industries, Bharti Wall Mart, Future Group, Aditya Birla Group, and other corporate entered in the fresh produce sector. Organized retailing in Fresh Fruits and Vegetables (FFV) is gaining a lot of momentum in India with small to medium investment by leading Indian companies. A study by Deloitte-Stores (2007) predicts faster growth for the organized retail business in developing countries in the next decade due to rising numbers of middle class urban populations. In India, the organized food retail sector has been growing at annual rates between 16 and 50 % over the past few years (Reardon and Ashok Gulati 2008). This is referred as super market revolution of India. This trend has been started not only in medium and fast developing countries, but also in the poorer developing nations (Timmer 2005). Due to this revolution, all categories of farmers are benefited but not equally. Many organized retails work through service provider (job work for big retail chain) and big producers only. They face a lot of problems during collection from small farmers. Small and very small farmers also face difficulties in selling their produce directly to supermarkets; it was found that they sale to service provider and big producers' organization (Gulati and Reardon 2007). Similar observations have been made in other studies, which show that farmers connected to the organized retail sector in India had larger land holdings (Joseph et al. 2008; Mangala and Chengappa 2008; Alam and Verma 2007) and higher proportion of irrigated land (Joseph et al. 2008) than those supplying to traditional market channels.

Producers find many advantages by the entry of super market, retail chain, and wholesale trading by corporate companies. It was established by many researchers that those farmers who supply directly to retail chain receive comparatively higher prices (Dhananjaya and Rao 2009; Alam and Verma 2007), higher net profits (Joseph et al. 2008; Mangala and Chengappa 2008; Birthal et al. 2005), and also had lower transaction costs (Singh and Singla 2010; Joseph et al. 2008; Alam and Verma 2007). Farmers also raising their quality bar as only quality produce are demanded by retail chain. Adani Agrifresh Ltd. (Adani Group) and Reliance fresh appointed scientists and experts to train the farmers about quality production. Singh and Singla (2010) also reported that retail chains have raised quality consciousness among farmers, introduced grading (in primary processing), and have helped in cost-cutting through extension and training on input use for better yield. Modern formats such as Reliance Fresh, Choupal Fresh, More, Food World, Big apple, and Easy Day promoted by different companies are emerging very rapidly in small and large towns in the country. The important companies entered in fruits and vegetables retailing are Reliance Industries (Reliance Fresh) and Ranger Farms, Bharti-Wal-Mart (Easy Day), ITC, Food World, Spencer, Godrej, Future group (Big Baazar and Food Baazar), Aditya Birla Group, etc. (Abid Hussain 2009). Similarly, few important companies, such as Adani Agrifresh Ltd., Fresh and Healthy enterprises, and Harshana naturals, entered into wholesale marketing of fresh fruits.

Table 1.1 Major organized retails of India dealing with fruits and vegetable (Ahmad et al. 2014)

S. no.	Name of group	Company/brand name	Area of operation
1.	NDDB	Safal	Delhi NCR, Bangalore
2.	RPG	Food World	South India
3.	RPG	Spencer	South, Central, and East India
4.	Reliance	Reliance Fresh	All over India
5.	ITC	Choupal Fresh	North, South, and Central India
6.	Aditya Birla	More	All over India
7.	Heritage	Fresh@	South India
8.	Future Group	Food Bazaar	North, South, and Central India
9.	Bharti Wall mart	Easy Day	North, South, and Central India
10.	Mahindra & Mahindra	Mahindra Subhlubh	North
11.	TATA	Khet Se	North and South

Many retail brands of fruits and vegetables operating in India are listed in Table 1.1.

A study by FAO (2005) on food retailing in Asia indicated that, irrespective of type of store, various factors such as methods of procurement, the use of logistics, and quality standards applied have implications for farmers' incomes. The same study also indicates that farmers face many problems in supplying to supermarkets, including delisting of suppliers and rejection of produce by retailers for not conforming to volume, quality, and delivery and price competitions between retail chains, making it difficult for farmers to earn profit as well as on-farm investments. The Indian Government, however, considers organized retail to be beneficial as it can set up supply chains, give better prices to farmers, and facilitate agro-processing (GOI 2006).

In developed countries, mostly this business is under organized sector with turnover of major companies ranging between $3 and $10 billion. Each company works with its set of farmers. Majority of company employees are specialist and execute scientific pre-harvest and post-harvest management systems. It is also ensured by the specialist to plan properly to ensure that productivity and quality is good, products are handled and packaged well, and are marketed on time with sufficient shelf life.

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Chapter 2
Factors Affecting Postharvest Quality of Fresh Fruits

Introduction

From many studies and field observations over the past 40 years, it has been reported that 40–50 % of horticultural crops produced in developing countries are lost before they can be consumed, mainly because of high rates of bruising, water loss, and subsequent decay during postharvest handling (Kitinoja 2002; Ray and Ravi 2005). Nutritional loss (loss of vitamins, antioxidant, and health-promoting substances) or decreased market value is another important loss that occurs in fresh produce. Quality of fresh produce is governed by many factors. The combined effect of all decides the rate of deterioration and spoilage (Siddiqui et al. 2015; Barman et al. 2015; Nayyer et al. 2015). These factors, if not controlled properly, lead to postharvest losses on large scale. According to Kader (2002), approximately one third of all fresh fruits and vegetables are lost before it reaches to the consumers. Another estimate suggests that about 30–40 % of total fruits and vegetables production is lost in between harvest and final consumption (Salami et al. 2010). Quality deterioration starts as soon as it is harvested and continued till consumed or finally spoiled if not consumed or preserved. The success or failure of any business plan related to fresh produce is totally dependent on the management of factors affecting the quality. This is obvious because fresh fruits and vegetables are living in nature, complete remaining life cycle after harvest, and then naturally spoil. This character puts fresh fruits and vegetables in the category of highly perishable commodities. Developed countries are in a very good position as they have developed good systems of postharvest management and infrastructure for quality maintenance. At the same time, developing countries are far behind in the same business, i.e., lacking in good postharvest practices and supporting infrastructure for quality maintenance. The outcome of this lacuna is considerably very high in developing countries. This is one of the reasons that postharvest losses in fresh fruits and vegetables are estimated about 5–35 % in developed countries and 20–50 % in developing countries (Kader 2002). In another report, it is reported that

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_2

40–50 % of horticultural crops produced in developing countries are lost before they can be consumed, mainly because of high rates of bruising, water loss, and subsequent decay during postharvest handling (Kitinoja 2002; Ray and Ravi 2005). In both fruits and vegetables, many more additional changes take place after harvesting. Changes are noticed more in climacteric fruits and vegetables than non-climacteric. Some changes are desirable from consumer point of view, but most of them are undesirable. Development of sweetness, color, and flavor are best examples of desirable changes. These desirable changes persist for few days only. This is the stage liked by almost all consumers. At the same time, shelf life decreases and many undesirable changes take place such as water loss, shrinkage, shriveling, cell wall degradation, softening, physiological disorder, overripening, disease attack, rotting, and many more. All these changes, if not governed, ultimately affect the quality. These changes in fresh produce cannot be stopped, but these can be slowed down within certain limits if factors responsible for such deterioration can be minimized. This is important because it increases shelf life and marketing period of fresh produce and maintains their quality during postharvest handling. There are few proven methods and technologies used to slow down the undesirable changes for extended availability such as control of optimum low temperature and humidity during storage, suitable packaging, transportation, and maintenance of storage atmosphere.

Preharvest Factors Influencing Postharvest Quality of Fresh Produce

Postharvest management starts with preharvest managements. Once the fruits are harvested, the overall quality of fresh fruits can hardly be improved but it can be maintained. The final market value of the produce and acceptance by the consumers depends upon the grower's ability to apply best available preharvest technology followed by harvesting and then to apply best available postharvest handling practices. The preharvest factors influencing postharvest quality are frequency of irrigation, use of fertilizers, pest control, growth regulators, climatic conditions like wet and windy weather, natural climates such as hailing, high wind velocity, heavy rainfall, and tree conditions (age, training pruning, light penetration, etc), which influences overall fruit quality and suitability for storage by modifying physiology, chemical composition, and morphology of fruits. One such preharvest factor is spray of Gibberellic acid (10 ppm), if applied at color break stage, results in delay in color development and maintains firmness. This is important because it in extending harvesting period. Similarly, the use of calcium solution as foliar sprays increases firmness of fruits as well as extends the shelf life.

Postharvest Factors Influencing Postharvest Quality of Fresh Produce

There are many postharvest factors that affect quality of fresh produce as mentioned below:

1. Maturity stage
2. Methods of harvesting
3. Tools for harvesting and assembling
4. Time of harvesting
5. Precooling
6. Sorting and grading
7. Packaging, packaging materials, and pallatization
8. Use of cushioning materials in the package (foam net, paper cutting, rice straw, etc.)
9. Storage
10. Types of storage
11. Temperature during storage and transportation
12. RH during storage and transportation
13. Transportation
14. Road condition
15. Pattern of loading and unloading
16. Exposure to packed and unpacked boxes to sunlight

Maturity Stage

This is the starting point of postharvest quality management. Therefore, it must be ensured that properly matured fruits should be harvested. It must be harvested when it attains the appropriate stage of development based on physiological and horticultural maturity. Harvest maturity varies in accordance with the crop concerned. Fresh produce is ready for harvest when it has developed to the ideal condition for consumption (FAO 1989). Immature or overmatured fruits are inferior in quality and spoil more quickly even if other factors are favorable. The maturity of harvested fruits has an important role on shelf life, quality, and market price. Hence, certain standards of maturity must be kept in mind while harvesting the fruits.

At which stage of maturity, a fruit should be harvested is crucial to its subsequent storage, marketable life, and quality. Maturity always has a considerable influence on the quality of fresh produce as well as the storage potential and occurrence of many storage disorders (Siddiqui and Dhua 2010). There are mainly three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. For climacteric fruits, maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. Ripening follows or overlaps

Table 2.1 Example of few climacteric and non-climacteric fruits

Climacteric fruits	Non-climacteric fruits
Mango, Banana, Papaya, Sapota, Apple, Custard Apple, Kiwi fruit, Peach, Jack Fruit, Guava, etc.	Grape, Kinnow Mandarin, Sweet Orange (all citrus fruits), Litchi, Pomegranate, Pineapple, etc.

maturation, rendering the produce edible, as indicated by texture, taste, color, and flavor. Senescence is the last stage, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavor, etc. (senescence ends with the death of the tissue of the fruit). Here, ripening treatment is an important operation in many climacteric fruits before retailing. This gives an opportunity for uniform ripening and availability based on market demand. Few examples of climacteric fruits are mango, banana, sapota, apple, custard apple, etc. For non-climacteric fruits, development of eating quality before harvesting is indicative of the fruit being ready for harvest. Therefore, non-climacteric fruits should be harvested after attaining proper development of eating quality (ripening) while still attached to the mother plant. In this case, ripening treatment is not given before retailing. Few examples of non-climacteric fruits are oranges, grape, litchi, etc. Climacteric fruits are harvested at full matured stage (before onset of ripening). Here, ripening treatment is given in few fruits before retailing. Examples of climacteric and non-climacteric fruits are listed in Table 2.1. It is important to note that each fruit has a set of maturity standards (physical as well as chemical) and growers are capable of identifying it easily. Only few chemical analyses are difficult to perform. For example, the most commonly used measure to access maturity for harvesting of Mandarin oranges is peel color (physical). Fruits are considered mature, if they have a yellow orange color on 25 % or more of the fruit surface. Chemical measure, however, includes TSS (total soluble solids contents) and acidity of the juice. The juice should have a TSS of 8.5 % or higher. TSS content is determined by squeezing a few drops of juice on a hand-held refractometer.

Skin/Peel Color

This factor is commonly used for the fruits, where skin color changes as fruit ripens or matures and thus it is regarded as a quality index. Huybrechts et al. (2003) reported peel color also acts as a maturity index for some cultivars of apple, which can be used to determine the maturity of the fruit. Peel color is also used for grading in many countries before storage or marketing (Watkins 2003). This is also true that few cultivars exhibit no perceptible color change during maturation (stay green character). Assessment of harvest maturity by skin color depends on the judgment and experience of the harvester. Now color charts are also available for cultivars, such as apples, tomatoes, peaches, banana, and peppers. One more reliable method to measure skin color is optical method. Here, light transmission properties can be used to measure the degree of maturity of fruits in terms of chlorophyll degradation

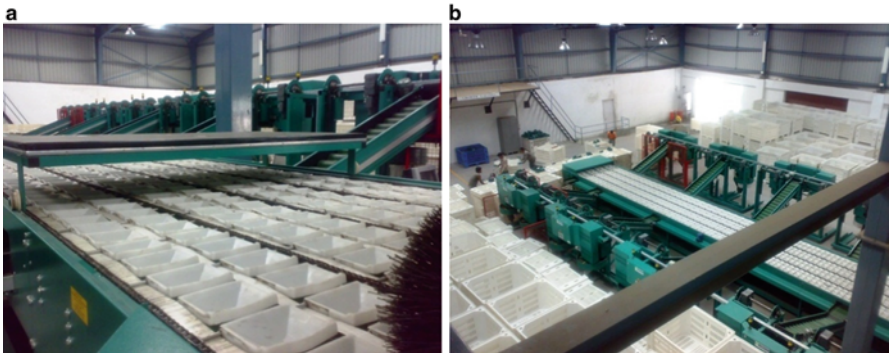

Fig 2.1 (**a**) GREEFA (*close up*); (**b**) GREEFA (*upper view*)

or development of color pigments. This method is based on the principle of reduction in chlorophyll content during maturation and ripening and development of color pigments at harvest maturity. Practically, fruits are allowed to pass through a camera unit, where camera takes 27–50 snaps of individual fruits, process it through CPU, and then put in a color range say above 70 % color, 60–70 % color, etc. One such grader based on optical method is GREEFA (Fig. 2.1a, b) widely used for apple grading all over the world.

Shape

In many fruits and vegetables, shape changes during maturation and thus gives an idea to determine harvest maturity. For instance, a banana fruit becomes more rounded in cross-sections and less angular as it matures on the plant. It is the stage when harvesting of banana is recommended. Mangoes also change shape during maturation. This is evident by comparing the relationship between the shoulders of the fruit and the point at which the stalk is attached changes. The shoulders of immature mangoes slope away from the fruit stalk, but as maturity advances, the shoulders become level with the point of attachment, and with final maturity, the shoulders may be raised above this point (Fig. 2.2a–c). This stage gives maximum yield and better quality attributes upon ripening.

Size

Change in the size of any fruit or vegetable crop while growing is frequently used to determine harvest maturity and quality. It is one of the oldest methods of maturity determination. Size increases as any fresh produce approaches towards maturity. For example, the size of a cauliflower curd or cabbage head increases up to full maturity with compactness in nature. This gives an idea for harvesting a quality curd or head.

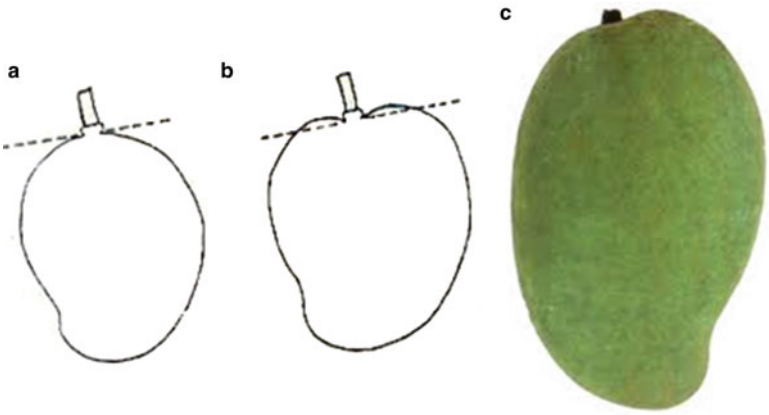

Fig 2.2 (**a**) Immature stage; (**b**) mature stage; (**c**) ideal mature mango

Aroma (Flavor)

Most fruits synthesize volatile compounds as they ripen. Such chemicals give fruit its characteristic odor and can be used to determine whether it is a good quality ripened fruit or not. For example in many instances, consumers bring ripe mango fruit near to nose in order to detect characteristic flavor of mango. This flavor may only be detectable by humans when a fruit is completely ripened, and therefore, this method has limited use in commercial situations.

Leaf/Flowers/Inflorescence Condition Changes

In many cases, leaf quality often determines when fruits and vegetables should be harvested. In root crops, the condition of the leaves can indicate the condition of the crop below the ground. For example, if potatoes are to be harvested for storage, then the optimum harvest time (optimum maturity) is soon after the leaves and stems started drying and most leaves have dried. If harvested earlier, (before yellowing of leaves) the skins will be less resistant to harvesting and handling damages and more prone to storage diseases. The same is true for onion and garlic. In case of banana, dryness of inflorescence at the tip of fingers and disappearance of angularity of fingers are often taken as a maturity index (Fig. 2.3).

Development of Abscission Layer

As part of the natural development of a fruit, an abscission layer is formed in the fruit stalk. For example, in melons, harvesting is done after development of abscission layer. Harvesting before the abscission layer has fully developed results in inferior quality fruit, compared to those left on the vine till abscission layer is developed.

Fig 2.3 Observe dried flowers at the tip of each fingers and disappearance of angularity

Firmness (Flesh Firmness)

The texture or firmness of any fruit changes during ripening and maturation. This is more prominent towards ripening when it losses texture more rapidly. Excessive loss of moisture may also affect the texture of the crops. These textural changes are detected by touch, and the harvester presses the fruits or vegetables gently and can judge whether the crop is ready for harvest or not. This method is widely used in Indian fruit markets for apple. They also judge storable quality by simply pressing with thumb and fingers. This is an experience gained over years by producers, traders, and buyers. Today, sophisticated devices have been developed to measure texture in fruits and vegetables. For example, texture analyzers and pressure testers; they are currently available for fruits and vegetables in various forms. A force is applied on the surface of the fruit (after peeling), allowing the probe of the Penetrometer to penetrate the fruit flesh, which then gives a reading on firmness. Hand-held pressure testers are widely used in apple and pears world over. However, in some cases it could give variable results because the basis on which they are used to measure firmness is affected by the angle at which the force is applied and support to the hand holding the fruit. Table top pressure tester is used in order to minimize the error. Two commonly used pressure testers to measure the firmness of fruits and vegetables are the Magness-Taylor and UC Fruit Firmness. One more instrument is used for this purpose and is called Instron Universal Testing Machine. It is not portable and mainly used in laboratories. Flesh firmness (FF) is the most important quality measurement of apples and pear that has been used to determine optimal storage maturity by private companies. Flesh firmness varies among the cultivars (Watkins 2003).

Juice Content

The juice content of many fruits increases as fruit matures on the tree. To measure the juice content of a fruit, a representative sample of fruit is taken and then the juice is extracted in a standard and specified manner. The juice volume is related to the original mass of juice, which is proportional to its maturity. This method is mostly used in citrus fruits.

Sugars

In climacteric fruits, carbohydrates accumulate during maturation in the form of starch. As the fruit ripens, starch is broken down into sugars. In non-climacteric fruits, sugar tends to accumulate during maturation. A quick method to measure the amount of sugar present in fruits is with a brix hydrometer or a refractometer. A drop of fruit juice is placed in the prism of the refractometer and a reading taken; this is equivalent to the total amount of soluble solids or sugar content in the fruit juice. This method is widely used in grapes in many parts of the world to specify maturity.

Starch Content

Measurement of starch content is a reliable technique used to determine maturity in apple and pear cultivars. The method involves cutting the fruit in two and dipping the cut pieces into a solution containing 4 % potassium iodide and 1 % iodine (Potassium iodide solution). The cut surfaces stain to a blue-black color in places where starch is present. Starch converts into sugar as maturity advances. Harvest should be at the stage when the samples show that 65–70 % of the cut surfaces have turned blue-black leaving only the core (middle) part unstained.

Brix:Acid Ratio

In many fruits, the acidity changes during maturation and ripening, and in the case of citrus and other fruits, acidity reduces progressively as the fruit matures on the tree. Normally, acidity is not taken as a measurement of fruit maturity by itself but in relation to soluble solids, giving what is termed the brix:acid ratio.

Specific Gravity

Specific gravity is the relative gravity, or weight of solids or liquids, compared to pure distilled water at 62 °F (16.7 °C), which is considered unity. Specific gravity is obtained by comparing the weights of equal bulks of other bodies with the weight

of water. In practice, the fruit or vegetable is weighed in air, then in pure water. The weight in air divided by the weight in water gives the specific gravity. This will ensure a reliable measure of fruit maturity. As a fruit matures, its specific gravity increases. This parameter is rarely used in practice to determine time of harvest, but could be used in cases where development of a suitable sampling technique is possible. It is used, however, to grade crops according to different maturities at postharvest. This is done by placing the fruit in a tank of water, wherein those that float are less mature than those that sink.

Methods of Harvesting

There are basically three methods most commonly used for harvesting any fruits or vegetables.

(a) Harvesting individual fruits/vegetables with hand by pulling or twisting the fruit pedicel
(b) Harvesting individual fruits or fruit bunch/vegetables or vegetable bunch with the help of fruit clippers/secateurs/scissors
(c) With harvester specially designed for harvesting

Harvesting Individual Fruits/Vegetables with Hand by Pulling or Twisting the Fruit Pedicel

This is simple and most commonly used method of harvesting. Harvester can easily pick the optimum mature fruits. One important demerit of this method is pulling little peel along with pedicel end renders the fruits for quick spoilage.

Harvesting Individual Fruits, Fruit Bunch/Vegetables, or Vegetable Bunch with the Help of Fruit Clippers/Secateurs/Scissors

This method is an advance form of hand pulling and twisting method. Here, fruit stalk is cut close to the point of attachment of fruit, leaving a very small portion of pedicel attached with fruits. This is highly accepted and widely used in almost all citrus fruits. Postharvest quality is found better in this method compared to any others. One important precaution should be in cutting fruit stalk close to the fruit; otherwise, the part of pedicel attached with fruit may puncture other healthy fruits during subsequent handling and marketing. Fruits born in bunch like grapes are harvested with scissors or secateurs.

Mechanical Harvesting

This method is used on commercial scale and specially designed machines are only used. Fruits and vegetables get more damage with harvester and quality deteriorates rapidly. Therefore, it is advisable to use harvester where harvested produce are intended to use for processing. This is most economic method of harvesting for processing grade fruits and vegetables.

Tools for Harvesting and Assembling

Postharvest quality also depends on the tools used for harvesting fresh produce. It is because faulty tools also affect quality. Depending on the type of fruits or vegetables, several tools are employed to harvest the produce. Commonly used tools for harvesting of fruit and vegetable are secateurs, scissors, fruit clippers, knives, and hand-held or pole-mounted picking shears. When fruits or vegetables are difficult to catch with hand, such as mangoes or avocados, a pole mounted with picking shear or scissors is used. Harvested fruits are collected in a bag attached with the pole itself. Where there is no provision of collecting in bags, fruits are allowed to fall on the ground directly or on a net above the ground or on a sheet of gunny bags or some cushioning material is placed on the ground just beneath the tree to prevent damage to the fruit while directly hitting the ground. Harvesting bags with shoulder or waist slings can also be used for fruits with firm skins, like citrus and avocados. They are easy to carry and leave both hands free for climbing, harvesting, and assembling. Harvested produce are assembled in a container before sorting, grading, and packing. These containers too influence the quality. Plastic containers such as crates, buckets, and bins are suitable containers for assembling harvested produce. These containers should be of enough strength and smooth without any sharp edges that could damage the produce. Additionally, cushioning materials should be used in order to reduce bruising. Commercial growers use plastic crates and bulk bins with varying capacities and crops such as apples and cabbages are placed and sent to packing houses for selection, grading, and packing or directly to market. Gunny bags, plastic bags, and Hessian bags are used for vegetables like potato, onion, garlic, etc.

Time of Harvesting

Harvesting time also affects quality. Fruits harvested before 10 AM in the morning and transported to pack house for sorting, grading, and packing yield better quality and lasts longer. Therefore, morning harvesting and within 10 AM transportation to destination pack house or market is always preferred in order to control damage due to high temperature. In case of grapes harvesting in India, it starts at 6 o'clock in the morning and harvested produce reach pack house by 10 AM. It facilitates faster precooling also and yield better quality.

Precooling

The quality of fresh fruits and vegetables largely depends on precooling before storage and marketing. This is a compulsory postharvest treatment followed in developed countries for almost all perishable commodities. The rapid cooling of fresh produce from field temperature (pulp temperature at the time of harvesting) to its best storage temperature is called precooling. It is an important postharvest operation recommended in almost all flowers, fruits, and few vegetables. The main objective of any precooling operation is to remove field temperature (field heat). This is important because it increases shell life of the produce. Removing field heat reduces rate of respiration and all biochemical reactions from newly harvested produce. Since fruits, vegetables, and flowers are still alive after harvest, the produce continues to respire. Respiration results in produce deterioration, including loss of nutritional value, changes in texture and flavor, and loss of weight. These processes cannot be stopped, but they can be slowed down significantly by precooling before storage or distribution. Generally, the higher the respiration rates of a fruit or vegetable, the greater the need for postharvest precooling. Precooling also reduces disease incidence. Wet or damp produce must be cooled, as warm, wet produce creates an environment that encourages the growth of decay organisms. Precooling facility is usually erected within pack house premises and it is the responsibility of grower-shipper or pack house owner. The four basic methods of precooling can be applied based on the texture and sale value of the product. These are forced air, hydro cooling, vacuum cooling, and icing. Each method was developed with specific crops in mind. For each crop, it is critical to know how to handle the produce at harvest, whether precooling is necessary, and which one is the best method of cooling. Forced air cooling is the most common and widely used method of precooling. Cost, easiness, and maintenance are also important considerations when you select a precooling method.

Forced Air

In this method, cool air with high speed moves over a product to remove the field heat. Both packed and unpacked fruits and vegetables can be precooled. Inside precooling chamber, fans pull hot air through the produce boxes and back into the cooling unit and this process continued till desired temperature is not achieved. During precooling, weight loss is expected. When a room is designed for pre cooling, it must be equipped with enough refrigeration capacity and proper humidity control. These steps can prevent excess weight loss. Forced air units are affordable for many small-scale growers and traders. An existing cold room can be augmented into precooling chamber by making use of portable fans, wooden or plastic pallets, and tarps. Line up two rows of produce and set up a fan to draw air down the aisle between the rows. Cover the aisle with a sturdy tarp to force the system to draw air through the boxes of produce. Forced air cools most commodities effectively, but those best adapted to this method include berries, stone fruits, and mushrooms.

Hydro Cooling

Hydro cooling cools produce with chilled water. Hence, packed fruits are difficult to cool by this method. The water usually is cooled by mechanical refrigeration, although cold well water and ice sometimes are used. The size of hydro cooling units varies depending on the size of the operation, but considerable refrigeration or large quantities of ice are required to keep the water at the desired temperature of 33–36 °F. The produce is cooled by a water bath or sprinkler system. The produce either is dumped in the bath or under the sprinkler or is left in bins or plastic crates. Small operations might have an ice-water tank in which to "stir" the vegetables for rapid cooling. Pay special attention to water quality. Unfiltered and unsanitized water can spread undesirable microorganisms.

Most vegetables and many fruits that can withstand wetting can be hydro cooled. Asparagus, celery, cantaloupes, green peas, leaf lettuce, peaches, radishes, and sweet corn can be cooled successfully with this method.

Vacuum Cooling

This method of precooling is based on the principle of "water evaporates at a very low temperature if pressure reduced" and maintained to a desired level. Vacuum cooling is one of the more rapid cooling systems and cooling is accomplished at very low pressures. At a normal pressure of 760 mmHg, water evaporates at 100 °C, but it evaporates at 1 °C if pressure is reduced to 5 mmHg. Produce is placed in sealed containers where vacuum cooling is performed. This system produces about 1 % product weight loss for each 5 °C of temperature reduction. Modern vacuum coolers add water as a fine spray in the form of pressure drops. Similar to the evaporation method, this system is in general used for leafy vegetables because of their high surface-to-mass ratio (Table 2.2). Produce is placed in a specially designed room, and air pressure is reduced. At lower atmospheric pressure, some water from the produce evaporates as the produce uses its own heat energy to convert water into water vapor. This lowers the temperature of products. Heat and moisture are removed from the vacuum tube by mechanical refrigeration. Commercial vacuum units usually cool the product to the proper storage temperature in less than 30 min. Units are available for cooling different amounts of product, from two pallets to a full truckload. Since initial investment and maintenance cost is high, this method is not commercialized on large scale.

Table 2.2 Vegetables (leafy vegetables) suitable for vacuum cooling

Belgian endive	Chinese cabbage	Kohlrabi	Spinach
Broccoli	Carrot	Leek	Sweet corn
Brussels sprouts	Escarole	Parsley	Swiss chard
Cantaloupe	Green onions	Pea/snowpeas	Watercress

Source: Sargent et al. (2000), McGregor (1987)

Table 2.3 Fresh produce suitable for ice cooling

Belgian endive	Chinese cabbage	Kohlrabi	Spinach
Broccoli	Carrot	Leek	Sweet corn
Brussels sprouts	Escarole	Parsley	Swiss chard
Cantaloupe	Green onions	Pea/snowpeas	Watercress

Source: Sargent et al. (2000), McGregor (1987)

Icing

Crushed or slurry ice is placed directly into the produce box. This can be an effective way of precooling individual boxes of certain vegetables. The produce can be cooled in a short time and the temperature could be maintained in transit also. Fresh produce that can be ice are listed below in Table 2.3.

Sorting and Grading

This is one of the most important postharvest operations after harvesting. This is done primarily for quality packing and removal of diseased and defective produce from the lot. Proper sorting and grading gives assurance of quality produce. This is either done in the farmer's field or in the pack houses. Both manual and mechanical graders are used for grading. All round-shaped fruits and vegetables are easily graded by mechanical graders. Grading may be based on color, size, and extent of defects, while sorting is totally dependent on man power for removal of diseased, defected, and damaged fruits or vegetables. Grading is done by simple to highly sophisticated graders. Today, many sophisticated graders are in use for fresh produce such as *GREEFA*. Both size and color grading simultaneously is possible and is being used on commercial scale in apples.

Packaging, Packaging Materials, and Pallatization

Both packing and packaging materials play many important roles in quality maintenance of fresh produce. Packing starts with placing the produce in the box. While placing, care must be taken to place in line, pedicel end of all fruits should be in one direction, separation layers or trays must be used where it is necessary. The box should not be underfilled or overfilled. Overfilling is generally noticed in India where a farmer fills more in a box beyond the capacity of the box designed by the manufacturer. They do this primarily for two reasons: (a) *Demand by the commission agent* (*Traders*)—It was observed that those lots containing more weight in a box priced more.

In general, all apple boxes are designed for 20 kg but it contains 22–23 kg, and in many cases it is found 25–30 kg is found, where the capacity is only 20 kg (Ahmad et al. 2014). This results in heavy touching marks and bruising during handling; (b) *To save the cost of packing and transportation*—Farmers want to save something immediately and he/she calculates the cost of empty boxes, packing charges, handling and transport charges by saving number of boxes, and to do so they prefer overfilling. The practice results in damage and touching (pressure marks) in almost all fruits. The type of boxes and quality in terms of strength and ventilation of each boxes play very important role in maintaining quality of any fresh produce. A number of boxes are used for packing fresh produce such as bamboo baskets, wooden boxes, CFB boxes, and thermocol boxes. Among them, CFB boxes are most common and widely used all over the world. However, quality in terms of strengths, printability, and perforations varies from country to country and even region to region within the country.

In India, Himachal and J&K farmers use CFB boxes of very weak strength (3-ply) for packing apple, pear, and few stone fruits. These boxes generally become very loose or even torn during transportation from Himachal or Kashmir to various wholesale markets (APMC Azadpur, Delhi, Chandigarh, etc.) of India. Just to strengthen these boxes, buyers or forwarding agents prefer wrapping of boxes by thin plastic ropes. The idea is to give little strength to these boxes during further transportation.

Wooden boxes are the second most important packing boxes widely used in many countries including India. However, unavailability and cost of wooden box is a concern during peak season. Government regulations also discourage the use of wooden boxes for sake of trees. Bamboo baskets with gunny bags are also in use for less value crops. Repackaging of fruits and vegetables is common when the product has been packed in large containers, such as sacks, CFB boxes, and plastic containers. The repackaging process is often carried out by repackers, who open the box, regrade, and again pack in the same box. During repacking, any damaged or rotting fruit is found, it is thrown away. It gives the product an appearance more appealing to consumers.

Use of Cushioning Materials

Cushioning materials are used in many stages during postharvest handling operations. But there are three main stages, where it becomes compulsory in order to maintain postharvest quality. The first stage is putting harvested produce into plastic crates or any rigid container. All crates have hard surfaces and while keeping produce inside, there is a chance of dropping off from little height, causing impact bruising popularly called touching marks. The second stage is transportation from field to pack house. In general, plastic crates are used for transportation from field to pack house and the distance may vary from few kilometers to many kilometers.

Based on the condition of roads, there would be impact and vibration bruising; these bruising may not be visible immediately, but after few days, browning or blackening symptoms develop and finally produce starts rotting.

Cushioning materials if used in plastic crates reduce these bruising and touching marks drastically. The third stage is transportation of packed produce from pack house to destination markets. Loading, unloading, and transportation jerks causes bruising. Therefore, it is recommended to use cushioning material to preserve postharvest quality of fresh produce. There may be many types of cushioning materials such as newspaper sheets, newspaper cuttings, rice straw, bubble sheet, specially designed foam nets, moulded trays, gunny bags, leaves, khaskhas, and other locally available material.

Storage

Almost all fruits are seasonal in nature. Every year, harvesting season falls during a fixed period, say 2–3 months. This period may differ from state to state for the same fruit and for different fruits also. For example, in India, apple harvesting season falls from July to October in Himachal Pradesh and from August to November in J&K every year. This may be little early or late due to prevailing weather conditions during growing periods. Demand for many fruits and vegetables are round the year. The demand of any fruit or vegetable beyond the harvesting season is called off-season demand. This demand can be fulfilled only if fruits are stored in the harvesting season and sold during off-season. The management of temperature, ventilation, and relative humidity are the three most important factors that effect postharvest quality and storage life of horticultural produce. There may be many objectives of storage but the main objectives are:

- To minimize glut and distress sale in the market, thus assuring good price to the farmers.
- To insure availability of food in off-season.
- Save horticultural produce from being spoiled.
- Storage in season when cost of produce is relatively low and marketing in off-season at a better price. This gives higher returns to growers and traders.
- To regulate the price of the commodity during season and also in off-season.
- Mostly apple, pear, grapes, potato, onion, and chilli are stored in large quantities to feed the market round the year.

Lowering the temperature to the lowest safe level is of paramount importance for enhancing the shelf life, reducing the losses, and maintaining fresh quality of fresh produce. For example, mango needs a temperature above 8 °C, banana above 12 °C, apple 1–2 °C, etc. The safe temperature of few important fruits and vegetables are mentioned in Table 2.4

Table 2.4 Optimum storage temperature of few important fruits and vegetables

Crop	Optimum temperature (0 °C)	Relative humidity (%)
Apple	1–4	90–95
Apricot	−0.5 to 0	90–95
Artichoke	0	95–100
Asian pear	1	90–95
Asparagus	0–2	95–100
Avocado	3–13	85–90
Banana	13–15	90–95
Broccoli	0	90–95
Brussels sprouts	0	90–95
Brinjal	8–12	90–95
Cabbage	0	98–100
Carrot	0	95–100
Cassava	0–5	85–96
Cashew apple	0–2	85–90
Cauliflower	0	95–98
Celery	0	98–100
Cherimoya	13	90–95
Cherries	−1 to 0.5	90–95
Coconut	0	80–85
Cucumber	5–10	90–95
Custard apple	5–7	85–90
Dates	−18 to 0	75
Fig	−0.5 to 0	85–90
Garlic	0	65–70
Ginger	13	65
Grape	−0.5 to 0	90–95
Grapefruit	10–15	85–90
Green onions	0	95–100
Guava	5–10	90
Jack fruit	13	85–90
Kale	0	95–100
Kiwi fruit	−0.5 to 0	90–95
Lemon	10–13	85–90
Lettuce	0–2	98–100
Lima bean	3–5	95
Lime	9–10	85–90
Longan	1–2	90–95
Loquat	0	90
Lychee	1–2	90–95
Mandarin	4–7	90–95
Mango	13	90–95
Mangosteen	13	85–90

(continued)

Table 2.4 (continued)

Crop	Optimum temperature (0 °C)	Relative humidity (%)
Melon (Others)	7–10	90–95
Mushrooms	0–1.5	95
Nectarine	−0.5 to 0	90–95
Okra	7–10	90–95
Onions (dry)	0	65–70
Olives, fresh	5–10	85–90
Orange	0–9	85–90
Papaya	7–13	85–90
Parsley	0	95–100
Parsnip	0	95–100
Passion fruit	7–10	85–90
Peach	−0.5 to 0	90–95
Pear	−1.5 to 0.5	90–95
Peas	0	95–100
Pepper (bell)	7–13	90–95
Persimmon	−1	90
Pineapple	7–13	85–90
Pitaya	6–8	85–95
Plum	−0.5 to 0	90–95
Pomegranate	5	90–95
Potato (early)	7–16	90–95
Potato (late)	4.5–13	90–95
Prickly pear	2–4	90–95
Pumpkins	10–15	50–70
Quince	−0.5 to 0	90
Radish	0	95–100
Rambutan	10–12	90–95
Raspberries	−0.5 to 0	90–95
Rhubarb	0	95–100
Sapodilla	15–20	85–90
Scorzonera	0	95–98
Snapbeans	4–7	95
Snowpeas	0–1	90–95
Spinach	0	95–100
Sprouts	0	95–100
Strawberry	0–0.5	90–95
Sweet corn	0–1.5	95–98
Sweet potato	15–20	85–90
Swiss chard	0	95–100
Summer squash	5–10	95
Tamarind	7	90–95
Taro	7–10	85–90

(continued)

Table 2.4 (continued)

Crop	Optimum temperature (0 °C)	Relative humidity (%)
Tart cherries	0	90–95
Tomato (MG)	12.5–15	90–95
Tomato (red)	8–10	90–95
Tree tomato	3–4	85–90
Turnip	0	90–95
Watermelon	10–15	90
White sapote	19–21	85–90
Yam	16	70–80
Yellow sapote	13–15	85–90

Source: Cantwell (1999), Sargent et al. (2000), McGregor (1987)

Special Treatments (Curing)

Most root crops don't need curing before being placed in the storage chamber. Therefore, these crops should not be exposed to sunlight. Potato, for example, turns green and become toxic if exposed to sun. However, few root crops require curing before storage for proper quality maintenance during storage and subsequent marketing. Potato also requires curing for peel hardening and wound healing (suberization) under shade. Onion and garlic require at least 1 week curing process to dry out outer scaly leaves and tightening of neck portion. Pumpkin and squash need about 2 weeks curing to harden their skin before storage. Don't skip curing where it is required as curing affects quality.

Do's and Don'ts for Storage of Fresh Produce

- Store only high-quality produce, free of damage, decay, and of proper maturity (not overripe or undermature).
- Know the requirements for the commodities you want to put into storage, and follow recommendations for proper temperature, relative humidity, and ventilation. Never store carrot with apple or any fruit that releases ethylene gas because carrot is very sensitive to ethylene and develops bitterness due to formation of a compound called Iso-coumarin.
- Avoid lower than recommended temperatures in storage, because many commodities are susceptible to low temperature injury called freezing or chilling.
- Do not overload storage rooms or stack boxes tightly; it will hinder air movement through all boxes. Air follows the same path or easiest path if not blocked.
- Boxes should be stored on perforated wooden racks specially designed for air movement.

- Provide adequate ventilation in the storage room by keeping little space between two stack lines. Boxes should not be stored on the passage kept for the movement of staffs and labors.
- Storage rooms should be protected from rodents by keeping the immediate outdoor area clean and free from trash and weeds.
- Containers/Boxes must be well-ventilated and strong enough to withstand stacking. Do not stack boxes beyond their stacking strength.
- Monitor temperature in the storage room by placing thermometers at different locations.
- Don't store onion or garlic in high humidity environments.
- Control Inspect/Pest/rodents population inside the store.
- Check your produce at regular intervals for any sign of damage due to insect/pest/water loss, ripening, shriveling, etc.
- Remove damaged or diseased produce to prevent the spread of pathogens.
- Always handle produce gently and never store produce unless it is of the best quality.
- Damaged produce will lose water faster and have higher decay rates in storage as compared to undamaged produce and must be removed.

It is advisable not to store different crops together in one room of any cold store. But practically, it is very difficult to maintain and in some cases it is unavoidable, particularly at distribution or retail levels. A strategy widely practiced is to set cold chambers at an average of around 2–5 °C and 90–95 % relative humidity, irrespective of specific requirement. Frequent opening and closing of cold store chamber for product loading and unloading causes an increase in temperature and decrease in relative humidity. Therefore, it is advisable for specific chambers for specific products.

Thompson et al. (1999) recommended three combinations of temperature and relative humidity (RH): (1) 0–2 °C and 90–98 % RH for leafy vegetables, crucifers, temperate fruits, and berries; (2) 7–10 °C and 85–95 % RH for citrus, subtropical fruits, and fruit vegetables; (3) 13–18 °C and 85–95 % RH for tropical fruits, melons, pumpkins, and root vegetables. Storage of compatible groups of fruits and vegetables together (requires same temperature and RH) is advisable and necessary. Otherwise, quality of one produce affects the quality of other produce. Some fruits or vegetables can be stored together due to their common temperature and relative humidity requirements. At the same time, its reverse is also true. An overview of storage of compatible groups of fruits and vegetables is listed in Table 2.5.

Types of Storage

There are many types of storage system or structure, starting from as simple as field storage to as sophisticated as Controlled atmosphere and hypobaric storage. Among field storage, heap, cellar, underground tunnels or rooms, RCC rooms, and evaporative cool chamber or Zero Energy Cool Chamber (ZECC) systems are important.

Table 2.5 Compatibility groups of fruits and vegetables that can be stored together

Group	Temperature	Crops	Status of commodities
Group 1	0–2 °C and 90–95 % RH	Apple, Apricot, Asian Pear, Grapes, Litchis, Plum, Prunes, Pomegranate, Mushroom Turnip Peach	Produce ethylene
Group 2	0–2 °C and 90–95 % RH	Asparagus, Leafy greens, Broccoli, Peas, Spinach, Cabbage, Carrot, Cauliflower, Cherries	Sensitive to ethylene
Group 3	0–2 °C and 65–70 % RH	Garlic, Onions dry	Moisture will damage these crops

Source: Thompson et al. (1999)

ZECC is an important on-farm storage structure based on the principle of evaporative cooling for fresh produce for short-term storage (Roy and Khurdiya 1986; Pal et al. 1997). Among advanced and technologically superior, modern cold storage, Controlled Atmosphere storage and hypobaric storage are important. There are some basic requirements in all types of field storage which are summarized below.

Natural Ventilation

Among all field storage systems, natural ventilation is required. Due to this natural airflow around the product, heat is removed regularly. Produce is placed in heaps, bags, boxes, bins, pallets, etc. Problems of pest and rodents are severe in field storage. Therefore, there must be adequate provision to keep out animals, rodents, and pests. Another problem of field storage is development of hot and humid condition within the storage facility. This creates ideal conditions for the development of disease. It is possible to regulate temperature and relative humidity up to certain extent by opening and closing storage ventilation. At noon, ambient temperature increases and relative humidity decreases except rainy days. However, at night the opposite happens. To reduce the temperature of stored products, buildings ventilation should be left open at night when external air temperatures are lower.

Forced-Air Ventilation

Heat and gas exchange can be improved in a store room provided air is forced to pass through the stored produce. This system allows for more efficient cooling and control over temperature and relative humidity. Electric power facility is compulsory for forced air ventilation. As air follows the path of least resistance, loading patterns as well as fan capacity should be carefully calculated to ensure that there is uniform distribution of air throughout the stored produce. Inlet and exhaust fan can drag night cool air inside the chamber where difference in night and day temperature is more.

For modern cold stores, forced air ventilation is compulsory. This requirement is fulfilled by cooling fans. For smooth ventilation, perforated wooden floors for multi-storey cold stores and plastic or wooden plates for a single room are necessary. For Controlled Atmosphere Storage (CA) and hypobaric storage, fresh produce is stored in perforated plastic bins and crates and staked little away from the wall and door. This arrangement allows air movement through the produce.

Temperature and Relative Humidity

Since fruits, vegetables, and flowers are alive after harvest, all physiological processes continue after harvest such as respiration and transpiration (water loss), and supply of nutrient and water is not possible since produce is no more attached to the parent plant. Respiration results in produce deterioration, including loss of nutritional value, changes in texture and flavor, and loss of weight by transpiration. These processes cannot be stopped, but they can be reduced significantly by careful management of temperature and relative humidity during storage and transportation. Growth and multiplication of microorganism responsible for rotting and spoilage are also associated with low temperature. At sufficiently low temperature, many disease-causing microbes stop growth and multiplication. Respiration rates vary tremendously for different products. It can also be affected by environmental conditions, mostly by temperature. As a thumb rule, lower the temperature, the slower will be its respiration rate and the growth of decay organisms. According to Van't Hoff Quotation (Q10), the rate of deteriorative reactions doubles for each 10 °C rise in temperature. Generally, the higher the respiration rates of a fruit or vegetable, the greater the need for postharvest cooling.

Water is the main component found in fruits and vegetables. An important factor in maintaining postharvest quality is to ensure that there is adequate relative humidity inside the storage area. Water loss or dehydration means a loss in weight, which in turn affects the appearance, texture and, in some cases, the flavor also. Water loss also affects crispiness and firmness. Consumers tend to associate these qualities as poor with recently harvested fresh produce. For most fresh produce, relative humidity of about 90–95 % is recommended for storage and transportation. Since transportation period is only few hours to days, maintenance of RH is not of much importance except for leafy vegetables. But in storage, maintenance of RH is compulsory. In modern cold stores, humidifiers are used for humidity generation. The recommended temperature and humidity for fruits and vegetables are mentioned in Table 2.3.

Controlled atmosphere storage (CA) is a system of storage of fresh produce in an atmosphere that differs from normal atmosphere in respect to CO_2 and O_2 levels. At the time of loading in a CA chamber, levels of CO_2 and O_2 are similar to normal air. With the passage of time, the gas mixture will constantly change due respiring fruits and vegetables in the store. Leakage of gases through doors and walls is not allowed in any CA chamber. Once the predetermined levels of CO_2 and O_2 are achieved, it is constantly monitored. It is recommended that after loading, the chamber should be

Table 2.6 Examples of CO_2 injury in controlled atmosphere (CA) storage

Crop and cultivars	CO_2 injury level (%)	CO_2 injury symptoms	O_2 injury level	O_2 injury symptoms
Apple, red delicious	>3	Internal browning	<1 %	Alcoholic taste
Apple, Fuji	>5	CO_2 injury	<2 %	Alcoholic taint
Apple, Gala	>1.5	CO_2 injury	<1.5 %	Ribbon scald
Apricot	>5	Loss of flavor	<1 %	Off-flavor
Banana	>7	Green fruit softening	<1 %	Brown skin, discoloration
Green beans	>7	Off-flavor	<55	Off-flavor
Cabbage	>10	Discoloration of inner leaves	<25	Off-flavor
Cherry	>30	Brown, discoloration	<1 %	Skin pitting, off-flavor
Mango	>10	Softening	<2 %	Skin discoloration

Source: Thompson (1998)

closed and desired level of gas composition should be established within 48 h with the help of Nitrogen generator. The gases are then measured periodically and the levels maintained by introduction of fresh air or passing the store atmosphere through a chemical to remove excess build up of CO_2. Selection of the most suitable atmosphere depends on cultivars, stage of maturity, and environmental and cultivation parameters. No one atmosphere is best for all produce. If the level of CO_2 increases or O_2 decreases, an anaerobic condition may prevail with the formation of alcohol and physiological changes take place referred to as CA injury. Some examples of CA injury are mentioned in Table 2.6.

Several refinements in CA storage have been made in recent years to improve quality maintenance. These refinements include creating nitrogen by separation from compressed air using molecular sieve beds or membrane systems, rapid CA (rapid establishment of optimal levels of O_2 and CO_2), etc. All these refinements are for quality maintenance and to increase the length of storage period. Application of CA to all fresh produce is not found cost-effective, and therefore, commercially not exploited. Commercial use of CA storage is maximum on apples and pears worldwide and less on cabbages, sweet onions, kiwi fruits, avocados, persimmons, pomegranates, and nuts and dried fruits and vegetables (Kader 1986). Classification of fresh produce according to their CA storage potential at optimum temperatures and RH is mentioned in Table 2.7

Transportation and Transport Vehicle

Transportation may be a connecting link between producers and consumers. It holds key factor in postharvest quality maintenance of all fresh produce. Most fresh produce in India and other countries of the world is transported from farmers' field to

Table 2.7 Shelf life of few important fruits and vegetables in controlled atmosphere storage (CA)

S. no.	Storage duration (months)	Crops
	>12	Almond, Brazil nut, cashew, filbert, macadamia, pecan, pistachio, walnut, dried fruits, and vegetables
	6–12	Some cultivars of apples and European pears
	3–6	Cabbage, Chinese cabbage, kiwi fruit, persimmon, pomegranate, some cultivars of Asian pears
	1–3	Avocado, banana, cherry, grape (no SO_2), mango, olive, onion (sweet cultivars), some cultivars of nectarine, peach and plum, tomato (mature-green)
	<1	Asparagus, broccoli, cane berries, fig, lettuce, muskmelons, papaya, pineapple, strawberry, sweet corn; fresh-cut fruits and vegetables; some cut flowers

Source: Kader (1986)

nearby market or wholesale market and from wholesale market to terminal market up to final retailers' shops in open and non-refrigerated vehicles. Only few reputed firms use refrigerated vehicles for transportation and distribution in summer months only, starting from March to May/June in India. It is mainly due to the increased cost of transportation by reefer van. In open truck vehicles (Non-reefer), produce is always susceptible to a loss of quality. Ambient temperature alone spoils the produce. Other means of transport include rail transport (A/C and non A/C), air, and ship. All imported fruits are transported in A/C containers by ships only. In every country, a dedicated port is assigned for receiving and dispatch of fresh produce containers. In India, a large number of fresh produce containers are received at Mumbai and Chennai port.

After harvest, a number of vehicles (trucks, tractors, trains, boats, ships, utility vehicles, etc.) are used to transport the product from field to either packing houses or whole sale or retail markets. These vehicles are not equipped with refrigeration units and thus the produce decays faster, compared to that in refrigerated vehicles. If the produce is treated with edible wax or chemicals or additives after harvest, it can withstand little longer distances in open vehicles (non-reefer), without much damage. Refrigerated vehicles (trucks, trains, ships, airplanes, etc.) contain installed refrigeration units with sufficiently low temperatures to maintain freshness in fresh produce. These types of vehicles are sealed with insulation material inside the walls of the container, which maintains the inside container temperature at desired level and thus preserves maximum quality.

Fruits and vegetables must be classified in order to separate those susceptible to cold temperatures (mango, banana, tomato, etc.) and those not (apple, pear, cauliflower, peppers, etc.). This eliminates the possibility of product damage (chilling and freezing injury) when cooling at low temperatures during transport. Refrigeration temperatures can vary from 0 °C (32 °F) to 13 °C (55.4 °F) and RH from 70 to 95 %. Reefer van transport is an example of temporary refrigerated storage. Mixed loads cause incompatibility problems in transport also because packaging dimensions are

different for different produce and it is not fully stackable. It is therefore not advisable to transport mixed lots for long distance. However, for short distance, there may not be any problem.

There is usually little or no humidity control available during transport and marketing. Thus, the packaging must be designed to provide a partial barrier against movement of water vapor from the product. Plastic liners designed with small perforations to allow some gas exchange may be an option.

Road Condition and Duration of Transportation

Both road condition and duration of transportation affect quality of fresh produce. In hilly tracks and rough road surface, more touching and bruising take place as compared to smooth surface. Longer duration during transportation also affects quality. Reefer van should not be hold unnecessary. It not only increases the cost of produce, but also affects quality.

Pattern of Loading

Pattern of loading also plays crucial role in maintaining quality of fresh produce. Here pattern of loading means number of packed boxes in one layer (stacking height). In case of fresh produce, stacking height depends on extent of perishable nature of packed commodities and strength of packing materials. If produce are more perishable or box strength is weak, stacking height is kept low and vice versa.

For example, height of grape boxes is kept low or it is packed in five ply corrugated boxes or thermocol boxes. This precaution must be taken to preserve postharvest quality of this highly perishable commodity. While loading, another important criteria is interlocking between the boxes. Loading and unloading fruits and vegetables directly affect quality of fresh produce. It can be done either by hand or with the aid of a forklift. Forklift is used for palletized boxes and shipping containers only. Generally, fruits and vegetables are stacked on pallets to ease the loading and unloading process and to prevent damage to the product and packages. Export/Import commodities arrive at the port in containers and are unloaded directly into the vehicle with the aid of conveyor belts connected from the vehicle to the container (Fig. 2.4a–c).

Another important consideration while loading as discussed above is interlocking systems of loading. In this system, a little space is left in each layer on alternate basis (once in left side and once in right side). This facilitates air movement through the produce and provides strength to the boxes during transportation. Exposure to sun while awaiting loading at local mandis or transport can reduce quality drastically. The exposed portion turns black or brown and starts decaying. It is advised for non-reefer transport to move continuously while under sunlight and stop and park your vehicle under a tree shade, especially during sunny days.

Fig 2.4 (**a**) Reefer container; (**b**) inside view of a reefer container; (**c**) ship loaded

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Chapter 3
Factors Affecting Marketing of Fruits

Introduction

The sale price and consumers acceptability of fruits depend on various factors. These factors affect the sale volume and brand promotion. The major factors are described below, which affect domestic sale volume and price.

Quality Factors

Factors affecting quality of fruits are more or less same in all domestic fruits of developing countries. Here factors in Indian context are described. These factors are:

Color Mixing

There are quality grades in all fruits sold in India. However, the grades are not well defined and not followed strictly. For example, there are three grades of apple sold in domestic markets and their color varies from grade to grade. The color of A-grade apple varies between 70 and 100 %, B-grade 50–70 %, and C-grade 0–100 %. A common malpractice prevalent in mandi is color mixing in both A- and B-grade apple boxes. The innermost two layers possess less color and top two layers are full of red color apples. This practice is followed in all fruits and vegetables where color is a quality parameter and it affects overall quality of a lot and its price. During auction sale or any form of sale, only upper layer fruit color is visible or up to second layer, but inner layers are not visible.

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_3

The Commission agents[1] or sellers who open the box and show upper layers only. This practice is followed by growers and loaders, sub-wholesalers, and even mashakhors[2] (Seller of few boxes directly to the retailers of consumers). The buyers try to see the inner layers before purchasing. In few cases, buyers evaluate the color mixing after purchasing also, and if found very less color with respect to upper layer, buyer may return it to commission agent from where he purchased the lots or asks claim for sale price reduction. The same color mixing can be noticed in all fruits where color is a parameter of quality, e.g., Kinnow, Nagpur oranges, Cherry, Tomato, etc.

Quality Mixing

Quality mixing is a routine and one of the most common malpractices affecting sale value of fruits. Low-grade fruits are always packed in the lower layers and good quality on the upper layers so that the buyers can see only the best quality of the upper layers. In good-quality apple/pear/sapota boxes, low quality, small size, and droppings are also mixed and packed. These low-quality apples are packed at lower layers of apple boxes, which are not judged easily.

In some cases, buyers open both sides (lower and upper), front, back, and full five layers before purchasing the lot. In case of grapes, quality varies with respect to size, water berries, disease infestation (powdery mildew and mealy bug), sunburn, etc. During packing, these bunches are kept in the bottom layers and good-quality bunches are packed at the top layers only as top coverings. Thus, whole box quality seems to be good when displayed, but actually the top layer quality is not in the whole box. Even loose berries are packed in the lower layer. This practice ultimately affects the overall quality of a box or a lot. The buyers who know this practice try to see the lower portion of the box through the corners or side of the boxes. The same case is with other fruits also.

Size Mixing

Size mixing is similar to quality mixing and this is also a very common malpractice among the growers, wholesalers, and sub-wholesalers. As a thumb rule, medium and large size fruits fetch higher price than oversized and undersized fruits.

[1] Commission agents are basically the seller of any fruit mandi and possess one shop and mandi license. They sell all fruits and vegetables booked to their shops on behalf of growers/pre-contractors. Theye charge their commission and labor charges from growers/pre-contractors.

[2] Mashakhors are those who acts as sub-wholesalers and who buy the produce either from commission agents or from wholesalers and sell directly to retailers or consumers. Sale quantity is not a problem for them. They used to sell even one box.

Therefore, undersized fruits are packed with medium-sized fruits and extra large fruits are packed with oversized fruits. In case of grapes, size means berry size in a bunch. Generally, bunches with small size berries are kept at the bottom of the box and good berry size bunches are kept on the top layers.

Size mixing ultimately affects the overall quality of a box or a lot and also selling price. Buyers, while purchasing any lot, try to see the size of fruits placed at the lower most layers before his or her decision to purchase. In case of two- and three-layer boxes, both quality and size mixing chances are minimized drastically as here it is easy to see the quality of bottom layers. This is one of the reasons that two-layer fruit boxes fetch more price than five-layer boxes of the same fruit.

Harvesting, Packing, and Ripening Problems

Immature Harvesting

Harvesting stage of any fruit or vegetable has a major impact on both quality and freshness. The fruits are often harvested immature and at the wrong time of the day. This generally happens to catch the early market when market price is high for that particular commodity. Immature harvesting of apple and mango is a common practice in order to catch the early market. This practice is very much prevalent in case of fruits and such fruits cannot be stored and transported to 7–8 days journey in non-reefer van.

According to Siddiqui and Dhua (2010) and Ahmad et al. (2014), maturity always plays a considerable influence on the quality of fresh produce as well as the storage potential and occurrence of many storage disorders. If immature fruits are sent to distant market, they start rotting during the journey itself, and in some cases cost of transportation is difficult to recover. Immature harvesting affects quality at a greater extent than any other factors.

Application of Ethephon

Application of ethephon on standing crop of apple is very common by apple growers to improve color aiming to fetch higher price in the market. As a thumb rule in mandi, more red-colored apple will fetch more prices and vice versa. Indian consumers prefer apples that are red, sweet, crunchy, and uniform in shape (Venkataraman 2011). However, these apples are not suitable for storage. It should not be stored in Controlled Atmosphere Storage (CA) and also normal cold storage. Application of ethephon initiates color development but also initiates ripening and hence not suitable for storage. Naturally developed red color is also taken as a maturity index for some cultivars of apple and can be used to determine the maturity of the fruit (Huybrechts et al. 2003).

Table 3.1 The fruits and countries where calcium carbide is used for artificial ripening of fruits

Fruits	Countries
Mango	Brazil, Costa Rica, India, Malaysia, Pakistan, Philippines, Senegal, South Africa
Banana	Australia, Egypt, India, Pakistan, Philippines, South Africa, Sudan, Taiwan, USA, Yemen
Citrus fruits	Australia, Philippines, South Africa
Plums	South Africa
Peaches	South Africa
Tomato	Australia, Morocco, Philippines, USA

Fig. 3.1 Calcium carbide wrapping in newspapers (*left*) and placing sachet in the box (*right*)

Ripening with Calcium Carbide (CaC_2)

Ripening is an essential operation in majority of fruits before retailing, which is done with calcium carbide, a banned chemical worldwide (Table 3.1; Siddiqui and Dhua 2010). This chemical is very cheap, easily available, and easy to use for ripening. This is called masala in many fruit markets in India as well as in other developing countries. A small quantity wrapped in newspaper is placed in the box or inside the heap of fruits as shown in the Fig. 3.1. Care is taken that the box is closed and heaps are covered with newspapers or gunny bags. Within 24–48 h of placing, ripening is completed. Actually, acetylene gas (C_2H_2) is released by calcium carbide upon reaction with moisture. Fruits such as mangoes, sapota, and papayas are often harvested at a mature but unripe stage and are ripened by calcium carbide. In natural conditions they ripen slowly, leading to high fruit weight loss, desiccation, and uneven ripening.

Modern Ripening Process

Nowadays, use of ripening chamber by organized retails is gaining popularity (Fig. 3.2). Using a ripening chamber helps to maintain precise conditions specific to the product's requirement. The ripening is more or less uniform and the fruit has a

Fig. 3.2 Banana ripening chamber (*inside view*); banana ripening chamber

Fig. 3.3 Pressure marks (touching) in apple due to overfilling in the box

firmer texture and a better flavor. Farmers can also choose to pause or hasten the ripening process based on market demand if ripening chamber is used. Use of ripening chamber results in less spoilage and higher price realization.

Overfilling and Overloading

It is a very common tendency of apple growers to fill too much apple in one box and too many boxes in one vehicle (beyond the normal carrying capacity of the vehicle). This is true for other fruits also. They do this primarily for two reasons: (a) *Demand by the commission agents*: It was observed that those lots containing more weight in a box are priced more. In general, all apple boxes contain 22–23 kg, but in many cases it is found that the boxes carrying 25–30 kg are designed to carry only 20 kg; (b) *To save the cost of packing and transport charges*: Growers want to save something immediately and he/she calculates the cost of empty boxes, packing, handling, and transport charges by saving number of boxes, and to do so they prefer overfilling and overloading. The practice results in damage and touching in apples (Fig. 3.3a–c). These apples start rotting within 2 days. The maximum postharvest

Fig. 3.4 Re-sorting of overfilled boxes in the mandi

Fig. 3.5 Sunburn apple

losses in apple take place due to touching followed by rotting. Immediate effect of touching may not be noticed, but when rotting starts, one can easily find out the reason.

Buyers prefer resorting to these boxes to remove badly damaged fruits (Fig. 3.4) and put best and colorful apples on the top layers. In some cases, buyers increase number of boxes by reducing quantity of overfilled boxes and this is a win-win condition for them.

Exposure to Sun

Exposure to sun during growth and maturation as well as during holding time of loading for local mandis or transportation to distant markets can reduce quality drastically. The latter case can be avoided by covering the fruits with tirpal or gunny bags. The exposed portion turns black or brown and starts decaying during storage and transportation (Fig. 3.5).

Fig. 3.6 Poor-quality CFB boxes

Poor Quality Packaging Materials

The CFB boxes used by fruit growers, especially by Himachal and J&K farmers (India), are very weak in strength (Fig. 3.6) and generally become very loose or even torn during transport from Himachal or Kashmir to APMC Azadpur, Delhi (India). The fruits packed in these low-quality boxes are more or less damaged in every box during handling. These boxes are three ply only and corners of the boxes are also as weak as other portion. Wholesale mandi buyers or forwarding agents prefer wrapping of boxes by thin plastic ropes if these boxes have to be sent to other distant markets. The idea is to strength the boxes during transportation.

Wrong Method for Determination of Fruit Firmness

Firmness is a very important quality parameter, especially of pome fruits. This is one of the most important quality measurements of apples and pear and has been used to determine optimal storage maturity by private companies. But fruit firmness varies among the cultivars (Watkins 2003). Storage and long distance transportation are totally based on this parameter. In case of apple, it is judged by growers and buyers by touching and pressing with thumbs and fingers on apple and no pressure tester or firmness tester is used. Their experience also plays an important role in the judgment. This type of judging firmness generally goes wrong and not gives better results during storage. This is not a malpractice, but lack of awareness among the growers and traders. All corporate buyers use pressure tester and a pressure of 16 psi or above is good for storage in both normal cold storage and controlled atmosphere storage (CA).

Storage and Handling Problems

Insufficient Storage Capacity

In the peak harvesting season, on an average 3–400 apple trucks reach Azadpur mandi. Storage capacity near mandi is highly inefficient and farmers have to sale their produce in the same day or by next day. Only few farmers take the risk to storage if their quality is suitable for storage. The commission agent prefers that the decision should come from farmer's side. All the expenses of handling and storage are borne by the farmers. The agents take their charges whenever they execute sale transaction. The charge of commission agents varies between 4 and 8 % on sale value. In few Indian markets, commission is not charged by growers, but by buyers. Other charges including handling charges are extra that will be paid by the growers only. Due to inefficient storage capacity, a huge amount of horticultural produce is wasted annually in India and other developing countries. According to the Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana, approximately 18 % of the country's fruits and vegetables, worth INR 133 billion, go to waste annually because of the lack of cold storage facilities. India wastes more fruit and vegetables than any other food product in India, mostly due to inadequate cold storages and inefficient handling.

Multiple Handling

Here multiple handling means how many times a product is being loaded and unloaded before reaching to retailer's shop. Multiple handling causes abrasion, damage, and quality deterioration. In a typical wholesale market in India, multiple loading is directly related to a number of middle men involved in a particular chain. Few chains are described here:

(a) Grower (Loading) → local market (Unloading & Loading) → whole sale market (Unloading & Loading) → Terminal market or district mandis (Unloading & Loading) → Retail shop (Unloading)
(b) Grower (Loading) → whole sale market (Unloading & Loading) → Terminal market or district mandis (Unloading & Loading) → Retail shop (Unloading)
(c) Grower (Loading) → Terminal market or district mandis (Unloading & Loading) → Retail shop (Unloading)

Shorter supply chain involves less number of loading and unloading operations which result in less damage to the crops.

Long Chain of Intermediaters

There is a long chain of middle men between growers and final consumers, a special character found in almost all developing countries. This is a unique feature of Indian fruit and vegetable business also. There are few prevalent marketing chain described here:

1. Grower → local market → Commission agents → Terminal market or district mandis → Sub-whole seller → Retail shop → Consumers
2. Grower → Commission agents in the whole sale market → Terminal market or district mandis → Sub-whole seller → Retail shop → Consumers
3. Grower → Terminal market or district mandis → Commission agents → Retail shop

Non-existent Infrastructure at the Wholesale Markets

The most important infrastructure a wholesale market should have is sorting, grading, packaging, and cold storage facilities. Sorting, grading, and packing facility is totally inefficient in the wholesale market of India. As far as cold storage is concerned, only a few wholesale markets have this facility, but capacity is very low than required. Many of the cold stores are far away from mandi and only companies and wholesalers use this facility for storage during peak season and sale during off-season. Most of the organized retailers keep fruits, especially apple, in cold storage for off-season sale. They hire full chamber for the season.

One of the main reasons of postharvest losses of perishable commodities in developing countries is lack of cold storage facility. Here in India, about 18 % of the country's fruits and vegetables, worth INR 133 billion, go to waste annually because of the lack of cold storage facilities. As of 2012, India had approximately 6300 cold storage facilities, with a capacity of 30.11 million metric tons. Of the total number of facilities, about 60 % are located in just four states: Uttar Pradesh, Gujarat, West Bengal, and Punjab. Uttar Pradesh has the highest present capacity of 10.187 million metric tons with a gap of 20 % pegged at 2.041 million metric tons.

Government agencies such as the Agricultural and Processed Food Products Export Development Authority (APEDA) and National Horticulture Board (NHB) were set up to help provide financial assistance for development of cold storage facilities in India. APEDA, which has achieved 29,929 metric tons of capacity by March 31, 2012 (as part of the XIth Five Year Plan), had targeted an increase of 6600 metric tons in 2012–2013.

Fig. 3.7 Unfair price fixation

Very High Postharvest Losses

Due to poor infrastructure and lack of processing facilities, huge postharvest losses occur in India and other developing countries. According to CIPHET, Ludhiana, two of the biggest contributors to food losses are the lack of refrigerated transport and the lack of high-quality cold storage facilities for food manufacturers and food sellers.

Unfair Price Fixation

In many fruit markets, price of fruits and vegetables is fixed under a piece of cloth (handkerchief and towels) by the movement of fingers (Fig. 3.7). This secret price is only known to buyers and traders. Farmers generally do not get the actual price paid by buyers although traders assure the actual price paid. The aim of this secret price is to sale to his close buyers on credit basis.

Factors Affecting Sales of Fresh Produce

The Indian Fresh produce are full of different horticultural produce starting from temperate produce to tropical and subtropical. The numbers may cross over 300 products. Despite this diversity, virtually all fresh produce share two fundamental attributes: perishability and seasonality. Due to this fundamental attribute, a high-level risk is always associated with fresh produce marketing. This risk arises from the combination of many factors including weather variability. Weather affects demand and supply. A rainy day decreases demand of fruits and supply of vegetables. These factors are mentioned below.

Presence of Substitute Crops

Presence of substitute crops affects demand and sale volume. For instance, the demand of apple in off-season in Andhra Pradesh is largely affected by the arrival of local mango, Safeda. Off-season sale of apple in south markets is very profitable, but sale volume and demand decrease as soon as mango variety Safeda hits the market. Also, sometimes prices of Indian apple and imported apple decrease drastically due to more arrival of mango. Similarly, in case of Maharashtra, grape harvesting season coincides with imported and stored apple and affects the sale of apple.

Remarks: It is true that one can find always more than one crop in the mandi, but it affects the sale of other crops. Buyers find more options and thus competition among crops increases.

Sale Price of Substitute Crops

The sale price of substitute crops affects sale of main crops. If substitute crop price is less, more buyers are turned towards low-price fruits. This may not be true for vegetables, but it is true for fruits. This is the reason that most of the fruits' rate or supply decreases after mango arrival in the market. For example, if grape retail price is Rs 60/kg and apple Rs 100/kg, grape selling will reduce the sale of apple.

Remarks : Traders try to sale out their stored apple before April of every year due to mango arrival from south, which starts in April to May. Also, pressure of cold-stored apple decreases drastically and rotting starts after February onwards. You will not find juice in cold-stored fruits in February also. *Adani Agrifresh Limited takes the advantage of CA stores and sale apple up to May*. Very little pressure reduces in CA store. Apple remains fresh, crunchy, and juicy for 5–6 months in properly maintained CA stores.

Presence of Festivals

Presence or absence of festivals always affects the sale of horticultural produce. In general, all fruits sale increases during festivals (Navratri, month of Ramadan, Deepawali, Holi, etc.). Regional festivals such as Chat Puja in Bihar also increase sale of fruits and vegetables. Onion sale decreases in the month of Sawan and Dushehra simply because non-vegetarian Hindus observe fasting and becomes vegetarian during these occasions. In Deepawali (festival of lights), gift packets of fruits are on high demand. One-layer and two-layer boxes are sold in bulk quantities. At the end of festival, there is no demand or very less demand for fruits and the demand picks up at least after 5–7 days after the festival is over.

Marriage Season

Marriage season also affects sale of horticultural produce at a larger extent. Preparation of fruit baskets, preparation of varieties of vegetable dishes, and offering fruit salads at marriage or reception parties mainly consume fruits and vegetables. It has been observed that, in marriage season, the price of fruits increases manyfold.

Eating Habits and Preferences

Vegetarian and non-vegetarian food habits affect the sale of a particular fruit or vegetable. For example, in J&K and Andhra Pradesh, price of onion remains always on the higher side, because onion is an important ingredient for non-vegetarian preparation. Also small-size fruits are preferred in Bihar, West Bengal, and Orissa. Large-size fruits are preferred in North India, especially in Punjab, and medium-size fruits are very much preferred in South Indian markets.

Price of Imported Fruits

Off-season price of Indian apple largely depends on price of imported fruits, especially Fuji apples. Higher price of imported apple facilitates sale of Indian stored apple and vice versa. Red Delicious of Washington always fetches higher price than any other imported fruits.

Presence of Competitor Crops

Here, competitor crops mean same type of crops such as Kashmir apple vs. Shimla apple, Nagpur mandarin vs. Kinnow mandarin, and Maharashtra grape vs. Andhra Pradesh grape. If Kashmir apple production is good and price during season is low, people prefer to buy Kashmir apple and automatically demand of Himachal apple will decrease and its price too. Similarly, Kinnow suppresses the demand and sale price of Nagpur mandarin and vice versa.

Price During Season

In general, price during season remains low and buyer keeps produce in cold store for sale in off-season at higher price. In this way, a higher margin is possible, and in adverse condition, there will not be a big loss. This is a general practice followed

every year. However, if season price is very high, off-season price may not be higher than season price. In few years, people who store at high price purchase in the season lost heavily. Traders store mainly apple in all major terminal markets of India during season. If price in the season is high, then traders store less quantity due to fear of low price during off-season. Heavy rain, landslide, and unavailability of vehicle at major producing states during season also hinder storage in wholesale and terminal markets.

More Arrival in a Particular Day

The number of buyers is almost fixed in every market. Their number fluctuates, but not drastically. On the other hand, arrival pattern in mandi is not uniform. Sometimes arrival may increase or price may fall more than expectations and vice versa.

Sunday Factor

Most of the wholesale mandi are closed on Sunday. On Monday, one can find more arrival because Sunday arrivals are also sold on Monday. There is a chance of good price on Monday because retailers and local buyers mainly assemble on Monday for 1-week purchase. Loaders or Ladanis also prefer to buy on Monday where a Journey of 6–7 days are expected (Azadpur to Chennai market or Vijayawada) so that next Monday arrival in terminal market may be assured. Maximum transaction also takes place on this day. The trend of price rise or price fall greatly depends on Monday marketing. If there is fall in price, it means less demand and more arrival and vice versa.

Weather Factor

Weather factor (heavy rainfall, landslide and road blocked, heavy snowfall, etc.) in production and sale area affects demand of both fruits and vegetables. Fruit prices in general decrease because consumers prefer hot snacks and foods during rainfall and vegetable prices increase because supply and production decreases.

Quality

Quality is a major factor affecting sale of all horticultural produce. In a particular year when healing in apple and black spots in mango is a problem, sale as well as price will remain low irrespective of color of apple and size of mango. Buyers will

resist for lower price and every time give more emphasis on quality issue. Demand of such defected produce from terminal market also reduces. Healed apples are not preferred for storage and thus demand decreases from every sales point.

Remarks: Organized retailers and modern formats never accept low-quality fresh produce. A-class counters and retailers from posh locations also do not purchase B-grade produce.

Presence of Corporate Buyers

The corporate buyers such as Mahindra Subhlubh, Reliance fresh, and Big Bazaar purchase in bulk quantity. They select good quality produce and put everyday indent. Commission agents ask more price from them and this increases overall price of the market.

Currency Value

When dollar value rises, cost of imported fruits increases. This facilitates domestic fruits' sale. But when the situation is reverse, sale of imported fruits increases. Fuji apple from China is the strongest competitor of off-season apple sale in India. Retailer's preference is diverted more towards Fuji apple if price difference compared to Indian apple is less than Rs 100/- due to its sweet–sour taste and durability.

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Chapter 4
Growing Areas and Harvesting Season of Commercially Important Fruits

Harvesting season varies with produce, but at the same time the harvesting season of many fruits overlaps each other and also harvesting of many fruits falls under one season. Harvesting seasons of some of the commercially important fruits and major producing state are listed below.

Apple

Major apple-producing states of India are Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. On small scale, apple is also grown in Arunachal Pradesh and Sikkim. Harvesting season for apple starts in the month of July and ends in November. However for storage purpose, harvesting in the month of August to the last week of October in Himachal Pradesh (HP) and September to the last week of November in Jammu and Kashmir (J&K) is supposed to be ideal. Harvesting in J&K starts with low chilling varieties such as Hazratbali and Razzakbali and ends with Kullu Delicious followed by Red Delicious (locally called Delicion). Commercially important varieties From J&K are (a) Delicion and (b) Kullu Delicion (Royal Delicious). Kullu Delicious is priced more due to full color development as compared to Delicion (Red Delicious). Harvesting season of apple in Himachal Pradesh starts from July and ends in November. Here also harvesting starts with low chilling varieties and pollinizer varieties such as Early Tydeman, Red Gold, and Golden Delicious and ends with Red Delicious and Royal Delicious from Kullu and finally Royal Delicious from Kinnaur. Commercially important varieties from the state HP are (a) Royal Delicious, (b) Red Delicious, (c) Rich-a-Red, and (d) Golden Delicious. Only Royal and Red Delicious are suitable for storage. Rich-a-Red could also be stored but sale price during off-season is not satisfactory, hence not preferred for storage. Royal Delicious further may be divided into two groups, namely, Dharidar Royal and Sapaat Royal. Dharidar Royal possesses less color, whereas Sapaat Royal possesses full color. Early maturing varieties and varieties grown on

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_4

Table 4.1 The lean and peak harvesting period of apple in India

States/UTs	June	July	Aug	Sep	Oct	Nov	Dec
Jammu and Kashmir		Lean period	Lean period	Peak period	Peak period	Lean period	
Himachal Pradesh	Lean period	Lean period	Peak period	Peak period	Lean period	Lean period	
Uttarakhand	Lean period	Peak period	Peak period	Lean period			

Source: Director of Horticulture/Agriculture of respective State/UTs
Remarks: A fluctuation of 10–15 days (early or late) from peak harvesting season may be experienced due to weather conditions during flowering till fruit maturation in all states
**NA* means Not applicable

Table 4.2 Important growing belts of apple-growing states (India)

S. no.	States	Growing belts
1	Himachal Pradesh	Kinnaur (Pooh, Kalp, Ribba, Rispa, Nicher), Kullu, Kharapather, Sainj, Theog, Shimla, Rohru, Sirmour, Mandi, Chamba
2	Jammu and Kashmir	Srinagar, Sopre, Sopian, Budgam, Pulwama, Anatnag, Baramullah, Kupwara
3	Uttarakhand	Almora, Pithoragarh, Tehri Garhwal, Uttarkashi, Chamoli, Dehradun, Nainital
4	Arunachal Pradesh	Tawang, West Kanneng, Lower Subansiri

lower heights (Theog, Mandi, Champa, etc.) are not suitable for storage. Harvesting season of major apple-growing states with peak harvesting period is shown in Table 4.1.

There are few pockets (growing belts) in each state where best quality apple is produced. The important growing belts or areas in each state where quality apple are grown are listed in Table 4.2.

Banana

Banana is produced almost by every state of India, and in few states, it is available round the year. However, the major banana-producing states are Tamil Nadu, Maharashtra, Karnataka, Kerala, Gujarat, Andhra Pradesh, Bihar, and West Bengal. The harvesting periods showing lean and peak periods of important states are mentioned in Table 4.3. Similar to any other fruits, production of banana is also localized in each state. The main growing belts (localized area) are shown in the Table 4.4.

There are many varieties of banana that are available and grown on commercial scale in India. However, local name may vary from state to state. Important varieties grown are listed in Table 4.5.

Table 4.3 The lean and peak harvesting period of banana in the states (India)

States/UTs	Jan–June	July	Aug	Sep	Oct	Nov	Dec
Andhra Pradesh	Banana harvesting season is almost round the year						
Assam	Banana harvesting season is almost round the year						
Bihar			Lean period	Peak period	Peak period	Peak period	Lean period
Karnataka[a]	Lean period	Peak period	Peak period	Peak period	Peak period	Peak period	Lean period
Gujarat[a]			Lean period	Peak period	Peak period	Peak period	Lean period
Maharashtra	Banana harvesting season is almost round the year						

Source: Director of Horticulture/Agriculture of respective State/UTs
[a]In Karnataka and Gujarat, banana is available from January to June as lean period

Table 4.4 Banana-growing belts of important states (India)

S. no.	States	Growing belts
1	Maharashtra	Jalgaon, Ahmednagar, Buldhana, Pune, Wardha, Dhule, Nanded, Parbani, Nandurbar, Satara, Sangli, Osmanabad, Akola, Yeothmal, Amravati, Thane, Kulara, Alibag
2	Tamil Nadu	Theni Thoothukudi, Tiruchirapalli, Coimbatore, Tirunelveli, Karur, Erode, Kanyakumari
3	Karnataka	Bangalore, Chitradurga, Shioroga, Hassan, Chikka Mangloor
4	Andhra Pradesh	Pulluvendula, East Godavari, West Godavari, Kurnool, Cuddapah
5	Gujarat	Surat, Vadodara, Anand, Kheda, Junagadh, Narmada, Bharuch
6	Kerala	Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam, Idukki, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Wynadu, Kannur, Kasargod
7	Bihar	Bhagalpur, Kishanganj
8	West Bengal	Hooghly, Nadia, North 24 Parganas

Table 4.5 Important varieties of banana grown in different states of India

State	Varieties grown
Andhra Pradesh	Dwarf Cavendish, Robusta, Rasthali, Thellachakrakeli, Karpoora Poovan, Chakrakeli, Monthan and Yenagu Bontha, G-9
Bihar	Dwarf Cavendish, Alpon, Chinia, Chini Champa, Malbhog, Muthia, Kothia, Gauria, G-9
Gujarat	Dwarf Cavendish, Lacatan, Harichal (Lokhandi), Gandevi Selection, Basrai, Robusta, G-9, Harichal, Shrimati
Karnataka	Dwarf Cavendish, Robusta, Rasthali, Poovan, Monthan, Elakkibale
Kerala	Nendran (Plantain), Palayankodan (Poovan), Rasthali, Monthan, Red Banana, Robusta
Maharashtra	Dwarf Cavendish, Basrai, Robusta, Lal Velchi, Safed Velchi, Rajeli Nendran, Grand Naine, Shreemanti, Red Banana
Tamil Nadu	Virupakshi, Robusta, Rad Banana, Poovan, Rasthali, Nendran, Monthan, Karpuravalli, Sakkai, Peyan, Matti
West Bengal	Champa, Mortman, Dwarf Cavendish, Giant Governor, Kanthali, Singapuri

Mandarin Oranges

Mandarin (*Citrus reticulate Blanco*) is the third most important horticultural crop grown in India. Mandarin is a group name for oranges having loose peel (loosely attached peel) that can be easily peeled off. Mandarins include a diverse group of citrus fruits that are characterized by bright-colored peel (deep yellow red) and pulp, excellent flavor, easy-to-peel rind, and segments that separate easily. It is usually consumed in raw form or in fruit salads as well as juice. It is mainly grown in Maharashtra, Assam, Karnataka, Madhya Pradesh, Meghalaya, Mizoram, Nagaland, Rajasthan, Punjab, Tamil Nadu, and West Bengal. In Maharashtra, the mandarins are mainly grown at Satpura hills (Vidharba region) while in West Bengal they are grown at the hilly slopes of Darjeeling. In Karnataka, Coorg is the main producing area. In Tamil Nadu, Wynad, Nilgiri, Palney, and Shevroy hills are the major mandarin-growing belts. Similarly, in Assam, Brahmaputra valley and Dibrugarh districts are famous for mandarin production. The hills of Meghalaya (Khasi, Dusha, Garo, Jaintia), Mizoram, Tripura, Sikkim, Himachal Pradesh, and Arunachal Pradesh are the other mandarin-growing states.

The harvesting season of mandarin oranges falls under two harvesting seasons per year called bahar. However, the period may vary from state to state. For example, the two bahars are (a) *Ambe Bahar:* This season starts in the first week of October and continued till last week of December. (b) *Mrig Bahar:* This season starts in the last week of January and continued till the middle of April. The harvesting season of mandarin oranges is mentioned in Table 4.6. The major growing belts of mandarin oranges are listed in Table 4.7.

The fruit, mandarin, consists of three layers as described below.

1. The outer yellow/orange peel containing oil glands which exude the essential oils, producing the typical orange odor.
2. The whitish thread like mesocarp.
3. The endocarp consisting of 8–10 segments filled with juice sacs (vesicles).

Besides these three important layers, each variety possesses some special characters. These characters of important varieties are mentioned in Table 4.8.

Table 4.6 The harvesting period of Mandarin oranges in India

States/UTs	Jan	Feb	Mar	Apr	Oct	Nov	Dec
Maharashtra	Mrig Bahar fruits are harvested during this period				Ambe fruits are harvested during this period		
Assam	Peak period	Lean period		Lean period	Peak period	Peak period	Peak period
Punjab	Peak period	Lean period			Lean period		Peak period
Madhya Pradesh	Peak period	Peak period			Lean period		Lean period

Source: Director of Horticulture/Agriculture of respective State/UTs

Table 4.7 The major mandarin growing belts (India)

State	Major growing belts
Maharashtra	Nagpur, Akola, Amravati, Wardha, Bhandara, Chandrapur, Gadchiroli, Buldhana, Yawatmal, Wahshim
Assam	Tinsukia, NC Hills, Karbi Anglong, Kamrup, Goalpara, Dhemaji, Jorhat
Karnataka	Chikmagalore, Kodagu, Hassan, Bijapur, Gulbarga, Bagalkot
Madhya Pradesh	Chhindwara, Mandsaur, Betul, Ujjain, Shajapur, Khandwa
Meghalaya	East and West Khasi, Ri-Bhoi, Garo hills, Jaintia hills
Punjab	Abohar (Kinnow mandarin)
Orissa	Gajapati, Ganjam, Keonjhar, Kalahandi, Phulbani, Mayurbhanj,
Rajasthan	Sri Ganga Nagar, Jhalawad, Kota
Tamil Nadu	Dindigul, Salem, Nilgiris
West Bengal	Darjeeling

Table 4.8 Important varieties and their special characters

State	Varieties	Characteristics
Maharashtra	Nagpur Santra	Fruits are yellowish green to orange, oblate, rind thin, fine texture and good flavor and taste. Size is medium and the skin is easily peelable
Assam	Khasi orange, Assam orange	Fruits globose to oblate, surface smooth, color orange-yellow to bright orange, rind thin with very little adherence, segments usually 10–12
Punjab, Rajasthan	Kinnow orange (hybrid Mandarin)	The fruit is medium-sized somewhat oblate in shape, rind moderately thick, adherence with the pulp quite strong, thick mesocarp, easily peelable but not loosely attached, surface smooth and glossy, fruit color yellowish orange at full maturity, segments 9–10, firm, 3–5 seeds per segments, pulp yellowish orange, very juicy somewhat acidic
Karnataka	Coorg Mandarin and Kodagu, Kittale	Fruits oblate, color bright yellow and uniform, rind medium thick with little adherence, segments between 9 and 11, pulp yellow with fine texture and abundant juice
Tamil Nadu	Nagpur Graft, Kodai/ Kamala and Coorg	Fruits are yellowish green to orange, oblate, rind thin, fine texture and good flavor and taste. Size is medium and the skin is easily peelable
West Bengal	Khasi orange, Mandarin orange or Darjeeling orange	Fruits are comparatively smaller in size somewhat flat in shape, color yellowish to orange when fully ripe, rind thin, adherence little, juice abundant and sweet flavor
Himachal Pradesh	Kinnow orange (hybrid Mandarin)	Similar to Punjab Kinnow mandarin

Kinnow, which belongs to the category of mandarins, is the first generation hybrid between King mandarin (*Citrus nobilis* Lour) and Willow Leaf mandarin (*Citrus deliciosa* Ten.) (Ghosh 1985). It was developed by late Dr. H.B. Frost in 1915 at the University of California and released for commercial cultivation in 1935 (Frost 1935). Kinnow was first introduced in India in 1959, in the form of virus-free bud wood from the fruit Research Station, Punjab Agriculture College and Research Institute, Lyallpur (Pakistan), where it was introduced earlier (Singh 1978). Due to the efforts of enterprising growers and because of its superb eating quality, better adaptability, capacity to withstand wind and hail storm, and frost resistance (Chundawat et al. 1978), it has become an important fruit crop of North-Western India, especially Punjab, Haryana, Himachal Pradesh, and parts of Rajasthan. The harvesting season for Kinnow mandarin starts in the first week of November and continued till first week of February. Punjab and Rajasthan are two major Kinnow growing states of India. Abohar in Punjab and Shriganga Nagar in Rajasthan are famous for quality Kinnow production. The quality of Kinnow fruits is greatly affected by the damages/injuries during harvesting. Therefore, great care should be taken during harvesting/plucking the fruits. The harvesting of fruits should not be carried out during wet weather or just after raining or early morning when fruits are wet due to presence of moisture over the fruit surface. It is preferable to use clippers for harvesting the fruits (Fig. 4.1). While harvesting, care should be taken that pedicel should be cut very close to the fruit without damaging the fruit peel and complete removal of pedicel. A very small portion of fruit stalk (pedicel) should be attached. Peel bruising, rubbing, scratching and skin puncturing, and pressure damage are the major cause for quality deterioration during marketing and storage. The other cause of deterioration in the fruit quality is harvesting of immature or overmature fruits. Similarly, fruits are spoiled when they are harvested by pulling the fruit, causing rupturing of the peel or a small piece of peel is also pulled along with the pedicel. The ruptured peel attracts fungal and bacterial spoilage. Harvested fruits need careful handling, till they reach the consumers. The harvesting season of Kinnow is listed in Table 4.9.

Fig. 4.1 Fruit clipper (*left*) and harvesting Kinnow fruit with fruit clipper (*right*)

Table 4.9 The harvesting season (lean and peak harvesting period) of Kinnow

States/UTs	Jan	Feb	Mar	Apr–Sep	Oct	Nov	Dec
Punjab	Peak period	Lean period	Lean period	No season		Lean period	Peak period
Rajasthan	Peak period	Lean period	Lean period	No season		Lean period	Peak period

Source: Director of Horticulture/Agriculture of respective State/UTs

Grapes

Grape is one of the most important fruit crops grown in India. Grapes (*Vitis vinifera*) belong to the *Vitaceae* family. Grape is the fourth most widely cultivated fruit after citrus and banana. Maharashtra (75.33 %) is the largest producer of grapes in the country. Maharashtra and Karnataka together contribute about 89.65 % of India's grapes production. Grapes are widely consumed as fresh in India. It is also used for producing raisins, wine, juice, juice concentrate, squash, beverages, jams, and marmalades. Grapes are highly digestible and have a number of therapeutic properties. Grapes are non-climacteric fruit that grow on the perennial and deciduous woody vines. Cultivation of grapes is known as viticulture.

The harvesting season of grapes in major producing areas of India differs considerably. Different harvesting seasons of grapes may be summarized as

1. Southern India—May to June and December to April
2. Western India—November to April
3. Northern India—May to June

Harvesting season of grapes in two important states is illustrated in Table 4.10. The important growing belts or areas in each state where quality grapes are cultivated are shown in Table 4.11.

Grape is produced on commercial scale in Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, and Punjab. Nasik and Pimpalgaon of Maharashtra are famous for grape cultivation. The season of grape harvesting in Maharashtra starts in the middle of November and continued till March. March harvesting fetches more price and mostly good quality fruits are stored from March harvesting. As temperature increases, mealy bug problem also increases and also problems of yellowing of berries increase due to intense sunshine. Berries turned yellow or brown are not suitable for storage but good for raisin making. To save grape bunches from intense sunshine and yellowing of berries, bagging with newspaper is a common practice in Maharashtra. Other grape-producing states are Karnataka, Madhya Pradesh, Punjab, Tamil Nadu, etc. The commercial varieties of grapes grown are listed in Table 4.12.

Table 4.10 The harvesting period of grapes in Maharashtra and Andhra Pradesh (India)

States/UTs	Jan	Feb	Mar	Apr	May–June	July–Oct	Nov	Dec
Maharashtra	Peak period	Peak period	Peak period	Lean period	Stored	No season	Lean period	Peak period
Andhra Pradesh	Lean period	Lean period	Peak period	Peak period	Stored	No season	Lean period	Peak period

Source: Director of Horticulture/Agriculture of respective State/UTs

Table 4.11 Major growing belts of grapes

S. no.	States	Growing belts
1	Maharashtra	Nashik, Sangli, Solapur, Pune, Satara, Latur, and Osmanabad
2	Karnataka	Bijapur, Bagalkot, Belgaum, Bangalore, Kolar, and Gulberga
3	Andhra Pradesh	Ranga Reddy, Mahbubnagar, Anantapur, Chittoor, and Medak
4	Punjab	Bhatinda, Ferozpur, Gurdaspur, and Ludhiana
5	Haryana	Hissar and Jind
6	Tamil Nadu	Coimbatore; and Madurai and Theni

Table 4.12 Commercial varieties of grapes grown in the states

States (India)	Varieties
Andhra Pradesh	Thomson Seedless, Sharad Seedless, Crimson Seedless, Anab-e-shahi,
Haryana	Anab-e-shahi, Perlette
Karnataka	Bangalore Blue, Anab-e-shahi, Thomson Seedless, Sharad Seedless, Dilkhush, Flame Seedless
Madhya Pradesh	Ganesh, Thomson Seedless, Sharad Seedless, Sonaka, Chirah
Maharashtra	Thomson Seedless, Kali Sahebi, Sonaka, Sharad Seedless, Flame Seedless, Ganesh, Red Globe, Sonaka (Black)
Punjab	Anab-e-shahi, Perlette
Rajasthan	Sharad Seedless, Anab-e-shahi, Perlette
Tamil Nadu	Bangalore Blue, Anab-e-Shahi, Gulabi, and Bhokri

Pomegranate

Maharashtra is the leading producer of pomegranate in India followed by Karnataka, Andhra Pradesh, Gujarat, and Tamil Nadu. In Maharashtra, harvesting season is not confined to any particular season. It is harvested round the year. However, in other states, both lean and peak periods are observed as mentioned in Table 4.13.

Only limited varieties are grown on commercial scale in India, namely, Ganesh, Bhagwa, Arakta, and Mridula. The characteristics of these commercial varieties are listed in Table 4.14.

The major growing belts of Maharashtra are Solapur, Sangli, Nasik, Ahmednagar, Pune, Dhule, Aurangabad, Satara, Osmanabad, and Latur districts. Similarly, the

Table 4.13 The lean and peak harvesting period of pomegranate in major states of India

States/UTs	Jan–Feb	Mar	Apr–May	June	July–Oct	Nov	Dec
Andhra Pradesh		Lean period	Peak period	Lean period		Lean period	Peak period
Karnataka	Lean period	Peak period	Lean period		Peak period	Peak period	Peak period
Gujarat		Peak period	Peak period	Peak period	Lean Period	Lean period	Lean period
Maharashtra	Pomegranate harvesting season is almost round the year						

Source: Director of Horticulture/Agriculture of respective State/UTs

Table 4.14 The characteristics of few important varieties are listed below

Variety/type	Characteristics
Ganesh	This variety has pinkish yellow to reddish yellow rind color, having light pink arils and soft seeds. Fruit weighs between 225 and 250 g
Ruby/Miridula	The fruit skin is red in color and weighs between 225 and 275 g. The grains are soft, having high T.S.S.
Arakta	Fruits are dark red in color with soft seeds and with high T.S.S.
Bhagwa	The fruit is glossy red in color with soft seeds and high T.S.S.

Table 4.15 Major growing belts of pomegranate in India

S. no.	States	Growing belts
1	Maharashtra	Solapur, Nashik, Sangli, Ahmadnagar, Pune, and Satara
2	Karnataka	Bijapur, Bagalkot, Belgaum
3	Andhra Pradesh	Anantapur
4	Gujarat	Bhavnagar, Ahmedabad, Sabar Kantha

major growing belts of Karnataka include Bijapur, Belgaum, and Bagalkot districts. Other important pomegranate-growing states are Gujarat, Andhra Pradesh, and Tamil Nadu. The major growing belts of each state are shown in the Table 4.15.

Pineapple

Pineapple is one of the major fruit crops covering an area of 1.052 lakh hac with total production of 15.70 lakh MT (National Horticulture Board 2012–2013). It contributes about 2.7 % of total fruit production of the country with a very good productivity of 14.9 MT per hac. It is grown in Assam, Meghalaya, Tripura, Sikkim, Mizoram, West Bengal, Kerala, Karnataka, and Goa on a large scale, whereas in Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, and Uttar Pradesh on a small scale.

Table 4.16 Harvesting period of pineapple in major growing states of India

States/UTs	Jan–Apr	May	June	July	Aug	Sep–Nov	Dec
West Bengal			Lean period	Peak period	Peak period	Lean period	
Assam			Lean period	Peak period	Peak period		
Karnataka		Lean period	Peak period	Peak period	Peak period	Lean period	Lean period
Kerala	Lean period	Peak period	Peak period	Lean period	Lean period	Lean period	Lean period

Source: Director of Horticulture/Agriculture of respective State/UTs

Table 4.17 Major growing belts of Pineapple

State	Growing belts
Karnataka	Shimoga, North and South Kannada, Chickmagalore, Kodagu
Kerala	Ernakulum, Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam, Idukki, Thrissur, Palakkad, Malappuram, Kozhikode, Wynadu, Kannur, Kasargodu
Nagaland	Kohima, Zunheboto
Assam	Nagaon, Kamrup, Karbi Anglong, N.C. Hills, Goalpara, Dhemaji, Sonitpur Dhubri
Manipur	Thoubal, Churchandpur, Imphal East
Meghalaya	Ri Bhoi, East Khasi, Garo Hills
West Bengal	Jalpaiguri, Siliguri sub-division of Darjeeling district, North Dinajpur, Cooch Behar

Pineapple fruits are mainly harvested during July–August. However, a small crop is harvested during December to March also. By regulating the flowering, harvesting is possible almost 8 months in a year. The harvesting period is mentioned in Table 4.16, indicating lean and peak periods.

The major producing hubs for pineapple are West Bengal, Assam, Karnataka, and Kerala. The major growing belts are listed in Table 4.17.

Mango

Mango is the most appealing and choicest fruit crop of India. It is rightly regarded as the king of tropical fruits. India ranks first in mango production, accounting for about 50 % of the world's mango production. Mango is cultivated in almost all the states of India. Mango season starts with the arrival of Safeda (Baneshan) from Andhra Pradesh in the month of March and continued till the last week of August. In this way, mango harvesting season lasts for 6 months starting to cover the entire country. This is mainly due to the ripening behavior of mango varieties. Based on

Table 4.18 Early, mid, and late season varieties of mango

Early	Baneshan, Bombai, Bombay Green, Himsagar, Kesar, Suvernarekha
Mid-season	Alphonso, Mankurad, Bangalora, Banganapalli, Dashehari, Langra, Kishen Bhog, Zardalu, Mankurad
Late	Fazli, Fernandin, Mulgoa, Neelum, Chausa

Table 4.19 The harvesting period of mango in major producing states

States/UTs	Feb	Mar	Apr	May	Jun	Jul	Aug
Andhra Pradesh	NIL	Lean period	Peak period	Peak period	Lean period		
UP	NIL	NIL	Lean period	Lean period	Peak period	Peak period	Lean period
Bihar	NIL	NIL	NIL	Lean period	Peak period	Peak period	Lean period
Karnataka	NIL	NIL	Peak period	Peak period	Peak period	Lean period	NIL
Maharashtra	NIL	NIL	Peak period	Peak period	Lean period	Lean period	Lean period

Source: Director of Horticulture/Agriculture of respective State/UTs

the time of ripening, mango varieties may be classified as mentioned in Table 4.18. The peak harvesting seasons of five important states are given in Table 4.19. Major mango producing states are Uttar Pradesh, Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Orissa, Tamil Nadu, and West Bengal. Other States where mangoes are grown on commercial scale include Madhya Pradesh, Kerala, Haryana, Punjab, etc.

As discussed earlier, mango is grown more or less in almost every states of India. The state-wise growing belts are given in the Table 4.20.

Litchi

Litchi/lychee is a potential fruit crop of India. It is grown in the states of Bihar, Tripura, West Bengal, Uttar Pradesh, Punjab, and Haryana. Bihar is the leading state in litchi production and contributes about 74 % of the total production. Productivity is also highest in Bihar followed by West Bengal. An interesting feature of litchi fruit is that maturity of litchi fruits commences first in Tripura, followed by West Bengal then Bihar. The first and second weeks of May are the time for harvest in the eastern region (Tripura), while litchi of Bihar matures in the 3–4 week of May and continues up to the first week of June. Litchi in Uttar Pradesh and Punjab is ready for harvest during the 2–3 week of June. In Himachal Pradesh, litchi of the same cultivar is harvested in the last week of June. Interestingly, in most of the states the

Table 4.20 Mango-growing states and growing belts under each state

State	Growing belts
Andhra Pradesh	Krishna, East and West Godavari, Vishakhapatnam, Srikakulam, Chittoor, Adilabad, Khamman, Vijayanagar
Chhattisgarh	Jabalpur, Raipur, Bastar
Gujarat	Bhavnagar, Surat, Valsad, Junagarh, Mehsana, Khera
Haryana	Karnal, Kurushetra
Jammu and Kashmir	Jammu, Kathwa, Udhampur
Jharkhand	Ranchi, Sindega, Gumla, Hazaribagh, Dumka, Sahibganj, Godda
Karnataka	Kolar, Bangalore, Tumkur, Kagu
Kerala	Kannur, Palakkad, Trissur, Malappuram
Madhya Pradesh	Rewa, Satna, Durg, Bilaspur, Bastar, Ramnandgaon, Rajgari, Jabalpur, Katni
Maharashtra	Ratnagiri, Sindhudurg, Raigarh
Orissa	Sonepur, Bolangir, Gajapati, Koraput, Rayagada, Gunpur, Malkanpuri, Dhenkanal, Ganjam, Puri
Punjab	Gurdaspur, Hoshiarpur, Ropar
Tamil Nadu	Dharmapuri, Vellore, Tiruvallur, Theni, Madurai
Uttaranchal	Almora, Nainital, Dehradun, Bageshwar, UdhamSingh Nagar, Haridwar
Uttar Pradesh	Saharanpur, Bulandshahar, Lucknow, Faizabad, Varanasi
West Bengal	Malda, Murshidabad, Nadia

best litchi orchards are seen along the rivers, big or small. The fruits are harvested in bunches along with a portion of the branch and few leaves. At the time of harvesting care is taken to harvest the selected bunches, which has attained the desirable maturity as determined by flattening of tubercles, peel color, Brix content, and taste of the pulp. For distant markets, fruits are harvested when TSS attains 16–19° Brix and acidity 0.3–0.4 %. The fruits are harvested early in the morning when temperature and humidity are congenial. At the time of harvest, fruits are collected in such a manner so that they do not fall on the ground. Only selected varieties are grown as listed in Table 4.21.

As discussed above, litchi maturity starts from Tripura in the first week of May and ends in Punjab in the last week of June. There may be a deviation of 1 or 2 weeks from the scheduled period of maturity and thus harvesting period. A summarized harvesting period of litchi is mentioned in Table 4.22 and the major growing belts are listed in Table 4.23.

It is practically observed that all growing belts are not procurement clusters where buyers visit in every season for procurement. The reason may be the quality of produce and ease of transportation. The Major Procurement clusters of major fruits are described in Table 4.24.

Table 4.21 Litchi varieties grown in India

State	Varieties
Bihar and Jharkhand	China, Deshi, Purbi, Early and Late Bedana, Mclean, Muzaffarpur, Rose Scented, Shahi, Kasba
Orissa	Muzaffarpur, Bombai, China
Punjab and Haryana	Saharanpur, Dehradun, Calcuttia, Muzaffarpur, Seedless (Late) and Rose Scented
Uttarakhand	Rose Scented, Calcuttia, Early and Late Seedless
Uttar Pradesh	Seedless Early, Seedless Late, Early Large Red, Late Large Red, Calcutta, Rose Scented, Dehradun
West Bengal	Muzaffarpur, China, Deshi, Purbi, Elachi Early, Elachi Late, Bombai, Goothi, Bedana, Potee, Kalyani Selection

Table 4.22 Harvesting period of litchi

States/UTs	Feb	Mar	Apr	May	Jun	Jul	Aug
Bihar				Lean period	Peak period		
West Bengal			Lean period	Peak period			
Jharkhand				Peak period			
Punjab						Peak period	

Source: Director of Horticulture/Agriculture of respective State/UTs

Table 4.23 The major litchi growing belts

S. no.	States	Growing belts
1	Uttaranchal	Dehradun, Pithauragarh, Nainital, Haridwar
2	West Bengal	Murshidabad, 24-Paraganas
3	Bihar	Muzaffarpur, East Champaran, Samastipur, Vaisali, Bhagalpur
4	Assam	Kamrup, Spmotpir, Bongaigaon
5	Punjab	Gurdaspur, Ropar, Hoshiarpur
6	Uttar Pradesh	Saharanpur

Table 4.24 Major procurement clusters of major fruits of India

Products	Procurement clusters		
	State	Places	Remarks
Apple	Himachal Pradesh	Rampur, Rohru, Kinnaur, Kullu etc.	*Apple from Kinnaur in HP and Sopian from J&K is supposed to be the best of India*
	J&K	Sopian, Pulwama, Sopore	
	Uttarakhand	Dehradun	
Apricot	Himachal Pradesh	Rampur	
Banana	Maharashtra	Jalgaon	
	Andhra Pradesh	Puluvedala	
	Tamil Nadu	Theni	

(continued)

Table 4.24 (continued)

Products	Procurement clusters		
	State	Places	Remarks
Citrus-Orange	Maharashtra	Varud, Pune, Amravati	Mirig bahar citrus is best for storage
Citrus-Kinnow	Punjab	Abohar, Hoshiarpur	December and January—peak harvestings season
Grapes	Rajasthan	Shriganganagar	Starts early in November
Citrus-Mosambi	Maharashtra	Aurangabad, Amravati	Mosambi is used for fresh juice consumption
	Andhra Pradesh	Anantpur	
Mango	Andhra Pradesh	Vijayawada	The early mango variety Safeda Starts from Andhra Pradesh
	UP	Saharanpur	
	Bihar	Bhagalpur	
	Gujarat	Valsad	
Pomegranate	Maharashtra	Solapur, Nasik, Sangli, Ahmadnagar, Pune, Satara	Nasik is famous for quality grape production
	Karnataka	Bijapur, Bagalkot, Belgaum	
	Gujarat	Bhavnagar, Ahmedabad, Sabar Kantha	
	Andhra Pradesh	Anantpur	
Plum	Himachal Pradesh	Rampur, Shimla	
Pear	Himachal Pradesh	Rohru	
	J&K	Sopore, sopian	

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Chapter 5
Commercial Quality of Fruits: Part I

Introduction

Marketing of fresh fruits largely depends on quality of fruits. Quality depends on both chemical and physical attributes. From marketing point of view, attributes like the presence of external defects or disease infection, firmness, and sweetness are more important than any other physical and chemical attributes. The consumer's preference for a quality fruit depends on the absence of external defects, free from disease and insect pest, crunchy, and sweet taste. For the consumers, good quality is what they can see. Hence for them, maturity and ripeness, appearance (shape, size, and color), absence of mechanical damage, and good flavor constitute quality. Safety and nutritional value appears not to be a prime consideration. Quality of any fruit depends on maturity stage at which it is harvested and affects the storage life during marketing. Maturity standards of few commercially important fruits are described below.

Harvest Maturity Indices of Apple

Various non-destructive maturity indices can be used to determine proper stage for harvesting of apple. These indices include the number of days from flowering, fruit size, and external color. Destructive indices are more reliable to judge correct maturity stage. Under this method, seed color, flesh firmness, and starch iodine test are important. It is important to harvest apple fruit at the proper maturity stage because fruits became insipid and shrivelled if harvested immature. The most obvious index of fruit maturity for growers is external skin color. As the fruit matures, the skin color will change from green to red (for Delicious groups). Quality parameters of few commercially important fruits are described hereunder.

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_5

Quality Parameters of Apple

Apple production is mainly confined in three states of India, namely, Himachal Pradesh, Jammu and Kashmir, and Uttarakhand. There are certain parameters on which quality of apple is judged. Grade-wise quality description is given in Table 5.1 which is standard quality parameters for domestic apple marketing. In mandi also, apples are graded in three grades. These grades are A, B, and C.

The quality parameters are described below

Table 5.1 Quality parameters of Indian apple

Parameters	Apple grades			
	Grade-A	Grade-B	Grade-C	Remarks
Color (%)	75–100	50–70	0–100	5 % variation/box may be allowed
Weight (net) kg	20 (LMS)	21 (LMS)	22	In case of Es and 240 counts, weight may be above 23 kg
Note: In wholesale markets, more weight per box is preferred in a box designed for 20 kg only. However, private firms like Adani Agrifresh Ltd., Fresh and Healthy Enterprises, Harshna Naturals, etc. use 20 kg as standard weight in Grade A, very similar to imported fruits. Grade B and C are kept at little more weight. Fruits get very less or no pressure marks or touching if packed only 20 kg in a box designed for 20 kg only. It is necessary for long distance transportation, especially for South Indian markets				
Firmness (lb)	14 and above	13–15	Not fixed	Grade C also includes droppings
Russeting	Below one rupee coin	Below one rupee coin but 10–15 fruits/box is allowed	No limit	5 % fruits above one rupee coin is allowed/20 kg in A-grade
Shape	Well-formed	Well formed but 10–20 % deshaped fruits/box is allowed	No limit	Lambotra shape is more preferred in grade A
Hail damage	Nil to 3 %/box (minor 1–2 hailed hail spots)	10–20 %/box (minor healed hail spots)	No limit	As we move from top layer to bottom layer no. of hail damage fruits increases. This is a malpractice very common in Indian apple boxes
Sunburn	0–3 % per pack may be allowed	10–20 % per pack may be allowed	No limit	Mild sunburn is difficult to be judged at the time of packing, thus can be found in A-grade also
Skin puncture	NIL	10–20 % per pack may be allowed	No limit	Skin puncture is not allowed in A-grade
Pressure marks	1–2 % per pack may be allowed	10–20 % per pack may be allowed	No limit	Only hard pressure marks are allowed in grade-A (1–2 fruits/pack). As we move from top layer to bottom layer pressure marks in fruits increase in B-grades
Fly specs	1–2 % per pack may be allowed	10–20 % per pack may be allowed	No limit	This is not a major insect disease of commercial importance

(continued)

Table 5.1 (continued)

Parameters	Apple grades			
	Grade-A	Grade-B	Grade-C	Remarks
Sooty blotch	NIL	5–10 % per pack may be allowed	No limit	This is a major fungal disease prevalent in Himachal Pradesh. It spreads more in continuous rains. Fruits having sooty blotch are not preferred for storage
Shriveling	NIL	10–20 % per pack may be allowed	No limit	Never allowed in A-grade fruits
Bruising	NIL	10–20 % per pack may be allowed	No limit	Never allowed in A-grade fruits
Scab	NIL	10–20 % per pack may be allowed	No limit	Minor spot of scale in B-grade may be allowed but not in A-grade
Insect damage	NIL	10–20 % per pack may be allowed	No limit	Never allowed in A-grade fruits

Source: Ahmad et al. (2014)

Peel Color

It is the most important quality parameter of apple in both domestic and imported apple. It is because price is determined on the basis of peel color and the presence or absence of external defects. For Indian apple, color of A-grade apple varies from 70 to 100 %, B-grade 50–70 %, and C-grade 0–100 %.

The peel color plays many important roles in Indian apple business starting from maturity determination to consumption. In other developing or developed countries also, color is an important parameter that decides its price. The price of Fuji apple from China varies according to the number of layers of red blush per pack. Three-layer blushes per pack is more costly than two-layer blush per pack of the same count. Change in peel color is a combination of red blush and the background (BG) color of the peel. Initially, apple is green in color and changes take place as the fruit reaches towards maturation and ripening stage. Peel color also acts as a maturity index for some cultivars of apple and can be used to determine the maturity of the fruit (Huybrechts et al. 2003). Peel color is used to grade the fruit in almost all countries before storage and marketing (Watkins 2003). Now, automatic color grading machine is readily available.

Weight

Weight is the second most important quality factor upon which price is fixed. In general, more weight fetches more price and vice versa. The stock keeping unit (SKU), Large, Medium and Small (LMS) weight 23 kg and Extra small (ES) and

240 counts weight is above 24 kg is regarded as a good lot. Wholesaler and sub-wholesaler offer more prices for heavy weight boxes. It gives an opportunity to the wholesaler and sub-wholesaler to increase the number of boxes if weight is reduced to 20 kg approx. The disadvantage of heavy-weight boxes is damage during handling and transportation. The damage occurs due to compression popularly called touching. This damaged portion ultimately turns black and starts rotting within a week time. These apples fetch least price in the mandi.

The weight (Net Wt.) of imported apple boxes is only 20 kg and buyers are fully satisfied. This is because every fruit in imported apple box is of the same quality. The tendency of packing above 20 kg is totally absent in imported fruits and that is why pressure marks and touching in imported apple are almost negligible. The weight of Jammu and Kashmir (J&K) apple varies between 14 and 17 kg. They use both wooden boxes and CFB boxes of same capacity, i.e., 14–17 kg. They use straw as cushioning material, but Himachal and Uttarakhand farmers use CFB boxes of 20-kg capacities with trays. There are many varieties of apple grown in India, but all do not have much commercial value. The varieties with commercial value are described in Table 5.2.

Table 5.2 Commercial cultivars of apple with their characteristics

Name of cultivars	Characteristics of cultivars
 Royal Delicious	Most common cultivar of Himachal Pradesh fetches highest price as compared to other varieties. Area under this crop is highest in India. On the basis of commercial value, this is further divided into two types (a) *Sapaat Royal and* (b) *Dharidar Royal*. Sapaat Royal possesses full color whereas Dharidar possesses less color
 Red Delicious	This is also as good as Royal Delicious, but lack of uniform full color keeps this variety comparatively less priced then Royal Delicious. This is one of the reasons that area under this crop is decreasing day by day as compared to Royal Delicious
 Golden Delicious	This is a pollinizer variety and also bears golden yellow color fruit. This variety is not kept in store for long period. A very good demand of Golden Delicious is from district Kinnaur of Himachal Pradesh to Azadpur, New Delhi, and other parts of the country
 Rich-A-Red	The skin of this variety is thick and full red but market demand is very less and also fetches less price during season and off-season, hence not preferred for storage on commercial scale

(continued)

Table 5.2 (continued)

Name of cultivars	Characteristics of cultivars
 Ambari	This is supposed to be indigenous to Jammu and Kashmir. This is mainly grown in Jammu and Kashmir. Not grown on large scale and also commercially not important and also lacking storage quality
 Maharaji	This is sour variety of Jammu and Kashmir. It is very much liked in Tamil Nadu due to its sour taste. Not grown on large scale and also commercially not important. Possesses store quality
 Hazratbali	This is the earliest variety from Jammu and Kashmir and highly perishable, not suitable for storage. This variety fetches very low price in mandi
Red Gold	Early variety of Himachal Pradesh, grown in lower heights of Himachal Pradesh

Size/SKU

The common SKU of apple in the market is Extra large (EL), Large (L), Medium (M), Small (S), Extra small (ES), Extra-extra small (EES), and Loose. These SKUs are followed in Himachal Pradesh and Uttarakhand, but not in Jammu and Kashmir. The common counts are described in Table 5.3.

Shape

De-shaped apple fetches fewer prices. Generally, good shape characteristics to varieties are packed. In A- and B-grade apples, 5–10 % shape variation per box is allowed.

Table 5.3 Different SKUs of Himachal apple

S. no.	SKU	No. of layers/box	No. of fruits/layer	Diameter (mm)	Total no. of fruits/box	Remarks
1	Extra-large (EL)	4	20	>80	80	Not advisable for storage for more than one month
2	Large (L)	5	20	75–80	100	All three SKUs are sold at the same rate
3	Medium (M)	5	25	65–73	125	
4	Small (S)	5	30	60–64	150	
5	Extra small (ES)	5	35	50–60	175	More storage life and more demand in eastern part of India
6	Extra-extra small (EES)	6	35	<50	200	More storage life and more demand in eastern part of India
7	Extra-extra small (EES)	6	40	<50	240	Also called heavy pack with trays. Packed with separators also
8	Loose packaging with separators				>80	Boxed packed with separators only

Source: Ahmad et al. (2014)

Physical Characteristics

It includes common defects of apple such as hail damage, sunburn, skin puncture, pressure marks, shrivelling, bruising, and insect pest damages. All defects with respective grades are mentioned in the Table 5.4.

Disease and Insect

The common diseases that affect apple quality are Scab and Sooty blotch. Scab badly affects the appearance of apple and priced very low in wholesale and retail markets. Apples from Himachal Pradesh are almost free from this disease, but Kashmir apple is highly infested. Sooty blotch, another fungal disease, affects quality badly, but upon rubbing with cloths, the black spots or patches on apple disappear. The apple lot infested with sooty blotch is not suitable for storage because during storage pressure reduces rapidly and it easily gets damaged during transportation. Major diseases and defects with photograph are described in Table 5.4.

Table 5.4 Important diseases and defects of apple

Type of damage	Remarks
 Pressure damage	Most common damage in apples and pears. Only careful handling car reduce this damage. It is of two types (a) Soft pressure damage and (b) Hard Pressure damage. The former turns black within 2–3 days and rotting starts in cold storage also and 90 % value of apple is lost. The second keeps well in cold storage but fetches less price
 Russeting	This is a common disorder in Himachal apple. The area surrounding pedicel is affected only. This area becomes rough and lacks color
	Russeting of apples in a humid environment is a major concern of the fruit growers. Russeting occurs shortly after petal fall. The apple cultivars, which have thin cuticle, are more susceptible to russeting. It is commonly noticed on exposed fruits than on fruits under shade. Frost during the blossom or at the early fruit formation stage may also cause russeting. Severe russeting leads to rupture of the fruit skin and development of cracks and not advisable for CA storage
 Apple showing fly speck disease	This is not very common and severe problem, but market value reduces if fruits are infected with fly specks
 Punctured Skin	Identification of punctured skin apple is difficult during sorting and these apples start rotting if stored or packed. Stalk puncture is most common. Stalk of one fruit damages other fruits
 San Jose Scale	This is a serious pest of both J&K and Himachal apple. The fruits infected with this insect are not recommended to keep in cold store or CA store. This is identified easily by the presence of red marks at the distal ends. Fetches low price, but not easily noticed by consumers in the market
 Misshaped fruit	Misshaped fruits fetch low price and should always be included in C-grade. These fruits should be sold in local markets. Nutritionally not inferior but consumer acceptance is NIL or very less
 Hailed Fruit	Most common natural calamities affect apple quality. Hailed apple fetches low price and not liked by consumers. Not preferred for storage because of low price offered during off-season

(continued)

Table 5.4 (continued)

Type of damage	Remarks
 Sunburn	This physiological disorder occurs due to intense heat of the sun. Fruits on the southwest side of the tree are generally affected. Water stress can also increase the incidence of sunburn. Initial symptoms are white, tan, or yellow patches on the fruits exposed to the sun. With severe skin damage, injured areas of the fruit can turn dark brown before harvest. Fruit exposed to the sun after harvest can develop severe sunburn
 Apple scab	Most common in J&K fruits and commercial value reduces drastically. Apple scab is spread through fungus growing in old apple leaves on the ground and spreads during warm spring weather to infect the new year's growth
 Sooty blotch	This is a fungal disease, removes upon rubbing and washing, but fruits infected with this disease are not suitable for storage. This disease spread rapidly during continuous rainy season. Fruit pressure reduces drastically if stored
 Water core	Large size fruits are mostly susceptible to this type of disorder. Disorder at preharvest stage results in the development of water-soaked regions in the flesh. Water-soaked areas are found near the core or on the entire apple. If symptoms are mild to moderate, they may disappear completely in CA storage. Severely affected fruits may smell and have a fermented taste. Severely affected fruits are not recommended for storage

Quality Specifications of Kashmir Apple

Harvest Maturity Indices of Kashmir Apple

Maturity indices of Kashmir apple are more or less same to that of Himachal apple. Maturity standards are judged by both non-destructive and destructive methods. Non-destructive methods are used by farmers and destructive by organized vendors including back-end and front-end companies. Under non-destructive method, number of days from flowering, fruit size, and external color are important, and under destructive, seed color, flesh firmness, and starch iodine test are important. The most obvious index of fruit maturity for farmers is external skin color. As the fruit matures, the skin color will change from green to red. However, organized retails and fresh produce firms use pressure test and starch iodine test to identify maturity and quality for storage.

Quality of Kashmir apple and Shimla apple are almost same. However, little differences in the form of grade name and other parameters are listed in Table 5.5.

Grade A is also called Premium quality. This quality fetches highest price in the market. The quality assumption and standards may vary from buyer to buyer and

Table 5.5 Quality grades of Kashmir apple

Parameters	A (Ex-Fancy)	B (Fancy)	C	Remarks
Color (%)	>75	50–70 %	0–100 %	Quality variation/box in A and B should not exceed 5 %
Count	4-layer, 5-layer and Roll (6-layers)	4-layer, 5-layer and Roll (6-layers)	Loose packing	Number of layers per box. Loose packing have no layers
Note: In 4-layer boxes, 60–68 fruits may be packed, 5-layer boxes 110–112 fruits may be packed, rolls contain 170–180 fruits/box. (In Kashmir packing 4-layer means Ex-large and large fruits, 5-layer means- medium and small and roll means Extra small and pittu)				
Firmness	Firmed (pressure—15 lb or above)	Firmed (pressure—12–14 lb or above)	Firmed but also includes droppings (pressure—8–14 lb)	
Note: Pressure must be checked by pressure tester. Pressure value of Kashmir apple is less than Shimla apple but Kashmir apple is more sweeter than Shimla apple				
Russeting	Below one rupee coin	Below one rupee coin, 5–10 fruits/box above one	No any criteria	
Note: In general, russeting is not a problem in Kashmir apple. Naturally very less russeting is found (<50 paisa coin) at higher elevation in the district of Sophian and Pulwama. Apples from sopore district possess russeting and also dull color, not prefered much for storage				
Shape	Well-formed (Lambotra shape of Kullu Delicious)	misshape up to 10–20 %	Mainly de-shaped Fruits (50–100 %)	Grade A also include 2–5 % de-shaped fruits
Hail damage	Nil to 3 % (fruits with single-healed hail is allowed up to 3 % in a single pack)	Up to 5–10 % (fruits with single- and double-healed hails are allowed up to 10 % in a single pack)	No limit	As we move from top layer to bottom layer no. of hail damage fruits increases. This is a malpractice very prevalent in Kashmir apple

(continued)

Table 5.5 (continued)

Parameters	A (Ex-Fancy)	B (Fancy)	C	Remarks
Sunburn	2–3 % on surface are and not more than 3 % in a box	5–10 % note more than a one rupee coin size 10 % in a box	No limit	Mild sunburn is difficult to judge at the Time of Packing, thus it can be found in A-grade also. Sunburn apples are not suitable for storage, as deterioration starts from sunburn portion
Skin puncture	NIL	10–20 %	No limit	Skin puncture is not allowed in A-Grade
Pressure marks	1–2 %	10–20 %	No limit	As we move from top layer to bottom layer, pressure marks in fruits increases in B-grades
Fly specs	2–3 %	20–30 %	No limit	
Sooty blotch	NIL	5–10 %	No limit	Fruits having sooty blotch are not preferred for storage
Shriveling	NIL	10–20 %	No limit	As we move from top layer to bottom layer, quality decreases in A- and B-grades
Bruising	NIL	10–20 %	No limit	
Scab	Nil	5–10 %	No limit	In Himachal Apple generally no scab found or miner scab
Insect damage	Nil	5–10 %	No limit	

Source: Ahmad et al. (2014)

Table 5.6 Quality grades of premium quality apple

S. no.	Parameters	Premium quality
1.	Color	Fruits having color on >75 % surface area (Characteristic to the variety). Fruits which do not meet this criteria shall not exceed 5 % per box
2.	Shape	Characteristic to the varieties/fairly well formed
3.	Count	4-layer box—60–68 counts and 5-layer box—110–112 count
4.	Firmness	Average—14 lb and not more than 10 % fruits with pressure 12–13 lb
5.	Hail damage	Fruits with single-healed hail mark may be allowed up to 2 % of the total count
6.	Sunburn	Fruits with sunburn on 2 % surface area should not exceed 2 % fruits by count per box
7.	Russeting	Russeting up to shoulders allowed only 3 % of fruits per pack
8.	Skin puncture	Free of skin puncture
9.	Fly speck	Free of fly speck (1–2 % fruits per pack may be allowed)
10.	Sooty blotch	Not allowed
11.	Pressure marks	Not exceed 50 paisa coin size allowed in 3 % fruits per pack. Only hard pressure marks are allowed not soft pressure marks
12.	Shriveling	Not allowed
13.	Soft patch	Not allowed

Source: Ahmad et al. (2014)

Fig. 5.1 A-grade apple (premium quality) color >90 %

firm to firm, but in general, quality attributes of a Premium quality fruit should have minimum quality standards as listed in Table 5.6. Figures 5.1 and 5.2 show grade A and grade B, respectively.

Fig. 5.2 B-grade apple color >60 %

Selection Criteria

A general selection and rejection criteria before purchasing and marketing are applied to all fruits and that also holds true for apple.

- Apple shall be mature, firm, clean, fresh, of shinning surface, and well formed and shall have color and shape characteristics of variety.
- Shall be free from bruises, sunburn, spray burn, superficial scald, water core, rusetting, dark brown marks, cuts, broken skin, ruptured skin, internal browning, dry look, bitter pit, holes, scab, fly speck, sooty blotch, San Jone scale, scab, shrivelling, etc.
- Shall also be free from any type of injury caused by hails, packing, pressure, and mechanical means.
- Shall be sound and free from rotting, fungal infection, insect, and disease infestation.

Rejection Criteria

During marketing, buyers may reject the lot on the basis of following defects:

- Holes or mechanical damage on the surface (Cracks, cuts)
- Water core (Flesh with Water-soaked patches), Bruised
- Bitter pit (Sunken Brown spot on the skin)
- Internal breakdown (Browning and breakdown of the internal flesh)
- Overmatured fruits with soft scald on the surface and internal breakdown
- With Moldy Core (Generally Red Delicious is more prone to moldy core)
- Misshaped, immature, and overripe

Quality Parameters of Banana

In general, banana is available round the year in few states of India. However, during the winter season, its availability in the market reduces drastically. South India is the major producer centre of Banana. Tamil Nadu, Andhra Pradesh, Maharashtra, and Karnataka are the leading states of banana producer and supplier to modern formats and North Indian states. Other important banana-producing states are West Bengal, Bihar, Orissa, Madhya Pradesh, and Assam. Quality of banana depends upon the maturity stage at which it is harvested. The maturity stages are described below.

Harvest Maturity Indices of Banana

Various non-destructive maturity indices can be used to determine proper stage for harvesting banana. These indices mainly include number of days from inflorescence emergence, fruit shape, and drying of flowers at the tip of banana fingers. It is important to harvest banana fruit at the proper maturity stage because fruits do not ripen well and taste good if harvested immature. The most obvious index of banana fruit maturity used by growers is the shape of the fingers. A mature banana exhibits round fingers (triangular shape of banana fingers disappears), whereas immature show triangular shape as shown in Figs. 5.3 and 5.4, respectively.

There are two commercial qualities of banana: first green quality and second ripe quality. The green quality is important because it decides final quality of ripened fruit and transportation ability to distant markets. The ripe quality determines shelf life during distribution and marketing and provides consumer satisfaction. Banana from Southern part to Northern part of India is transported at mature green stage. Ripening treatment is given at the sub-wholesaler or retailer end. Banana quality depends on harvesting stage and subsequent handling. Fruits develop its full characteristic flavor, taste, and color during ripening if it is harvested at optimum maturity stage. Fruits harvested at an early stage of maturity are more susceptible to shrivelling. Improper handling results in development of spots and mechanical

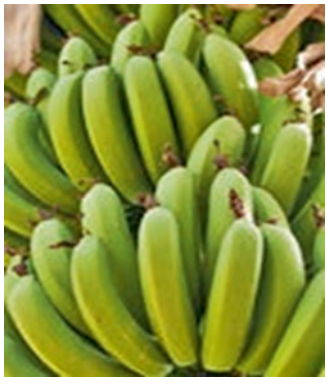

Fig. 5.3 Mature banana

Fig. 5.4 Immature

Table 5.7 Finger length and diameter (mm) of commercial varieties of banana

S. no.	Name of verities	Finger length (mm)	Finger diameter (mm)	Remarks
1	Robusta	>220	>35	Used for table purpose
2	Rasthali	>140	>40	Used for table purpose
3	Poovan	>120	>30	Used for table purpose
4	Nendran	>200	>40	Suitable for chips
5	Dwarf Cavendish	>180	>35	Used for table purpose
6	Hill Banana	>130	>30	Suitable for cooking
7	Red Banana	>180	>40	Used for table purpose

Source: Ahmad et al. (2014)

damage and quality becomes poor after ripening. On the other hand, harvesting at an advanced stage of maturity is unsuitable for long distance transportation. Banana generally is not stored in cold storage, but just for few days at 12–13 °C.

The hands are graded based on the number and size of fingers in each hand. Overripe and injured fruits are discarded at this stage. Major criteria for quality are based on loom size in terms of weight and number of fingers. Grading is done on the basis of fruit length and diameter of the fingers. Bruised marks, cuts, crack, misshape, twin fruits, mechanical damage, sunburn, and pressure damage are considered as defects.

General Characteristics

Banana fingers shall be free from rotting, fungal infection, insect and disease infestation, bruises, spots, sunburn and chilling injury symptoms, cuts/cracks, misshape or double, rupture skin, and any type of damage caused during handling. The fruit should be clean, firm, and mature and shall have shape characteristics of the variety. Stalk and crown portion of the banana hands shall not be black and damaged and shall be free from rotting or fungal infection. Finger length and diameter of banana fingers are taken as quality criteria for export and domestic markets. Important varieties with finger length and diameter are listed in Table 5.7.

Table 5.8 Defects tolerance limit of banana grades

Defect tolerance	Grade-A (%)	Grade-B (%)	Grade-C (%)
Minor defects	10	20	100
Major defects	Up to 2	10	50
Serious defects	0	2–5	5–20

Table 5.9 Major defects of banana

Defects	Descriptions
 Double or twin	Not allowed in A-grade fruits. This is edible but not liked by consumers hence sold at very low price. Generally rejected before ripening. Not inferior in terms of nutrition
 Natural crack	Occurs in many varieties, not allowed in A-grade fruits but may be allowed in B-grade fruits up to 10–20 % fruits per pack provided that cracks are small and covers 1/4th of fruit length. Rotting takes place within 2–3 days and highly disliked by customers
 Black spot on peel	Not allowed in A-grade fruits. This indicates overmaturity and starting of senescence. Black spot on peel also indicates fungal infection
 Black and brown marks	Black or brown marks on the peel is due to mechanical damage develops after ripening, less than 5 % fruits per pack may be allowed in A-grade and 10–20 % in B-Grade. Black spots on peel develop upon ripening and during marketing period
	10–20 mm deep cut in 10–15 % fruits may be allowed in B-grade fruits but never allowed in A-grade fruits

Defect and *size tolerance* (*by weight*): In every consignment, there is a tolerance level indicated by the consigner and accepted by consignee. It may vary from buyer to buyer or place to place. Here defect tolerance level for banana is listed in Table 5.8, major defects in Table 5.9, and size tolerance in Table 5.10.

Table 5.10 Size tolerance limit of banana grades

Varieties	Grade-A		Grade-B		Grade-C	
	Length (mm)	Diameter (mm)	Length (mm)	Diameter (mm)	Length (mm)	Diameter (mm)
Dwarf Cavendish	>130	>35	<130	<35	Any size	
Robusta	>120	>35	<120	<35		

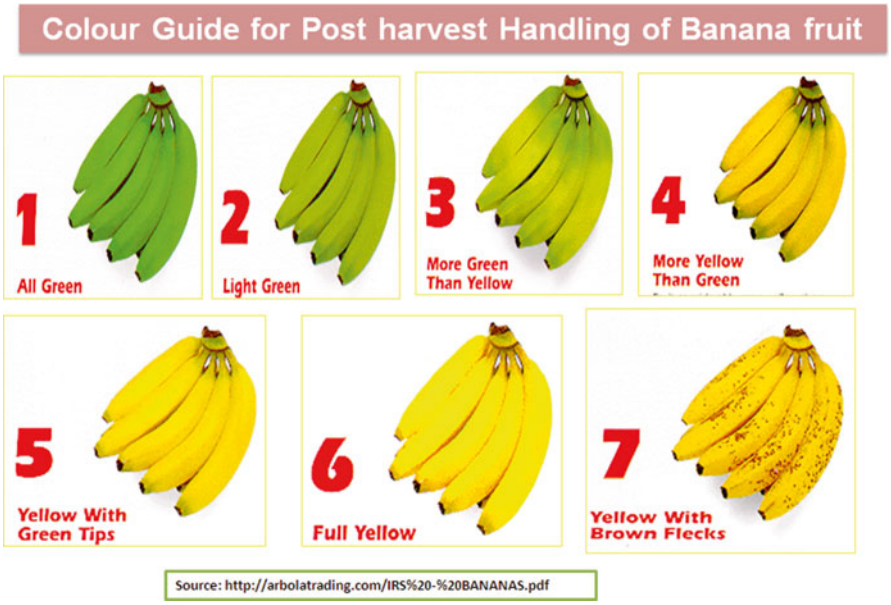

Fig. 5.5 Color chart for judging ripening quality of banana

Marketing Quality After Ripening

Banana is ripened based on market demands and distance of the market to be supplied. As ripening starts, peel color of banana changes. Best color develops if harvested at optimum maturity stage. (The most important and reliable maturity indices are disappearance of angularity of fingers and drying up of flowers at the tip of the finger.) However, there are few varieties where peel color remains green after ripening. For example, the peel color of Harichal banana would not change even after ripening has been completed. Color development during ripening of banana indicates transportation ability, marketing period, and shelf life of fruits. A color guide is shown in Fig. 5.5 and described in Table 5.11.

Table 5.11 Descriptions of color chart

Indicator numbers	Quality parameters	Descriptions	Remarks
1	All green	Firm and hard fruits with very low sugar content. Before retailing, ripening treatment is suggested	Appropriate stage for long distance transportation
2	Light green	Fruit becomes less firm as starch begins to convert into sugar. Ripening process has begun and fruit generates heat which must be removed to control ripening	This stage confirms beginning of ripening process
3	More green than yellow	Fruit softens as starch converts into sugar continued. Heat generated in ripening chamber must be removed	Long distance retail delivery recommended
4	More yellow than green	Proper color for retail display provides. Many consumers prefer to buy at this stage	This is firm yellow stage
5	Yellow with green tips	Proper color for retail display provides good consumer acceptance	This is soft yellow stage
6	Full yellow	Soft fruit with good flavor. Fruit should be on display shelf and not in storage	On the same day consumption is recommended
7	Yellow with brown flecks	Brown flecks indicate high sugar, mealy texture, and fungal infection	Senescence started

Source: http://arbolatrading.com/IRS%20-%20BANANAS.pdf

Quality Standards of Grapes

Traditionally, grape quality is judged all over the world by visual, taste, total soluble solids (TSS), and acidity (Krstic et al. 2003). The most commonly used quality parameters in India are TSS, visual, and taste. The combined assessment of all gives good quality, and it is not possible to adequately assess quality by taste alone (Cozzolino et al. 2006). Commercially important varieties are Thompson seedless, Sonaka, Black Thompson, Black Sonaka, Bangalore Blue, Anab-a-shahi, and Flame seedless. Among these, Thompson seedless is widely grown and marketed in India. This is also the best variety suitable for storage. Other varieties stored for short periods are Sonaka, Black Thompson, and Red Globe. Red Globe is an exotic variety, but many farmers adopted this cultivar in district Nasik of Maharashtra and highest price is paid to this variety.

General Characteristics

Grape berries shall be fresh, clean, mature, and firm and shall have shape and color true to its variety. Berries shall be firmly attached and evenly spaced on the stalk and be intact in the bunch. Berries shall be free from discoloration, brown stem and stalk, bruising, holes, natural brown marks, and any type of damage caused by pressure, mechanical and other means. Berries shall not be immature, overripe, shriveled, misshaped, and soft/pulpy. Grape bunches shall be compact and well formed and shall not have loose/single berries. Berries shall be sound and free from rotting, fungal infection, insect, and disease infestation. General quality description with size requirements of varieties is given in the Table 5.12.

The grape production is mainly confined in Nasik, Sangli, and Solapur districts of Maharashtra and Bijapur district of Karnataka. Grapes are also produced in Theni (Tamil Nadu) and Cuddapa (Andhra Pradesh). Quality standards of grapes also depend on varietal characteristics. Thompson seedless can be kept in store, but quality of flame seedless, Tas-A-Ganesh, or Anabesahi is not suitable for storage. Black Thompson seedless and Sonaka cannot be stored for more than 1 month because the bunch stem/stalk dries within 1 month. Only Thompson seedless and up to some extent Sonaka can be stored in cold store after sorting, grading, packing, and precooling. Precooling is a compulsory operation for storage of grape. Thompson seedless can be stored for 2–3 months or even more at 1–2 °C with 90 % humidity. Forced air precooling method is used for grapes. Putting grape gourd after is another important step followed in domestic as well as export market. However, quality of grape gourd differs for domestic and export. The quality of grape is judged on the basis of following parameters:

(a) *Berry size*:

Berry size should be greater than 15 mm for Thompson and 18 mm for Sonaka both for domestic as well as for Dubai market. A variation of 2–5 % per bunch is allowed.

(b) *Sugar content* (*TSS*):

Sugar content should be equal to or greater than 17 degree brix (°B) measured by Refractometer (Hand Refractometer).

(c) *Diseases free*:

Two major diseases of grapes have commercial importance: one is powdery mildew (Fungal disease) which is easily identified with the presence of powder-like substance on the peel and stalk of berries. The second is mealy bug (Insect attack) which can be identified easily with the presence of honey- or dew-like substance on berry and fruit stalk. This disease spreads very fast in the field. It is better not to purchase mealy bug-infested orchard. Grapes infected with either of the disease are not suitable for storage. Both spreads during storage and infection may spread to other healthy boxes. For European Union export, grape bunch should be free from all diseases.

Table 5.12 General descriptions and size requirement of grape varieties

Varieties	Color	Berry shape	Berry size (mm)	Bunch weight (g)
 Thompson Seedless	Yellowish green/ Golden yellow	Oblong	12–15	>200
 Tas-A-Ganesh	Yellowish green/ Golden yellow	Elongated	12–15	>200
 Black seedless (Thompson)	Black/Purplish black	Oblong	12–15	>200
Black seedless (Sonaka)	Black/Purplish black	Elongated	12–15	>200
Sonaka Seedless	Yellowish green/ Golden yellow	Elongated	12–15	>200
 Bangalore blue	Dark blue/Purplish black	Oblong	15–23	>250
Anab-a-shahi	Pale green	Elongated	Min. 20	>500

(d) *Tightly held berries*:

Best quality grapes bunch should have tightly held berries. One berry can hold the full weight of the bunch. This is a test, widely used by growers and buyers. This gives an idea of berry droppings during storage and long distance transportation.

(e) *Physiological disorders*:

There are few physiological disorders of grapes strictly prohibited for storage and export. Physiological disorders are pink berry, hard berries (Karak money), water berries (Puchka), and yellow berries (Sunburn). Pink berries, water berries, and sunburn berries get spoiled during storage. Hard berries and water berries taste sour, not desirable and also not suitable for storage. The water berries are identified easily by dark green color of berry. Initial experience is required for identification of physiological disorders mentioned above.

Water berries, pink berries, hard berries, and discoloration in the bunch are not allowed in export consignment, but in few cases, they are allowed for Middle East countries (Dubai, Saudi Arabia, Iran, etc.) as per the allowed tolerance limits. During sorting or cleaning of bunches, all defected berries are removed before packing and precooling. The sorted and packed boxes are palletized and precooled. For storage purpose, grape is either packed in perforated plastic crates with newspaper as lining material with grape gourd or CFB boxes with perforated pouches of 500–600 g each with grape gourd. One plastic crate contains 18–20 kg approximately, whereas one CFB box mainly contains 8–9 polyethylene pouches and gives about 4.5 kg (net wt.). CFB boxes of 10–12 kg capacity are also available and used for domestic markets.

(f) *Total soluble solids*:

TSS shall be 16–22 % depending on varieties. For Bangalore blue and Anab-a-Shahi variety, minimum TSS shall be 13 %. TSS is judged by hand refractometer. Irrigation before harvesting decreases TSS, but increases bunch weight.

Note: *Irrigation should not be applied just 1 or 2 days before harvesting. It not only increases the bunch weight, but also decreases TSS and storage quality. It is advisable to stop irrigation 1 week before harvesting*.

Grades and Tolerant Limits

There shall be three Grades for Grapes, viz., Grade A, Grade B, and Grade C. The size requirement, defects, and tolerance limit are listed in Table 5.13.

For better shelf life and to maintain quality, the following points are indicative of good quality grapes:

- Grape berries which contain more pulp percentage have longer shelf life.
- Glucose sugar helps in better storage than fructose sugar. The sugar content of berries is related directly with postharvest life. If it is more, the shelf life is more and vice versa.
- The berries obtained from low nitrogen-applied vines show better shelf life.
- Grape berries which retain shining for more time have better storage life.
- Green-stemmed bunches of berries last longer.
- Healthy grape berries last longer in storage.
- Grapes harvested at low temperature and kept at low metabolic/physiological activities have more shelf life.
- By using grape guards, the freshness of berries can be retained which ultimately prolongs shelf life.

Table 5.13 Defects and tolerance limit among the grape grades

Defects	Levels of defects in grapes			
	Grade-A	Grade-B	Grade-C	Remarks
Overripe	Not allowed (1–3 berries/ bunch may be allowed)	Not allowed (10–20 berries/bunch may be allowed)	Allowed	Overripe berries also include yellow berries turned on exposure to sunlight
Discoloration/ Pigmentation	Not allowed	Not allowed (2–5 berries/bunch may be allowed)	Allowed	Pink berries are good example of pigmentation. These are sweet in taste but no commercial value hence not desirable
Brown stalk	Not allowed	Not allowed (10–15 % fruit stalk may turn brown upon dehydration/bunch may be allowed)	Allowed	Turning of fruit stalk/ stem into brown color is an indication of shelf life of harvested bunch and also indicate when it is harvested
Insect damage	Not allowed	Not allowed (5–10 % fruit/box may be infected but not severe)	Allowed	Mealy bug is the most important pest of grape. Infected bunch is not advisable for storage. During storage also it spreads from one to another bunch
Bruising	Not allowed (such berries must be trimmed out)	Not allowed (5–10 % fruit/box may be allowed with slightly bruised fruits)	Allowed	Bruised and damaged berries must be trimmed out. These berries spoil quickly

Source: Ahmad et al. (2014)

Quality Standards of Pomegranate

Pomegranate is mainly grown in Maharashtra, Gujarat, and Karnataka. This is a high-value fruit for both domestic and export. There are few varieties that are always on demand. The general characteristics are described in Table 5.14.

Pomegranate shall be clean, firm, fresh, and mature and shall have color and shape characteristics of variety. Pomegranate shall be free from cut/crack, holes, bruises, and natural brown/black spots. Pomegranate shall not be soft and mis-shaped and shall be free from damage caused by birds, packing, handling, and mechanical means. Pomegranate shall be sound and free from rotting, fungal infection, insect, and disease infestation. Outer rind of pomegranate shall have fresh and shiny look. Grades and tolerance limit for checking quality are listed in Table 5.15.

Table 5.14 General descriptions of commercial varieties

Varieties	Description
 Miridula	Very attractive aril (Blood red) color, good demand in the market
 Arakta	The fruits are bigger in size, sweet with soft seeds, bold red arils. It also possesses glossy, attractive, dark red skin. Fruits are dark red in color with soft seeds and with high TSS
 Ganesh	This variety has pinkish yellow to reddish yellow rind color, having light pink arils and soft seeds. Fruit weighs between 225 and 250 g with medium TSS
 Bhagwa	The fruit is glossy red in color with soft seeds and high TSS

Table 5.15 Defects and tolerance level in different grades of pomegranate grown in India

Defects	Grade-A	Grade-B	Grade-C
Dry skin	Not allowed	Allowed 10–20 %	Allowed
Bruises	≤1 cm^2 surface area/1–2 fruits/pack (Nt.wt. 4–5 kg)	20–50 % surface area	All Allowed
Natural brown marks on surface	>10 % surface area/2–5 fruits/pack (Nt.wt. 4–5 kg)	30–50 % surface area	Allowed
Pressure damage	Not allowed	10–20 % surface area	Allowed
Cut/crack	Deep cut/crack >2 cm long	Deep cut/crack 2–4 cm long	Allowed
Holes	≤2 holes (if no juice seepage)	Allowed	Allowed
Mechanical damage	Not allowed	>2 cm^2 surface area	Allowed
Diseased	≤1 % in a lot	≤2 % in a lot	Allowed
Misshape		Allowed	Allowed
Immature (dark green)	Not allowed	N.A.	Allowed
Black spots on surface	5–10 % surface area	10–20 % surface area	Allowed
Insect damage	Not allowed	N.A.	Allowed
Rotting/fungal infected	Not allowed	≤2 % in a lot	Allowed

Source: Ahmad et al. (2014)

Fig. 5.6 Important varieties of pomegranate

Fruit Characteristics

Pomegranates are an attractive, apple-shaped fruit that has a reddish-gold leathery skin with a large calyx or crown on one end. Inside is a mass of creamy white edible seeds, each encased in a translucent sac of deep pink or crimson pulp and held together by segments of bitter inedible yellow to white membrane that extends outward to the skin. Pomegranates from wild trees contain a high percentage of seeds and membranes. Their scanty pulp is often sour and astringent, but even these have found a use in an Indian condiment called "anardana" or in Middle Eastern condiments and garnishes. By contrast, cultivated pomegranates have plenty of juicy pulp with a sweet, sharp flavor, which is only slightly astringent. In the east, there are now some varieties that are almost free of seeds or have soft seeds, as those found in the cultivar Bedana in India. In general, there seems to be no seedless varieties grown in western countries, although types with soft seeds are often classed as "seedless." Fruit varieties having dark red color arils are suitable for processing.

Main Varieties in Demand (Fig. 5.6)

- Bhagwa: Attractive, shiny, and reddish orange color in skin and fruit is red in color. This is also called Kesar. Aril color is pink.
- Arakta/Miridula: Attractive and blood red color in skin and fruit is red in color. Aril color is blood red.
- Ganesh: Pinkish yellow skin and fruit is pinkish white. Aril color is whitish pink.

Packing and Pack Size

The fruit is packed in CFB cartons called Karandi, and to avoid damage, paper cuttings are used as cushioning. The weight of box and paper cuttings alone varies from 0.5 to 1.0 kg. Pomegranate marketing is based on number of fruits/box

popularly called counts or Dana. The prevalent counts in mandi are 9, 12, 15, 18, 22, 24, 27, 30, 36, 40, 45, 48, 60, and loose.

Counts 9, 12, 15, and 18 come in single layer and mainly come from Sholapur (Maharashtra). The packing from Nasik is in two layers which includes mainly 12, 14, 16, 18, 22, 24, 30 Dana.

Export Quality

Export quality pomegranate is packed in CFB boxes only with trays and cushioning materials. It varies from country to country and buyer to buyer. Export quality for Middle East countries are listed below in Table 5.16. Grades and criteria for selection of grades are described in Table 5.17.

Table 5.16 Export quality of grapes for Middle East countries

General description	Fruits should be wholesome of specified variety/cultivar with good appearance and within permissible limit of sign of spots on the peel/bruising/scratches/ pressure damage/rusting, etc. It shall be round-shaped, mature, firm, free from diseases, pest infestation and significant calyx damage and able to meet the specified export quality requirements			
Color	Yellowish Orange to Red/saffron			
Fruit weight (g)	9 count	12 count	15 count	18 count
	350–450	270–350	200–270	170–200
Brix	12–16 (Average of 6 fruits)			
Taste	Sweet taste			
Net wt./box	3.5 kg			
Quality attributes				
S. no.	Major defects	Max. permissible limit (%)		
1	Soft and black arils/seeds	1		
2	Cracked fruit/surface	0.5		
3	Superficial Fungal/bacterial spots	1		
4	Fruit borer infestation	NIL		
5	Mites attack on fruit-rusting	NIL		
6	Fruits with chilling injury symptoms	NIL		
S. no.	Minor defects	Max. permissible limit (%)		
1	Minor variation in surface color	10		
2	Minor sunburn spots	5		
3	All types of superficial blemishes (bruises, scratches)	5		
4	Minor thrip# marks	10		
5	Fruit weight less than specified	5		

(continued)

Table 5.16 (continued)

Critical rejection criteria	
1	Produce not matching the general requirement/description or not being fresh and wholesome
2	Presence of any critical foreign matter including glass, metal, filth, poisonous plant or insect, etc.
Mode of transportation: Sea Shipment	
Storage: At Temp. and RH of 5–7 °C and 92 ± 2 %	
Packing	In CFB (Carton)
1	No. of Fruits Per Box 9–12 or 15 OR as specified
2	Bubble sheet + Seperator or Tray
4	Net fruit weight per box 3.5 kg ± 5 % of net
#Remark	One thrips mark up to a maximum size of 5 cm × 1.5 cm (that can be covered by finger) per fruit is acceptable
Container capacity—15,400 kg	
Percentage of 9, 12, 15, and 18 count—as per order requirement	

Source: Ahmad et al. (2014)

Table 5.17 Criteria and description of grades

Grade name	Grade requirements	Grade tolerances
Extra class	Pomegranate in this class must be of superior quality. They must have the shape, development, and coloring that are typical of the variety and/or commercial type. They must be free from defects, with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality, and presentation in the package	5 % by number or weight of not satisfying the requirements of the grade, but meeting those of class I grade or, exceptionally, coming within the tolerances of that grade
Class 1	Pomegranates in this class must be of good quality. They must be characteristics of the variety and/or commercial type. The following slight defects may be allowed, provided these do not affect the general appearance of the produce, the quality, the keeping quality, and presentation in the package—a slight defect in shape—a slight defect in coloring;—slight skin defects (i.e., scratches, scars, scraps, and blemishes) not exceeding 5 % of the total surface area	10 % by number or weight of pomegranates not satisfying the requirements of the class, but meeting those of class II or, exceptionally, coming within the tolerances of that grade
Class 11	This class includes pomegranates which do not qualify for inclusion in higher classes, but satisfy the minimum requirements. Following defects may be there provided the pomegranates retain their essential characteristics as regards the quality, the keeping quality and presentation:—defects in shape;—defects in coloring—skin defects (i.e., scratches, scars, scrapes, and blemishes), not exceeding 10 % of the total surface area	10 % by number or weight of pomegranates not satisfying the requirements of the grade, but meeting the minimum requirements

Quality Standards of Mango

General Quality Aspects

Mango is regarded as the king of tropical fruits and quality is the most important criterion like any other fruit for marketing in domestic and international markets. Quality of mature green mango differs from ripe mango fruits (Siddiqui et al. 2014). Mature green mango fruits should have swollen shoulder (fullness of chicks), hard, and clean and shall have olive green color with whitish waxy layer (bloom). Mangoes shall be free from black/brown spots, bruises, cuts, watery patches, internal spongy tissue, and any type of damage caused by hail, packing, pressure, and mechanical means. Mangoes shall be sound and free from rotting (stem end rot or lateral rot, or any other rot), fungal infection, and insect and disease infestation. General characteristics of few commercially important mango varieties are described in Table 5.18. The permissible defects with tolerance limit and grades are enumerated in Table 5.19 and size grading in Table 5.20.

Table 5.18 General characteristic of few commercially important mango varieties grown in India

 Alphanso	Fruit medium in size, ovate oblique in shape, orange yellow in color; juice is moderate to abundant; excellent keeping quality, good for pulping and canning; mainly exported as fresh fruit to other countries; Flesh develops spongy tissue, a physiological disorder develops only in Alphanso. Main producing state is Maharashtra and Gujarat
 Banganapalli	This is also called as Baneshan or Safeda. Variety suited for dry areas; fruit large-sized, obliquely oval in shape, golden yellow in color; good keeping quality; good for canning also; biennial in habit. Earliest variety from South India. Main producing state is Andhra Pradesh
 Chausa	Fruit large, ovate to oval oblique in shape and light yellow in color, flesh fibrous; medium keeping quality; extremely sweet in taste; alternate bearing variety; shows apical dominance. It is mostly grown for table and processing purpose. It is a late variety
 Dashehari	One of the best variety of the country; fruit size is small-medium, shape is elongated with yellow fruit color, flesh is fiberless; good keeping quality; mainly used for table purpose; susceptible to mango malformation. Dashehari-51- regular bearing and yielding clone of Dashehari

(continued)

Table 5.18 (continued)

 Langra	Variety is alternate bearer; fruit medium and ovate. Peel color slightly turns yellow upon ripening, keeping quality medium
 Malika	Malika (Neelum X Dashehari) Fruit large, oblong elliptical yellow in color; fruit and keeping quality is good and is mostly used for table purpose
 Neelum	Fruit is medium ovate-oblique in shape and saffron yellow in color; good keeping quality; high yielding and regular bearing; ideal variety for transporting to distant places. This variety is mostly used for table purpose
 Totapuri	Fruits medium-large, oblong-shaped with pointed base with golden yellow color; good keeping quality; used for processing; heavy and regular bearing variety; susceptible to bacterial spot. Best mango variety for processing due to more pulp content and pulp is fiberless. Grown widely in South India
 Amrapali	Amrapali (Dashehari X Neelum) Dwarf, regular bearing and late maturing variety; suitable for high density planting; flesh is fiberless; average yield 16 t/ha

The quality of ripened fruits should be firm and ripe and shall have shape and color characteristics of the variety. Mangoes shall be free from black/brown spots,bruised marks, cuts, watery patches, internal spongy tissue, and any type of damage caused by hail, packing, pressure, and mechanical means. Mangoes shall not be soft, overripe, misshaped, and shrivelled. Mangoes shall be free from rotting (lateral rot or stem end rot or any other rot), fungal, and insect disease infestation. Mangoes shall be free from abnormal external moisture and foreign smell.

Table 5.19 Defects and tolerance level in different grades of mango grown in India

Defects	Grade-A	Grade-B	Grade-C
Bruised marks	5–10 % surface area	10–20 % surface area	No limit
Latex spots	5–20 % surface area	Allowed	No limit
Shriveled	Not allowed	Slight shrivelled	No limit
Discoloration	Not allowed	Slight discoloration	No limit
Watery patches	Not allowed	20–30 % surface area	No limit
Misshape	Slight misshape allowed	Allowed	No limit
Pressure damage	Not allowed	10–20 % surface area	No limit
Cut		Deep cut (30–50 mm long)	No limit
Mechanical damage	≤2 cm^2 surface area	2–4 cm^2 surface area	No limit
Spongy tissue (in case of Alphanso)	Not allowed	Allowed	No limit

Source: Ahmad et al. (2014)

Table 5.20 Grade-wise standard weight of mango varieties

Varieties	Grade-A (g)	Grade-B (g)	Grade-C
Mango Banganpalli	>300	200–300	Any size
Mango Alphanso	>180	130–180	
Mango Chousa	>250	180–250	
Mango Dashehari	>180	120–180	
Mango Langra	>220	150–220	
Mango Malgoa	>250	180–250	
Mango Mallika	>300	200–300	
Mango Neelum	>220	150–220	
Mango Pairi	>220	150–220	
Mango Raspuri	>250	180–250	
Mango Sindhuri	>200	150–200	
Mango Totapuri	>350	250–350	
Mango Rumani	>200	120–200	

Source: Ahmad et al. (2014)

This protocol for Mango Handling and Ripening is designed to help in improving mango handling practices (better quality maintenance, less prone to damage and disease infestation, greater consumer acceptance, and higher mango sales). This document provides knowledge of mango handling in the supply chain (grower's end, retailers, wholesalers, importers, exporters, and anyone who handles mangoes in any part of the country).

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Chapter 6
Commercial Quality: Part II

Quality Standards of Papaya

The papaya (*Carica papaya*) is a popular fruit in India, available throughout the year. Papaya trees begin to produce fruit within 9 months after transplanting, depending upon cultivar, production practices, and weather conditions; several types of papayas are grown in India ranging from the large elongated fruit type to the smaller round type. The fruit is widely distributed in the domestic market.

Harvest Maturity Indices

Various non-destructive indices can be used to determine papaya harvest maturity, including the number of days from flowering, fruit size, and external color. It is important to harvest papaya fruit at the proper maturity stage because fruits became insipid and not ripen properly if harvested immature. Papayas normally require about 3 months from flowering until fruit maturity. The smaller papaya fruit generally weighs between 350 and 500 g when mature. Native type fruits are significantly larger when mature, often weighing more than 500–1000 g or even more when matures. The most obvious index of fruit maturity is external skin color (Figs. 6.1 and 6.2). As the fruit matures, the skin color will change from green to yellow/orange.

General Characteristics

Papaya shall be fresh, clean, mature, firm, and oval/round shape with light green/yellow color true to its varietal characteristics. Papaya shall be free from cuts/cracks, holes, bruised marks, and any type of damage caused by birds, pressure,

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_6

Fig. 6.1 Fully mature

Fig. 6.2 Overmature fruits

mechanical, and handling means. Papaya shall be sound and free from rotting, fungal infection, insect, and disease infestation. Papayas for export should be harvested between the one stripe stage (one yellow stripe showing at the blossom end) and the quarter-ripe stage (some yellow at the blossom end).

Fruits harvested at these stages of maturity will withstand the rigors of shipping and transport to distant markets. Fruits harvested immature green will not ripen properly, will taste flat, and shrivel prematurely. Wholesale market in India prefers fruits to arrive at the half-yellow color stage. Flavor and edible quality generally improve with advancement in ripening, but deterioration also starts. Fruits intended for domestic markets can be harvested at a more advanced stage of ripeness than export market fruit. Fruits for domestic market should be harvested when the skin is partially yellow-orange in color (between one-quarter to half-ripe). A completely yellow-orange skin indicates full ripeness and generally a sweeter fruit. However, the postharvest life of this full ripe stage fruits will typically be less than a week.

Destructive indices used for determining harvest maturity include internal pulp color and % soluble solids content (sugar content). These indices are used to test randomly selected fruits in order to correlate fruit size with maturity. The internal

Table 6.1 Size and grade of papaya

	Grade-A (g)	Grade-B (g)	Grade-C (g)
Papaya	700–1400	>1400	Any size

pulp color of mature papaya fruit changes from cream to yellow orange as the external skin color changes from green to yellow-orange during ripening. The soluble solids content of mature fruits should be at least 11.5 % and can be determined by placing 2–3 drops of juice on a hand-held refractometer. Experienced growers use a combination of external and internal maturity indices to determine when to harvest.

Grades

There shall be three grades for papaya, viz., Grade-A, Grade-B, and Grade-C. The size requirements for these grades are described in Table 6.1.

Harvesting Methods

Papayas should be harvested during the coolest part of the day, which is typically the morning period. It should reach packing house before 10 AM in the morning. As the fruit temperature rises, it is more susceptible to bruising injury. The highest postharvest losses in papaya occur due to bruising followed by pathological decay. Avoid harvesting during the heat of the afternoon. Papayas are harvested manually by hand, with a knife, or with a specialized cutting blade. When harvesting by hand or with a knife, the fruit is cut off from the tree with or without a small portion of fruit stalk. If a portion of the stem is still attached, it should be trimmed. Care is necessary to prevent staining of the fruit surface from the exudation of latex out of the cut stem end. When a ladder is required to reach the fruits on tall plants, the harvester typically tosses the fruit to another person standing below.

Papaya fruit is very sensitive to bruising and must be handled gently at all times. Fruits should not be allowed to drop to the ground, as this will soften and damage the pulp and scar the skin. Postharvest deterioration of dropped fruits will be rapid and brown spots will develop on the skin surface, resulting in reduced market quality and value. The initial sorting of marketable versus unmarketable fruits should be made in the field. Severely damaged or defective fruits should be put into a separate container and discarded in a location away from the papaya trees to minimize the build-up of disease inoculums in the area. In many developing countries, these badly damaged fruits are sold to zoo people to feed animals. The remaining marketable fruits, whether intended for local market or export, should be carefully placed in a strong, well-ventilated, padded, stackable field container. The field container should not hold more than 20 kg of fruit and should be put in a shaded area when full. Use of canvas,

sacks, or large volume field containers will result in considerable fruit bruising and skin injury. A better field container is a wooden crate or durable plastic container. Field containers which have a rough or uneven inside surface will scar the skin, especially when there is movement or vibration. This will result in uneven coloration of the skin as the fruit ripens. Skin abrasions result in blotchy coloration and green islands (areas of skin that remain green and sunken when the fruit is fully ripe) and accelerated water loss. In order to avoid skin bruising, field containers should be cushioned with bubble sheets.

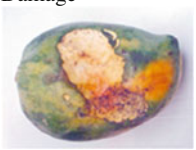
In many developing countries, plastic crates with bubble sheet or newspapers as cushioning material is used for papaya handling. The stem should be trimmed even with the shoulder of the fruit to prevent puncturing or surface abrasion of adjacent fruit. Field crates containing fruit should be put in a shaded area protected from the sun and rain, while awaiting collection for delivery to a packing facility. Care should be taken during transport to minimize fruit vibration in the field crates. Mesh bags, sacks, or baskets are unacceptable for papaya transport due to the high amount of bruising that would occur during transportation. The fruits should be transported to a collection area or packinghouse soon after harvest. The crates should be carefully loaded and stacked in the transport vehicle in order to minimize handling damage to the fruits. There should be adequate ventilation through the field containers and the transport vehicle should have a protective cover over the crates of papayas. Ideally, the fruits should be transported during the coolest time of the day in order to minimize heat build-up inside the transport vehicle. Papayas are very sensitive to heat stress and bruise easily during transport when the fruits temperature is above 32 °C (90 °F). Bruised pulp becomes soft and deteriorates quickly. Upon arrival at the consolidation facility, the crates should be unloaded with care and never dropped. Grades and criteria for checking papaya quality are described in Table 6.2.

Table 6.2 Grades and checking of quality of papaya

Defects	Grade-A	Grade-B	Grade-C
Misshape 	Slightly misshaped fruits are allowed	Allowed up to 50 %	Allowed
Green color	Not allowed if whole fruit is green as it denotes immature fruits	Allowed (up to 10 % fruits/pack)	Allowed
Bruises 	1–2 fruits per pack having bruising over 1–3 cm^2 surface area may be allowed. Minor bruises are allowed only up to 10 % per pack	5–10 fruits per pack having bruising over 10–30 cm^2 surface area may be allowed. Minor bruises are allowed	Allowed

(continued)

Table 6.2 (continued)

Defects	Grade-A	Grade-B	Grade-C
Damage 	Not allowed, minor damage (≤2 cm^2 surface area) may be allowed in 1–2 fruits/pack	Major damage (>3 cm^2 surface area) allowed 5–10 fruits/pack	Allowed
Soft and mealy texture/overripe 	Not allowed (only firm)	5–10 % per pack allowed	Allowed
Black/brown spots on skin	2–3 fruits per pack covering 5 % surface area may be allowed	5–10 fruits/pack having 10–20 % surface area	Allowed
Holes	Not allowed	Minor holes are allowed	Allowed
Bird/insect damage	Not allowed	Allowed up to 5–10 fruits per pack	Allowed
Punctured skin	Not allowed (fungal spoilage starts)	5–10 % fruits per pack allowed	Allowed
Sunburn	Not allowed	5–10 % surface area in all fruits are allowed	Allowed
Cut/crack 	Not allowed	Deep cut/crack 2–6 cm long may be allowed	Allowed
Pressure damage	Not allowed	5–15 % surface area	Allowed
Shriveling	Not allowed	>20 % surface area	Allowed
Rotting/fungal infected 	Not allowed	Not allowed	Allowed

- The above-mentioned quality specification may vary from agency to agency
- Percentage of defects allowed or disallowed in a particular grade will be determined based on weight in a sample lot. Since weight of fruits is more, therefore defects are not calculated on number of fruits
- More than one defect in an individual piece will be considered as major defect
- Extent of defect not covered of Grade A, B, and C means it is allowed in that particular grade or as per company policy

N.A. not applicable

Quality Standards of Mandarin Oranges

General Characteristics

Mandarin oranges should be mature, firm, juicy, and well formed and should possess varietal characteristics. The fruit should be free from black/brown spots, sunburn, cuts/cracks, stem puncture, bruised marks, punctured skin, and any type of damage caused by mechanical, pressure, and compression on skin. Oranges should have smooth skin with uniform golden yellow color. Mandarin oranges should be free from rotting, fungal infection, insect infestation, and diseases. Oranges are non-climacteric in nature; therefore, harvesting should be at proper maturity stage. The maturity stages are described in Table 6.3.

Grading

Grading of Nagpur mandarin is based on diameter as mentioned below. Fruits generally vary from 40 to 80 mm in diameter. Diameter-wise classification is mentioned in Table 6.4

Table 6.3 Fruit maturity criteria of oranges

S. no.	Quality parameters	Specifications	Remarks
1	TSS	Not less than 8°B% brix	12–15 is ideal
2	Acidity	0.6–0.7 % as citric acid	
3	Juice content	Minimum 38–40 %	
4	TSS:acid ratio	TSS/acid ratio-not less than 14 and not more than 20	
5	Color	More than 50 % of the surface should be yellow-orange	
6	Firmness	Nearly 3 kg	

Table 6.4 Diameter of fruits (in mm)

Extra large (mm diameter)	Large (mm diameter)	Medium (mm diameter)	Small (mm diameter)	Extra small (mm diameter)
75–80	65–75	55–65	50–55	40–50

Quality Standards of Kinnow Mandarin

General Characteristics

Kinnow (*Citrus nobilis* Lour, x *C. deliciosa* Ten.) is a hybrid fruit developed by H.B. Frost in California, USA. It is not so easy to peel like Nagpur orange and also not as tough as sweet orange (*Citrus sinensis*). Its uniform yellow color attracts every one. Kinnow should be mature, firm, juicy, and well formed and should possess varietal characteristics. The fruit should be free from black/brown spots, sunburn, cuts/cracks, stem puncture, bruised marks, punctured skin, and any type of damage caused by mechanical, pressure, and packing means on skin. Kinnow should have tight and smooth skin with uniform golden yellow color and a very small part of fruit stalk. Kinnow should be free from rotting, fungal infection, insect infestation, and diseases.

Size Grades

Size grading in Kinnow is based on size of the fruits as mentioned in Table 6.5 and quality criteria in Table 6.6.

Quality Standards of Litchi

General Characteristics

Litchi shall be fresh, clean, firm, red/mehroon in color with round/oval shape and shiny look, characteristics of the variety. Litchi fruits shall be free from dry skin, discoloration, brown/black spots, ruptured skin, misshape, soft, cut/crack, blemishes, bruises, holes, and any type of damage caused by pressure and mechanical means. Litchi shall be with stalk and tied in bunches for fresh sale; sulphited litchi in polyethylene pouches of half kilogram (kg) or 1 kg. Polyethylene pouches should be perforated and it should be packed in CFB boxes of 5 kg. Fruits should be sound and free from rotting, fungal infection, insect, and disease infestation.

Table 6.5 Most common sizes of Kinnow

	Large	Medium	Small
No. of counts	28, 30, 32, and 36	42, 45, 48, and 54	60, 72, and 84

Table 6.6 Quality criteria of Kinnow mandarin oranges

Defects	Grade-A	Grade-B	Grade-C
Misshape	Misshape is not a problem in Kinnow. Negligible rejection on the basis of shape	Allowed	Allowed
Green color	Uniform yellow color is preferred. Less than 5 % fruits per pack (standard pack of 10 kg) may be allowed	Allowed (up to 20 % fruits/pack)	Allowed
Rough/thick skin	Generally Kinnow fruits are washed and waxed, hence rough and thick skin is not of much problem. 2–3 fruits/pack is allowed	Allowed	Allowed
Bruises	1–2 fruits per pack having bruising over 1–3 cm^2 surface area may be allowed. Identification of bruised portion is difficult, if surface area is less	5–10 % surface area allowed	Allowed
Loose jacket	Not Allowed (only firm). Generally the attachment of peel with fruit segments is not very loose. Therefore, loose jacketed fruits are not liked by the consumers	5–10 % per pack allowed	Allowed
Black/brown spots on skin	2–3 fruits per pack covering 5 % surface area may be allowed	10–20 % surface area	Allowed
Punctured skin	Not allowed (fungal spoilage starts). Pedicel or fruit stalk attached with the fruit should be very small, otherwise punctured skin problem will increase	5–10 % per pack allowed	Allowed
Sunburn	Not allowed. It is difficult to spot sunburn fruits	5–10 % surface area	Allowed
Cut/crack	Not allowed. Precaution during harvesting and handling reduces cut/crack drastically	Deep cut/crack 2–6 cm long	Allowed
Pressure damage	Not allowed. Generally plastic crates are used for transportation from orchard to pack house but after washing and waxing, it is packed in CFB boxes of 3-ply and transported to distant markets. Most of pressure damage occurs during transportation in weak CFB boxes and maximum in large fruits	5–15 % surface area	Allowed
Shriveling	Not allowed	>20 % surface area	Allowed
Rotting/fungal infected	Not allowed	Not allowed	Allowed

Percentage of defects allowed or disallowed in a particular grade is based on company policy and calculated on per pack of 10 kg boxes
More than one defect in an individual fruit may be considered as major defect

Maturity Standards

Litchi being a non-climacteric fruit requires to be harvested after attaining full maturity on the tree. It is found from the research that during fruit maturation, pericarp develops first, and then the seed and aril follow after seed (Barman et al. 2014). During maturity, acidity declines and TSS increases which corroborate the appearance and color on the fruit. Thus, the color of fruit is an important criterion to

decide harvesting stage of litchi (Singh and Yadav 1988). The red pigmentation in litchi is associated with anthocyanin pigments (cyanindin-3-glucoside, cyanindin-3-galactoside, pelargonidin-3-glucoside, and pelargonidin-3, 5-diglucozide), which develop better in the direction of good light penetration. Invariably, pericarp color and smoothness or flatness of tubercles are the best indicators (Singh and Yadav 1988). Depending upon the cultivar, 65–80 days are taken for maturity from fruit set. Litchi can be marketed as fresh as well as after sulphuring. Pericarp browning is the limiting factor for fresh litchi marketing. Sulphuring, on the other hand, reduces the risk of pericarp browning, but it needs infrastructure like sulphuring chamber, precooling facility after sulphuring, cold storage, and/or reefer van transportation to distant markets. Litchi quality parameters for sulphited litchi are described in Table 6.7 and quality checking parameters are described in Table 6.8. Grade-wise tolerance limit is mentioned in Table 6.9.

Table 6.7 Quality parameters of sulphited litchi

S. no.	Selection criteria	Requirements	Remarks
1	Shape	Round, oval or heart-shaped	Deshaped fruits upto 5–10 % allowed
2	Appearance	Whole fresh, clean, firm and free from pests, blemishes and mechanical damage	Shrivelled and desiccated are not allowed
3	Size	Diameter—25–35 mm, length—2.5–4 cm (A-grade)	As per demand, size varies, 10–15 % undersize fruits are allowed
4	Weight	20 g and above	As per demand, weight varies, 10–15 % underweight fruits are allowed
5	Color (Fresh)	Red to rose pink	Never green
6	Color (Sulphited litchi)	Uniform light yellow	Persistent of original red color shows improper sulphuring
7	Ripening stage	Flattening of tubercles and development of full red to red rose/pink color	TSS 15°B or above
8	% Pulp	At least 75 % of the weight	It is not mandatory for pulp recovery and processing
9	TSS	about 17–20 degree Brix	Land mark 15°B is must
10	External defects	Free from pests, blemishes, and mechanical damage	Black spots and mechanical damage must be removed, up to 5 % per pack may be allowed
11	Internal defects	Free from soft patches and brown/black aril color is not allowed	Soft patches show that these fruits are droppings and not harvested properly
12	Insect, disease infection	Must be free from insect and disease specially litchi fruit borer. Its identification is difficult before peeling	Presence of insect larvae at the pedicel end not liked by consumers
13	Rotting	Must be free from insect and disease incidence	Mechanical damage during handling develops into rotting during storage and transportation
14	If any other	Quality varies as per customers need	Always little tolerance level should be maintained

Table 6.8 Grades and quality checking criteria with permissible limits

	Grade-A			Grade-B		
Defects	Minor	Major	Serious	Minor	Major	Serious
Misshape	Slight misshape (up to 10 % per pack)	Allowed 2–5 % per pack	Not allowed (2–5 % per pack may be allowed)	Allowed	Allowed 10–20 %	Allowed up to 10 %
Dry skin	2–10 %	Allowed 2–5 % per pack	Not allowed	Allowed	Allowed up to 30 %	Up to 50 %
Discoloration	5–10 % surface area (5–10 fruits per pack)	>25 % surface area (10–30 fruits per pack)	Not allowed	Allowed	Allowed up to 30 %	Allowed up to 20 %
Black/brown spots	5–10 % surface area (5–10 fruits per pack)	>25 % surface area (10–30 fruits per pack)	Not allowed	20–50 % surface area	>50 % surface area	Up to 20 %
Bruises	10–20 % surface area	>20 % surface area	N.A.	20–50 % surface area	>50 % surface area	Up to 20 %
Mechanical damage	≤0.5 cm^2 surface area	>0.5 cm^2 surface area	N.A.	≤1 cm^2 surface area	>1 cm^2 surface area	Up to 20 %
Pressure damage	N.A.	Allowed	N.A.	N.A.	Allowed	Up to 20 %
Cut/crack/split	Deep cut/crack/split ≤1 cm long	Deep cut/crack/split >1 cm long	N.A.	Deep cut/crack/split 1–2 cm long	Deep cut/crack/split >2 cm long	Up to 20 %
Ruptured skin	≤0.5 cm^2 surface area	Not allowed	5–10 % per pack allowed	Up to 20 % fruits/ pack	10–30 %	Up to 20 %
Insect damage	Allowed 10–20 % per pack	Not allowed	Not allowed	Allowed 20–40 % per pack	Allowed up to 20 %	Up to 20 %
Diseased	≤1 % in a lot	Not allowed	Not allowed	Up to 20 %	Up to 10 %	≤2 % in a lot
Rotting	≤1 % in a lot	Not allowed	Not allowed	Up to 20 %	Up to 10 %	≤2 % in a lot

Table 6.9 Defect and size tolerance (by weight)

Defect tolerance	Grade-A (%)	Grade-B (%)	Grade-C (%)
Minor defects	10	20	100
Major defects	2	10	50
Serious defects	1	2	30

Fig. 6.3 Hand refractometer (*left*). Digital refractometer (*right*)

Quality Standards of Nagpur Mandarin

Mandarin is a group name for a class of oranges with loosely attached peel with segments. It is a citrus fruit of the species *Citrus reticulata*. It is distinguished from other citrus species by loose skin or peel attachment with segments. The maturity of harvested fruits has an important role on shelf life, quality, and market price. Hence, certain standards of maturity must be kept in mind while harvesting the fruits. However, the most commonly used measure to access maturity for harvesting the Mandarin is peel color. Fruits are considered mature, if they have a yellow orange color on 25 % or more of the fruit surface. Fruit quality for harvesting depends upon total soluble solids (TSS) and acidity of the juice. The juice should have a TSS of 8.5 % or higher. TSS content is determined by squeezing a few drops of juice on a hand-held refractometer (Fig. 6.3).

General Characteristics

Orange shall be mature, firm, juicy, and well-formed and shall have similar varietal characteristics. Orange shall be free from black/brown spots, sunburn, cut/crack, shrivelling, bird-punctured skin, hollow stem, nodes on surface, and any type of mechanical, pressure, and packing damage. Orange shall have tight and smooth skin (no granulation) with intact peel at stem end. Orange shall have minimum 75 % yellow/orange color. Orange shall be free from internal shriveling caused by frost. Orange shall be sound and free from rotting (fungal or bacterial rot or any other rot),

insects, and disease infestation. Orange shall not have any foreign taste and/or smell. Mirig season orange (Feb–Mar, i.e., 25 Jan–10 April) is suitable for storage. Ambe bahar and hasth bahar fruits are not suitable for storage.

Size and Grades

There shall be three grades for orange, viz., Grade-A, Grade-B, and Grade-C. On the basis of domestic market, grading of Nagpur mandarin is done on dimension basis. Fruits generally vary from 40 to 80 mm in diameter. Grades and size (mm) are listed in Tables 6.10 and 6.11, respectively. The maturity standards of Nagpur mandarin are listed in Table 6.12. Nagpur mandarin is sold in the market on the basis of count, i.e., no. of fruits per box as listed in Table 6.13.

Table 6.10 Classification of orange grades with respect to size tolerance (Nagpur orange)

	Grade-A	Grade-B	Grade-C
Diameter (mm)	>65	55–65	Any size

Note: The diameter is measured from the stem end to the blossom end

Table 6.11 Classification of orange with respect to size (Nagpur orange)

Extra large	Large	Medium	Small	Extra small
75–80 mm	65–75 mm	55–65 mm	50–55 mm	40–50 mm

Table 6.12 Fruit maturity standards of orange (Nagpur orange)

TSS	Not less than 8°brix
Acidity	0.6–0.7 % as citric acid
TSS: acid ratio	(TSS/acid ratio-not less than 14 and not more than 20)
Juice content	Minimum 38–40 %
Color	More than 50 % of the surface should be yellow-orange

Table 6.13 Common orange (Nagpur orange) counts prevalent in domestic markets

Orange count	Size (diameter in mm)	No. of fruits/kg	Weight/ fruit (g)	Remarks
141 count (Dana)	70–74	6–7	145–164	Highest demand in Delhi, Chandigarh
171 count (Dana)	66–69	7–8	125–144	Second highest demand
191 count (Dana)	60–65	8–9	105–124	Demand in Bihar, Orissa, West Bengal, and North east states
205 count (Dana)	56–59	10–11	85–104	
225 count (Dana)	51–54	12–13	65–84	
300 count (Dana)	Below 50	15–17	58–64	

Grades and Criteria for Checking

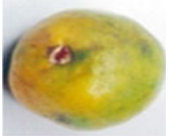
Price fixation or procurement is done on the basis of defects present in a particular lot or box. The following grades with their permissible defects are listed in Table 6.14. This may be taken as a reference for acceptance or rejection of any lot or box.

Table 6.14 Defects and tolerance level in different grades of Nagpur Mandarin grown in India

Defects	Grade-A	Grade-B	Grade-C
Misshape	Slight misshape (up to 5 %) per pack	Allowed (up to 20 %/pack)	Allowed
Green color	Allowed if matured (during start of the season it is not a defect)	Allowed (up to 20 %/pack)	Allowed
Rough/thick skin	>20 % surface area	>50 % surface area	Allowed
Bruises	1–3 cm^2 surface area	5–10 % surface area	Allowed
Loose jacket	Allowed	Allowed	Allowed
Black/brown spots on skin	5–10 % surface area	10–20 % surface area	Allowed
Punctured skin	Allowed if no juice seepage	Allowed	Allowed
Sunburn	1–3 cm^2 surface area	5–10 % surface area	Allowed
Cut/crack	Deep cut/crack ≤2 cm long	Deep cut/crack 2–6 cm long	Allowed
Hollow stem end	Allowed	Allowed	
Pressure damage	5–10 % surface area	10–25 % surface area	25–50 % surface area
Shriveling	≤20 % surface area	>20 % surface area	Allowed
Rotting/fungal infected	Not allowed	Not allowed	Allowed
Defects of Nagpur Mandarin			
Defects	Descriptions		
Misshape 	Not allowed in A-grade fruits. This is edible but not liked by consumers hence sold at very low price. Generally rejected before ripening		
Rough/thick skin 	Occurs in many varieties, not allowed in A-grade fruits but may be allowed in B-grade fruits up to 10–20 % fruits per pack. Rotting takes place within 2–3 days and highly disliked by customers		

(continued)

Table 6.14 (continued)

Defects	Grade-A	Grade-B	Grade-C
Brown/black spot on peel 	Not allowed in A-grade fruits. This indicates overmaturity and start of senescence. Black spot on peel		
Bruises 	Bruising marks on the peel, less than 5 % fruits per pack may be allowed in a grade and 10–20 % in B-Grade. Black spots on peel develop upon ripening and during marketing period. Bruising injury take place during handling		
Cut marks 	10–20 mm deep cut in 10–15 % fruits may be allowed in B- and C-grade only, not in A-grade		
Green fruits 	Not liked by consumers and also not suitable for storage. Generally sold in the market at very low price. Not allowed in A-grade fruits. This is edible but not liked by consumers hence sold at very low price. Generally rejected before ripening		
Rotting 	Rotting may be due to fungal or bacterial attack. Not allowed in A-grade fruits but may be allowed in B- grade fruits up to 5 % fruits per pack. Full rotting takes place within 2–3 days and highly disliked by customers		
Hollow stem end 	Not allowed in A-grade fruits. These fruits start rotting from stem end side and shrivelled at a faster rate. Also not liked by consumers. These fruits are generally kept in B-grade		
Sunburn 	Black or brown marks on the peel, less than 5 % fruits per pack may be allowed in an A-grade and 10–20 % in B-Grade. Black spots on peel develop upon ripening and during marketing and storage period. More susceptible to bruising injury during postharvest handling		

(continued)

Table 6.14 (continued)

Defects	Grade-A	Grade-B	Grade-C
Deep cuts/damaged 	10–20 mm deep cut in 10–15 % fruits may be allowed in B-grade fruits. No such fruits are allowed in A-grade quality. Damaged fruits started rooting within 2–3 days. Therefore, processing into value added products is the only option if not consumed within 2–3 days		
Stem end rot 	This is a very serious disease that occurs in almost all citrus fruits. Citrus fruits (Mandarin group/Loose jacketed) are more susceptible to this disease. This is basically a fungal disease and deeper infection makes taste unpleasant and reduces market value drastically		
Brown healed surface 	This is not a disease but occurs due to physical injuries and unfavorable weather condition. The fruit is edible but brown healed surface makes peel color unattractive		

Quality Parameters of Guava

General Characteristics

Guava shall be clean, firm, and mature and shall have color and shape characteristics of variety. Guava shall be free from cuts/crack, holes, bruises, natural brown marks on surface, rusetting, discoloration, and any type of damage caused by birds, packing, pressure, and mechanical means. Guava shall not be misshaped, immature, and overripe. Guava shall be sound and free from rotting/fungal infection, insect, and disease infestation. Guava shall be packed at firm and mature stage so as to avoid transport and handling damage.

Fruit Characteristic

When immature and until a very short time before ripening, the fruit is green, hard, gummy within, and very astringent. The fruit, exuding a strong, sweet, musky odor when ripe, may be round, ovoid, or pear-shaped, 2–4 in (5–10 cm) long, with 4 or 5 protruding floral remnants (sepals) at the apex; and thin, light-yellow skin,

Table 6.15 Quality testing parameters for guava

Fruit weight (g)	pH	% Acidity	Brix	Colored	Flavor	Black spots	Spoiled
50–600	3–5	0.3–0.7	6–12	Yellow to light green	Typical to Guava	<25 %	Nil

Table 6.16 Size grade of guava

	Grade-A	Grade-B	Grade-C
Diameter (mm)	66–80	55–65	Any size

Table 6.17 Defects and size tolerance (by weight)

Defect tolerance	Grade-A (%)	Grade-B (%)	Grade-C (%)
Minor defects	10	20	100
Major defects	2	10	50
Serious defects	>1	2	5

frequently blushed with pink. Next to the skin is a layer of somewhat granular flesh, 1/8 to 1/2 in. (3–12.5 mm) thick, white, yellowish, light- or dark pink, or near-red, juicy, acid, sub acid, or sweet and flavorful. The quality testing parameters are mentioned in Table 6.15.

Grades

There shall be three grades for guava, viz., Grade-A, Grade-B, and Grade-C. The size requirement for these grades is listed in Table 6.16 and defects and size grade in Table 6.17. A general description of quality parameters of A-grade guava is mentioned in Table 6.18.

Quality Parameters of Lime

General Characteristics

Lemon shall be firm, clean, mature, and well formed and shall have uniform yellow/greenish yellow color and round shape (Fig. 6.4). Lemon shall have thin skin and fairly smooth texture. Lemon shall be free from canker spots, brown spots, nodes on surface, cracks, bruises, sunburn, russeting, dry skin, discoloration, and any type of packing, pressure, and mechanical damage. Lemon shall be sound and free from browning at stem end, insect infestation, rotting/fungal infection, or any type of disease. Juice content of the lemon shall be not less than 50 % by weight. The total soluble solids content of the juice of lemon shall not be less than 7 %.

Table 6.18 General quality parameters for A-grade fruits

S. no.	Particulars	Specification	Tolerance
1.	Weight	Weight of fruit not below 150 g	10 % fruits are tolerable having weight less than 150 g
2.	Surface	Smooth, fruit having rough surface (not bruised) is not allowed	5–10 % fruits may be allowed per pack
3.	Shape	Round, ovate or roundish ovate	5–10 % misshape fruits are allowed in A grade for domestic markets
4.	Skin and skin colour	Thin greenish yellow, straw yellow, pinkish yellow	5–10 % fruits are allowed with green color fruits of proper maturity
5.	Pulp	Creamish, soft with small seeds, white or pink to red-colored as per variety	Not much specific in domestic market. However, pink color pulp is in more demand in domestic and International markets
6.	Disease attack	Free from disease attack	Fruit area affected more than 10 % are tolerable only 2 % and below 10 % area affected 10 % fruits are tolerable
7.	Pest attack	Not allowed in A-grade	Free from any insect and pest
8.	Punctured/ damaged	Free from punctured or damaged	Not tolerable in premium quality
9.	Rotten	Free from rotten	Rotten fruits are not allowed in A-grade fruits, up to 10 % in B-grades
10.	Cracking	Avoid cracked fruits	2 % fruits may be allowed in A-grade
11.	Mature and ripened fruits	All fruits must be matured and about 20 % ripened at the time of loading	Mature and ripened fruits. Fruits must be 10–20 % ripened, over ripened fruits up to 10 % is tolerable

Note

1. Percentage of defects allowed or disallowed in a particular lot will be determined on weight basis
2. More than one defect in an individual piece will be considered as major defect
3. Extent of defect not covered in minor, major, and serious categories of Grade A, B, and C means it is allowed in that particular grade

Fig. 6.4 Different maturity stages of lime

Grades

There shall be three grades for lemon, viz., Grade-A, Grade-B, and Grade-C. The size requirement for these grades is mentioned in Table 6.19 and defects with quality checking parameters are illustrated in Table 6.20. Defects and size tolerance are mentioned in Table 6.21 and defects with photographs are mentioned in Table 6.22.

Table 6.19 Lime size and grade

	Grade-A	Grade-B	Grade-C
Diameter (mm)	>40	30–40	Any size

Table 6.20 Quality parameters with grade-wise

Defects	Grade-A	Grade-B	Grade-C
Misshape	Slight misshape (up to 5 %) per pack	Allowed (up to 20 %/ pack)	Allowed
Major canker spots	Up to 2–5 % surface area in 5–10 % fruits per pack of 5 kg	Up to 25 % surface area	Allowed
Browning at stem end	1–2 pieces per pack	Up to 20 % per pack	Allowed
Green color	Allowed if matured (during start of the season it is not a defect but in later stage, deep green color represents immature)	Allowed (up to 20 %/ pack)	Allowed
Rough/thick skin	>20 % surface area	>50 % surface area	Allowed
Bruises	1–3 cm^2 surface area	5–10 % surface area	Allowed
Black/brown spots on skin	5–10 % surface area	10–20 % surface area	Allowed
Punctured skin	2–5 pieces per pack allowed if no juice seepage	Up to 30 % allowed if no juice flow	Allowed
Sunburn	1–3 cm^2 surface area	5–10 % surface area	Allowed
Cut/crack	Deep cut/crack ≤2 cm long	Deep cut/crack 2–6 cm long	Allowed
Pressure damage	5–10 % surface area	10–25 % surface area	25–50 % surface area
Shriveling	≤20 % surface area	>20 % surface area	Allowed
Stem end rot	Not allowed	10–20 % fruits per pack	Up to 50 %
Rotting/fungal infected	Not allowed	Not allowed	Allowed

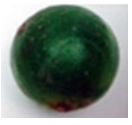
1. Percentage of defects allowed or disallowed in a particular grade will be determined based on weight in a sample lot
2. More than one defect in an individual piece will be considered as major defect and must not be placed in A-Grade quality. It may be placed either B or C based on the type and extent of defects

N.A. not Applicable

Table 6.21 Defects and size tolerance (by weight)

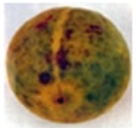
Defect tolerance	Grade-A (%)	Grade-B (%)	Grade-C (%)
Minor defects	10	20	100
Major defects	2	10	50
Serious defects	1	2	5

Table 6.22 Defects of limes with photograph

Defects	Descriptions
 Misshape	Not allowed in A-grade fruits. This is edible but not liked by consumers, hence sold at very low price. Generally rejected before ripening
 Citrus canker spots	This is a serious problem in citrus fruits, especially in lime and lemon. Fruits with canker spots have no commercial value and disliked by consumers
 Russeting	Russeting is not a major problem for sale of lime and lemons. However, commercial value may decrease if more than 10 % surface area is covered with russeting
 Brown stem end	Occurs in many varieties, not allowed in A-grade fruits, but may be allowed in B-grade fruits up to 10–20 % fruits per pack. Rotting takes place within 2–3 days and highly disliked by customers
 Brown/black spot on peel	Not allowed in A-grade fruits. This indicates overmaturity and start of senescence. Black or brown spots on peel
 Green color	Not allowed and preferred by consumers
 Thick skin	These fruits are less juicy and not in good demand and not allowed in A-grade fruits

(continued)

Table 6.22 (continued)

Defects	Descriptions
 Damage	Not allowed in A-grade fruits. These fruits start rotting within 2–3 days, hence sold at very low price. Generally rejected during sorting
 Over ripe	Not allowed in A-grade fruits. This is edible but not liked by consumers, hence sold at very low price. Generally rejected before ripening
 Cut marks	10–20 mm deep cut in 10–15 % fruits may be allowed in B- and C-grade only not in A-grade
 Dry Look	Rotting may be due to fungal or bacterial attack. Not allowed in A-grade fruits but may be allowed in B-grade fruits up to 5 % fruits per pack. Full rotting takes place within 2–3 days and highly disliked by customers
 Dry look	Peel becomes dry and hard, not preferred by consumers and not allowed in A-grade fruits
 Sunburn	Black or brown marks on the peel, less than 5 % fruits per pack may be allowed in A-grade and 10–20 % in B-grade. Black spots on peel develop upon ripening and during marketing period. Bruising injury take place during handling
 Stem end rot	This is a very serious disease that occurs in almost all fruits. No market value and also undesirable taste and flavor develops in stem end rot fruits
 Crack	Not allowed A-, B-, and C-grade. This is spoiled and must be thrown

Quality Parameters of Pineapple

Pineapple fruit should be harvested when firm and mature. Pineapples do not improve in eating quality after harvest due to being non-climacteric in nature. Therefore, the fruit must be picked at the optimum maturity and ready to eat stage (ripened stage) to suit the domestic markets. Marketing within the states, fruits should be harvested close to full ripeness, and for processing into slices, the same ripening stage is followed. But for distant markets, half yellow external eye color is required (Figs. 6.5 and 6.6).

The stage of maturity at harvest is dependent on the required storage or shelf life and the method of transportation to the export markets. The level of yellow coloration of the "eyes" of the fruit indicates maturity. Color stages are categorized in Table 6.23.

Fruits are mainly harvested during July-August. However, a small crop is harvested during December to March also. By regulating the crop, harvesting is possible almost 8 months a year. Sugar content should be assessed in the field prior to harvesting to ensure adequate sugar development. A minimum of 10 % sugar is

Fig. 6.5 Unripe but mature pineapple

Fig. 6.6 Ripe fruits (*right*) showing *yellow* eye colors

Table 6.23 Maturity standards based on development of eye color

S. #	Color stages (CS)	Characteristics	Remarks
1.	Color stage-01(CS1)	All eyes green, no traces of yellow	Export and distant markets
2.	Color stage-02 (CS2)	5–20 % of the eyes yellow	Export and distant markets
3.	Color stage-03 (CS3)	20–40 % of the eyes yellow	Export is risky by sea but by air is OK, canning
4.	Color stage-04 (CS4)	40–80 % of the eyes yellow	Only domestic markets and canning
5.	Color stage-05 (CS5)	90 % of eyes yellow, 5–20 % reddish brown	Local market, processing into pulp
6.	Color stage-06 (CS6)	20–100 % of eyes reddish brown	Processing into pulp

acceptable to major markets, although this may vary with market to market. Sugar content is not always related to the color development as agronomic and production factors will affect sugar development. For the export market where sea-shipment for 7–14 days is required, fruits should be harvested at CS1, where the fruits show no yellow colour development on the eyes. For air-freighted shipments, although generally cost-prohibitive, harvesting can be carried out at CS2 to CS3. Those harvested at more advanced stages are more susceptible to mechanical damage during postharvest handling.

Fruit intended for the export market should be picked slightly sooner, at the quarter-yellow of fully mature but green color stage. For export, it is also necessary to move the product from the field to the pack house and from there to the airport as soon as possible by refrigerated van. At seaport or airport, the cooling system of reefer van should be on. Fruits picked mature but prior to full ripeness (i.e., less than one quarter yellow) will be firmer and better able to tolerate long distance transport. However, they will have a less desirable flavor. Pineapples harvested when immature will not ripen and will have a low sugar content and poor flavor. On the other hand, fruit harvested overmature will get soft and bruise easily during transport and will have a very short market life.

The two components of quality that may change after harvest are external color and texture of the flesh. Pineapple fruit typically changes from a green to yellow-orange color during storage. In addition, the texture of the flesh softens with time. The crown (whorl of leaves attached to the apical end of the fruit) should be left intact and protected from damage. Consumers associate crown freshness and condition with fruit quality. The practice of crown removal by some vendors in the domestic market is not recommended for fresh sale, but for processing, it is OK. This leads to microbial decay of the wounded area and a rapid deterioration. In addition, the fruit appearance is less appealing without the crown.

Harvesting Methods

Pineapples are harvested by hand, with the pickers being instructed as to the stage of maturity required. The fruit should be broken off the stalk with a downward motion, or cut with a knife slightly below the base of the fruit. A large canvas picking sack which is strapped over the shoulders is commonly used as a harvest-aid in many parts of the world. Up to 6 fruits can be put in the sack, which is able to be opened from the bottom to allow the fruit to be transferred to a larger field container or padded wagon. The fruit may also be harvested in wooden or plastic field crates.

General Characteristics

Pineapple shall be clean, firm, fresh, and mature and shall have color and shape characteristics of variety. Pineapple shall be free from cut/crack, holes, long stem, and any type of damage caused by pressure, handling, and mechanical means. Pineapple shall not be soft, overripe, and misshape and shall be free from rotting, fungal infection, insect and disease infestation. Pineapple shall be free from foreign smell and/or taste. Pineapple shall be harvested at mature, firm, and green stage to avoid damage during transit. Pineapple shall be with green and fresh crown. The size of crown shall not be bigger than the length of fruit. The varietal characteristics are mentioned in Table 6.24. Grade, size, and defects with tolerance level are mentioned in Table 6.25. Defects and size tolerance are given in Table 6.26.

Table 6.24 General varietal characteristics of commercial varieties produced on large scale

Variety/type	Characteristics
Kew or giant Kew	Fruit is big in size, deep yellow to coppery yellow in color, eyes are broad and flat, flesh color is pale yellow to yellow, T.S.S. 12–14°brix
Queen or common Queen	Fruit is small in size, golden yellow in color, eyes are small and raised, flesh color is deep golden yellow, with T.S.S. of 15–16°brix
Mauritius	Fruit is medium in size, yellow and red in color

Table 6.25 Grade, size, and defects of pineapple fruit

	Grade-A	Grade-B	Grade-C
Weight (g)	800–1500	<800 or >1500	Any size
Misshape	Not allowed (1–2 fruits having slight misshape may be allowed)	2–5 fruits may be allowed	Allowed and have no limit
Immature	Not allowed	2–5 fruits may be allowed	Allowed and have no limit

(continued)

Table 6.25 (continued)

	Grade-A	Grade-B	Grade-C
Immature	Not allowed	2–5 fruits may be allowed	Up to 50 % fruits are allowed
Overripe	For domestic market, 1–2 fruits may be allowed	Up to 20 % fruits may be allowed	No limit
Pressure damage	Minor pressure damage may be allowed in maximum 1–2 fruits per pack	Up to 20 % fruits may be allowed	No limit
Cut/crack	Not allowed	Up to 20 % fruits with minor cut marks	All minor and major also allowed
Holes	Not allowed	Up to 5 % fruits are allowed	Allowed
Long stem	>5 cm long	5–10 cm long	No limit
Long crown	Allowed	Allowed	Allowed
Without crown	Not allowed	Allowed up to 20 % fruits	No limit
Mechanical damage	Not allowed	Allowed up to 20 % fruits on 2 % surface area	No limit
Insect damage	Not allowed	Allowed up to 20 % fruits on 2 % surface area	No limit
Rotting/ diseased	Not allowed	Allowed up to 20 % fruits on 2 % surface area	No limit

Note

1. Percentage of defects allowed or disallowed in a particular grade will be determined based on weight in a sample lot
2. More than one defect in an individual piece will be considered as major defect
3. Extent of defect not covered in minor, major, and serious categories of Grade A, B, and C means it is allowed in that particular grade

Table 6.26 Defects and size tolerance (by weight)

Defect tolerance	Grade-A (%)	Grade-B (%)	Grade-C (%)
Minor defects	10	20	100
Major defects	2	10	50
Serious defects	1	2	5
Size tolerance	10	20	N.A.

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Singh, H. P., & Yadav, I. S. (1988). Physico-chemical changes during fruit development in litchi cultivar. *Indian Journal of Horticulture, 45*, 212–218.

Chapter 7
Preparation of Fruits for the Market

Introduction

After harvesting, fresh fruits are sold in different markets of India starting from local to distant markets within and outside the state. To get maximum profit from the produce, it is outmost important to have better preparation and presentation of fruits for the markets. Preparation includes all unit operations such as sorting, grading, postharvest treatments, precooling, and packaging. Preparation of fruits before marketing, if followed properly, fetches premium price for the producers and better quality for the consumers. It also reduces postharvest losses to a greater extent and increases marketing period of the fruits. Postharvest losses in fresh produce including fruits are very high due to living nature of the produce and deterioration in quality starts just after harvesting. On an average, this loss is estimated about 5–35 % in developed countries and 20–50 % in developing countries (Kader 2002). In order to reduce this loss, freshly harvested fruits must be prepared before sending to the markets. There may be many unit operations for preparation starting from assembling to final sale in the market. All operations play an important role in extending marketing period of fruits and reducing quality deterioration. The unit operations are described below.

Assembling

Assembling is collection of harvested fruits in a suitable container and bringing to pack house or any place where other unit operations are completed. In majority of fruit orchards, plastic crates are used for assembling and the same crates are transported to pack house where sorting, grading, precooling, pretreatments, if any, and packaging are carried out. During collection and assembling, care should be taken that fruits should not be thrown and hit the hard surface. It causes impact bruising. Crates with bubble sheet for cushioning should be used for this purpose.

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_7

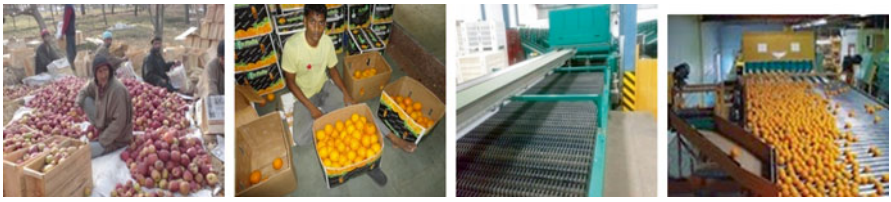

Fig. 7.1 Manual sorting and grading (*left*). Mechanical grader (*right*)

Sorting and Grading

Sorting and grading both are very important operations before marketing. These are done either in the orchard itself or in a pack house depending upon the facilities available. Sorting and grading are totally manual in India and depend on the type of fruits and trained labors. However, mechanical graders are also available (Fig. 7.1). At farmer's level, sorting is not a separate operation, but it is carried out during grading and packaging of fruits. However, on commercial scale, sorting is a separate operation performed by the people standing at both sides of the grader. This is a necessary operation before storage or packaging.

Washing

Washing of fruits is not very common in India, especially at farmer's level. Organized fruit business companies have created this facility in their pack house or at cold storage. Fruits are washed either before storage or before marketing, depending upon the company policy and nature of the fresh produce. Washing is also not necessary for all fruits like grapes and litchi. It is because washing removes natural wax from the grapes and adds browning to litchi, which is necessary for long shelf life and appearance. Fruits like apple, pear, plum, and guava are highly recommended for washing before storage. In pome fruits, washing before storage is found beneficial as it increases humidity of the storage chamber (Controlled atmosphere storage chamber) and reduces spoilage. Here, it is important to note that fruits should be stored in high-quality plastic bins or plastic crates only. Storage in corrugated fiber boxes (CFB) and in wooden boxes may be problematic if wet fruits are packed. Further, strength of CFB boxes will decrease if boxes are not moisture-proof and more fungal infection will occur in humid condition.

Washing is one of the most important postharvest treatments recommended for many fruits and vegetables. It not only decreases microbial load, but also removes field heat and increases shelf life of fruits and vegetables. Simply washing lettuce leaves in tap water reduced populations of micro-flora by 92 % (Adams et al. 1989). The advantage of this treatment largely depends on the purity of water used for washing.

Contaminated water used for washing can transmit diseases responsible for decaying the produce and adversely affects human health (Sanderson and Spotts, 1995). It is a well-established fact that upon washing, microbial load is drastically reduced in all commodities and therefore washing is highly recommended before consumption also. Washing of sponge gourd in tap water brought about more than 25 % reduction in bacterial population (Ahmad et al. 2003). Gomez et al. (2002) also reported that washing of cauliflower in tap water reduced about 25 % bacterial population. Wash water also acts as a medium for chemical applications on fresh produce. This operation is done again either before storage or after storage. Washing with different chemicals is mentioned in the following sections.

(a) Washing with chlorinated water
Chlorine treatment (100–150 ppm available chlorine) may be used in wash water to control inoculums build-up during harvesting and transportation to pack house. This operation is done either before packing or marketing or storage. Washing with chlorinated water reduces microbial load to a remarkable level. Many workers reported it in a wide range of fruits and vegetables. Garg et al. (1990) observed that dipping lettuce in water containing 300 ppm chlorine reduced total microbial counts by about 1000-fold. Ritenour et al. (2002) recommended a constant free chlorine concentration of 100–150 ppm maintained at a pH range of 6.5–7.5 for sanitizing purposes. Common sources of chlorine are sodium hypochlorite (NaOCl), calcium hypochlorite $Ca(OCl)_2$, and chlorine dioxide (ClO_2).

(b) Washing with water containing fungicides
Fungicides under permissible limit can be used during washing of fruits. This is necessary to control postharvest diseases. Many fruits like apple, pear, citrus, and banana are treated with permissible fungicides added in wash water before transportation to distant markets or storage. Ahmad et al. (2005) reported that Bavistin dip followed by packing of four fruits as a unit in a polyethylene film of 150-gauze thickness reduced spoilage in kinnow mandarin during 60 days of storage. Other workers have also reported that wash water containing fungicides reduced spoilage due to rots during storage (Kaushal and Thakur 1996; Pal et al. 1997; Shazia Hayat et al. 2013).

Postharvest Treatment with Ethylene Inhibitors/ Growth Regulator

Application of growth regulators or ripening inhibitors is commercially very important. These chemicals are applied easily through wash water. The most common chemicals are 1-MCP (1-methyl cyclopropene), AVG (Amenoethoxyvinyl glycine), 6-benzylaminopurine, silver nitrate, silver thiosulfate, cycloheximide, benzothiadiazole, etc. Yuan et al. (2010) observed 1-methyl cyclopropene inhibit ethylene production and/or action during ripening and storage of fruits. Similarly, application of

growth regulators such as GA_3 or cytokinin can be effectively applied through washing. Downs et al. (1997) reported that application of cytokinin reduced broccoli floret senescence. Growth regulators also increase the postharvest life of fruits by retarding of ripening, senescence, by minimizing the rate of respiration, and by reduction in weight loss. Respiration may be slowed by application of growth retardants such as gibberellic acid (GA), kinetin, and silver nitrate (Siddiqui et al. 2014a, b; Gautam and Chundawat 1990).

Postharvest Treatment with Calcium Chloride

The postharvest application of $CaCl_2$ (2–4 %) or Ca $(NO_3)_2$ plays very important role in enhancing the storage and marketing period of fruits and vegetables by maintaining their firmness and quality. Calcium application delays aging or ripening, reduces postharvest decay, controls the development of many physiological disorders, and increases the calcium content, thus improving their nutritional value. Increase in calcium content of the fruits has been associated with reduced softening (Siddiqui et al. 2014b; Haggag 1987), decreased incidence of physiological disorders, and improved storage life (Rasese 1986). Similar results were also reported by Chahal and Bal (2003) in ber fruits. Calcium infiltration reduces chilling injury and increases disease resistance in stored fruits. Calcium compounds are known to extend the shelf life of several fruits by maintaining firmness, minimizing the rate of respiration, protein breakdown, and disease incidence.

Thermal Treatment

Thermal treatment means either hot water treatment (HWT), vapor heat treatment (VHT), or hot water rinse brushing (HWRB). Being a non-chemical method, the application of heat treatments to reduce postharvest decay or pest infestation is most popular for many fruits. However, the temperature and time are the most important factors to be considered during its application as tolerance to heat treatments may vary with the commodity, cultivar, and the maturity stage. Therefore, the selection of appropriate treatment regimes (temperature × time) is a crucial factor in determining the overall quality of the fruits.

Heat treatment is a must treatment for mango export. There are few countries where both or either of two treatments are prerequisite for export of mango fruits. This is also country specific, for example, mango export to the United States is only possible if hot treatment is done. This treatment (HWT) is the most common quarantine treatment option used by the mango industry all over the world to satisfy

Table 7.1 Hot water treatments for different fruits

Commodity	Pathogens	Temp. (°C)	Time (min)	Remarks
Apple	*Gloeosporium* sp.	45	10	Commercially not adopted in India
	Penicillium expansum			
Grapefruit	*Phytophthora citrophthora*	48	3	Commercially not adopted in India
Lemon	*Penicillium digitatum*	52	5–10	Commercially not adopted in India
	Phytophthora sp.			
Mango	*Colletotrichum gloeosporioides*	52	5	To kill fruit fly larvae
Orange	*Diplodia* sp.	53	5	For control postharvest diseases
	Phomopsis sp.			
	Phytophthora sp.			
Papaya	*Fungi*	48	20	For control postharvest diseases
Peach	*Monolinia fructicola*	52	2.5	Limited application
	Rhizopus stolonifer			

requirements of USDA-APHIS for mango export to the United States from areas infested with fruit flies (Jacobi et al. 2001).

(a) Hot water treatment
Fruits may be dipped in hot water to control various postharvest pathogens (larvae, inoculums) and to improve peel color of a number of fruits (Table 7.1). In mangoes, the HWT is recommended at 50–52 °C for 5 min to kill fruit fly larvae and to control/reduce the microbial infection during marketing. This treatment helps in attaining uniform ripening within 5–7 days. Fruit should not be handled immediately after heat treatment. Cooling of fruit with water showers or forced air should be provided to bring the temperature back to their optimum temperature as soon as possible after completion of the heat treatment.

(b) Vapor heat treatment
This treatment proved very effective in controlling infection of fruit flies in packed boxes. The boxes are stacked in a room, which are heated and humidified by injection of steam. The temperature and exposure time are adjusted to kill all stages of insects (egg, larva, pupa, and adult), but fruit should not be damaged. A recommended treatment for citrus, mangoes, papaya, and pineapple is 43 °C in saturated air for 8 h and then holding the temperature for further 6 h.

(c) Hot water rinse brushing
The HWRB is a new system that can be used for heat treatment of fruits. In this system, the fruits roll over to brushes directly into the pressurized recycled hot water rinse at temperatures between 48 and 63 °C for 10–25 s. The HWRB system is being used in Israel and several other countries in commercial packing lines for various types of fruits as well as vegetables.

Jing et al. (2010) reported that HWRB treatments significantly reduce the epiphytic microbial population on fruit surface, decay development, and weight loss in strawberry. Strawberry fruits treated with HWRB (60 °C) showed less decay than the control fruits, and cold storage could enhance the effect of HWRB treatments.

Fumigation (Sulfitation)

Fumigation with sulfur dioxide gas (SO_2) is successfully used for controlling post-harvest diseases of grapes (especially for powdery mildew by *Botrytis cinerea*). This treatment is having great commercial application on many fruits by different ways.

(a) Fumigation by grape gourd
This is a commercial practice used in grapes and approved by all quality control agencies of the world. The main purpose of this pad is to control powdery mildew, a disease most common in grapes. This purpose is achieved by placing grape guards (sodium or potassium metabisulfite impregnated pads) into individual boxes of fruit to give a slow release of SO_2.

(b) Fumigation by sulfur powder
The SO_2 fumigation is used to prevent discoloration of skin or peel of litchi fruits. This is a commercial practice followed in India for domestic market. In case of litchi fumigation, sulfur powder is burnt in a closed room having ceiling fan for fast circulation of sulfur fumes inside the room for 40–45 min and an exhaust fan to expel the fumes outside the room after circulation period is completed. Litchis are kept in perforated crates of 10 kg capacity for better fume circulation touching almost all fruits. In general, *550–600 g* sulfur powder is sufficient for *1000 kg* of litchi fruits. Sulfur powder is kept on a paper piece in 3–4 places and allows it to burn. Immediately after sulfur fumigation treatment, litchi fruits turn in uniform yellow color. Now precooling is followed by fumigation and then storage at *low temperature* (*3–5 °C*). Transportation by reefer van is necessary for sulfited litchi. During storage and marketing, sulfited litchi again regains its original color up to some extent (Fig. 7.2). Sulfited litchi is packed either in perforated polyethylene pouches or punnets. The sulfitation

Fig. 7.2 Litchi fruits fresh; sulfited litchi; reappearance of color

treatment can also be achieved by placing the boxes of fruit in a gas-tight room where SO_2 gas is injected by SO_2 cylinder at a recommended concentration.

(c) Fumigation by paper pads
Paper pads or wraps impregnated with biphenyl fungicides are commonly applied to citrus fruits. The chemical vaporizes slowly, protecting the fruit from fungal infection. This has limited use on commercial scale.

Waxing

Waxing is another important postharvest treatment widely used in fruits and vegetables. These waxes are edible and reported by many workers as a promising postharvest treatment to extend the shelf life of many fruits as in mango (Abbasi et al. 2011; Singh et al. 2012), Kinnow (Ahmad et al. 2005), and sweet orange (Shahid and Abbasi 2011). The beneficial effects of waxing mainly include an improved appearance, less moisture loss and shriveling, reduced postharvest decay, and a longer shelf life (Fig. 7.3). Waxing of fruits and vegetables is a common postharvest treatment used all over the world. In some fruits and vegetables, it is mandatory also like apple, pear, capsicum, etc. Fruits and vegetables possess an outer protective epidermis, covered by a natural waxy cuticle layer containing the polymer cutin (Lequeu et al. 2003).

In recent years, coatings of some edible materials like lipid-based coatings, polysaccharide-based coatings, protein-based coatings, composite and bilayer coatings, etc. have been applied on the skin of different fruits and vegetables in order to reduce moisture loss, restrict oxygen entrance, lower respiration, and retard ethylene production (Baldwin et al. 1995). However, the main aim of waxing from commercial point of view is to make external appearance glossy and attractive. This is an important quality attribute of almost all fruits and vegetables. It is the first quality attribute that a buyer notices. Attractive peel color of any fresh produce is the most powerful attribute for price fixation and market acceptance. The second aim of waxing is to supplement the natural wax on the surface of a commodity, which is removed during harvesting, cleaning, and packing. Waxing consists of applying a

Fig. 7.3 Waxed apple

thin layer of edible wax on the surface of the product either by dipping, brushing, or spraying. The benefits of waxing, methods of application, and detrimental effects if applied in excess are described below in details.

Commodities that are generally waxed include citrus fruits such as mandarins, oranges, pomelos, apples, and pineapples. For pineapples, waxing ameliorates chilling injury, especially if pineapples are transported under refrigerated conditions. Methods of waxing include dipping, foaming, brushing, and spraying. Some commodities may not be suited to a particular method of waxing owing to their morphology (Esguerra and Bautista 2007).

Benefits of Waxing

(a) Improved appearance
Fruits and vegetables that are waxed generally have more attractive and fresh appearance. This fresh appearance of wax produce persists for quite a longer period than unwaxed. As discussed earlier, the appearance attracts consumers more than any other attributes as buyers initially judge the quality of a product based on external appearance only. Waxing can also improve the internal color of certain commodities. Mahajan et al. (2005) observed improved appearance in coated kinnow fruits even after 24 days of storage.

(b) Less moisture loss
The cell wall of fruits and vegetables is covered with cuticle, which acts as a barrier to moisture loss. This outer layer possesses tiny pores or natural passage allowing water loss through transpiration. Coating partially covers these pores and reduces both respiration and transpiration. However, some water vapor can move through the pores and micro-cracks in the cuticle. During the process of waxing, a tightly adhering thin film of the coating substance is applied to the surface of the fruit. The wax coating partially blocks the pores in the cuticle, which significantly reduces the amount of water vapor loss from fruits and vegetables which results in product shriveling and/or wilting. Marketing of such products which have suffered significant moisture loss becomes very difficult. Generally, when any fresh produce has lost 10 % or more of its original weight, it will not attract consumers. This amount of moisture loss typically lowers the grade of the product or makes it completely unmarketable. Application of a thin layer of wax coating can reduce product weight loss by 30–40 %, as noticed by Chaudhary et al. (2004) in kinnow mandarin and Bisen and Pandey (2008) in Kagzi lime.

(c) Good eating quality
On the basis of consumer's acceptance and sensory quality, it is observed that wax-coated fruits and vegetables retain better fruit quality as compared to non-waxed fruits at higher temperature (Mahajan et al. (2005)). Ladaniya (2001) found taste score was highest in fruits of "Musambi" sweet orange (*Citrus*

sinensis) treated with Sta-fresh 451 wax and Wang et al. (2004) revealed that due to the waxing, eating quality was good without unpleasant taste in fruits of Jincheng orange variety.

(d) Less economic loss and reduced postharvest decay
Water is the principal component of all fresh fruits and vegetables. It usually constitutes between 80 and 90 % of a product's fresh weight. Once harvested, the fresh product begins to lose moisture from the processes of transpiration and respiration. The rate of moisture loss varies among commodities. This results in weight loss, which is highly undesirable as it is directly related to economic loss. Growers often sell their fresh products based on weight and will obtain less economic return with increasing amounts of weight loss. Also, there is a loss by rotting and spoilage. Waxing reduces weight loss to a great extent. A fungicide can also be added to the wax emulsion to provide protection against decay.

(e) Reduces ripening and senescence (longer postharvest life)
Edible coatings reduce ripening and senescence in fresh produce and thus increase shelf life and marketing period, which is a well-established fact as reported by many workers in many fruits such as in mango (Abbasi et al. 2011; Singh et al. 2012), sweet orange (Shahid and Abbasi 2011), and banana (Abbasi et al. 2004). The science behind this is that waxing creates a modified atmosphere inside each product in which the oxygen content decreases and the carbon dioxide content increases (Kader et al. 1989). Therefore, these coatings create modified atmosphere in each product and reduces weight loss during transport and storage (Cuq et al. 1995). Many workers reported that Modified Atmosphere Packaging (MAP) technology is used for extending the shelf life of fresh fruits and vegetables (Ladaniya 2001; Wasker and Gaikward 2005; Sharma et al. 2012). This results in a reduction in the product's respiration rate and an increase in postharvest life. The higher CO_2 and lower O_2 concentration delayed ripening process by maintaining slow degradation of Polysaccharides (Abbasi et al. 2004). This could be due to delay in ripening and senescence.

(f) Less susceptibility to chilling injury
Fruits and vegetables of tropical origin are susceptible to chilling injury (CI), which occurs frequently during storage at lower temperature than optimum. The amount of CI depends on the temperature and duration of exposure to low temperature. Waxing reduces the severity of CI and allows for storage of CI-sensitive commodities at slightly lower temperatures. However, waxing does not eliminate CI on the susceptible commodities. The commercially available waxes are citra shine, Sta-fresh, Sta-fresh 451, 960, Semperfresh, Carnauba wax, etc. Import of insect-based waxes such as Shellac wax-coated fruits is not allowed in India. Coatings may be applied by either dipping, brushing, or spraying on the fruits and vegetables. Different countries have their own rules and regulations for the use of coatings on horticultural produce.

(g) Increased shelf life
Postharvest treatments and storage conditions are equally important for quality maintenance during storage (Ahmad et al. 2005).

Wax Application Methods

Waxes may be applied in several ways, ranging from manual rubbing to automated application by roller brushes.

Rubbing

Liquid waxes can be applied by manually rubbing the commodity over a soft surface saturated with wax emulsion. A soft absorbent cloth or foam sheet or fine brush can be used as a soft surface. After application, the products should be left to air dry for about 15–20 min or under fan before packing. This is mainly for lab testing and for small lots only.

Dipping

In this method, wax is applied by dipping fruits or vegetables in a solution of wax. Dipping time and wax concentration are product specific. It is recommended to keep coated materials for few minutes before packing. It is also very important that the product surface should be completely dry before waxing by dipping method where melted wax is used. If not dry, the high temperature of the melted wax converts the surface moisture on the product into steam and forms pockets or blisters under the wax coating. The wax will then loosen and drop off.

Roller Brushing

Liquid waxes can be applied automatically on the surface of the commodity by using a series of roller brushes. The wax is dispensed on the roller brushes from the nozzles fitted just above it. The speed of application is adjustable. All roller brushes rotate which facilitates produce to spin and rotate over the roller, and in this process a thin layer of coating is applied evenly over the surface of the product. The brushes on the wax applicator should be fed continuously with the wax solution during the operation. It is always advisable to wash fruits and vegetables prior to waxing. Therefore, fruit should be damp in a water tank and pass through hot air blowing unit and over dry brushes and then finally through waxing unit. This is necessary in order to prevent wax dilution. The roller brushes should have at least 50–60 % horsehair to help spread the wax over the fruit. Brush speed should not exceed 100 rpm. The brushes should be kept soft by regular washing with hot water.

Specification of a Desirable Wax

- The selected wax material should provide a lasting shine.
- It must be manufactured from food grade materials.
- It should not develop any off-flavor.
- It should reduce moisture loss of commodity from 30 to 50 %.
- After application, wax should dry rapidly.
- It should be easy to clean and price should be less.

Types of Food-Grade Waxes

Several different raw materials are used as a base for formulating food-grade waxes. The most commonly used materials are paraffin, carnauba, and shellac. Less frequently used waxes include beeswax and candelila wax. Each of these raw materials has unique and different properties which determine its shine, gas permeability, and other physical characteristics. The waxes available commercially are already premixed and ready for immediate application with or without dilution. The amount of wax applied to each individual fruit or vegetable is very small. Upon application, it provides a thin continuous coating on individual fruits or vegetables.

Example of some commercial waxes

1. Paraffin wax
2. Carnauba wax
3. Bee wax
4. Shellac
5. Wood resin
6. Chitosan

Paraffin (Candle Wax)

Paraffin is a petroleum-based wax obtained from the distillation of crude oil. It is solid at room temperature and must be heated at about 52 °C (125 °F) to melt. Temperature of the liquid wax influences the thickness of coating layer upon solidification. Paraffin wax is commonly used on cassava for export marketing. It can also be used on sweet potatoes, yams, coconut, and thick-skinned fruits like breadfruit.

Carnauba

Carnauba wax is obtained from the leaves of carnauba palm. On an average, 5–10 g of wax is obtained from each leaf. Carnauba is a moderate glossy wax. It imparts much better shine to the product than paraffin wax, but less than shellac. A carnauba wax coating is more permeable than shellac.

Shellac

Shellac is produced from the resinous secretions of lac insect (*Laccifer lacca*). This insect secretes the resin from its glands onto a host tree in the form of tiny platelets, which are gathered, crushed, washed, and purified into food grade wax called shellac. It is hard at normal temperatures but softens when heated. Shellac is a hard, tough resin that has good water resistance and produces high lustrous finishes. However, the waxed products are more likely to whiten or chalk upon removal from cold storage. Shellac is less permeable to gas exchange than carnauba and care must be taken to avoid over-application and possible product fermentation. It is the most popular wax currently used on citrus.

Trade name of some extensively used waxes

Trade name	Fruits
Tal-prolong	Banana, apple
Semper fresh	Guava, banana
Nutri-save	Apple
Brilloshine, Citrashine	Citrus fruits
Vapor gard	Mango
Waxol	Fruit
Ban-seel	Banana

Precooling

The rapid cooling of fresh produce from field temperature to its best storage temperature is called precooling. Precooling reduces field heat and hence reduces all physiological processes. Respiration is one of them. The lower the temperature of any fruit, the slower is its respiration rate and vice versa. There are four methods of precooling. These are forced air, hydro cooling, vacuum cooling, and icing. Each method was developed with specific crops in mind.

Hydro Cooling

Hydro cooling removes field heat and cool the produce with chilled water. The water used in hydro cooling is usually cooled by mechanical refrigeration. On a small scale, cold well water or ice may also be used depending upon the temperature requirement. The size of hydro cooling units varies depending on the size of the operation, but considerable refrigeration or large quantities of ice are required to keep the water at the desired temperature of 33–36 °F. The produce is cooled by a water bath or sprinkler system. The produce either is dumped in the bath or under the sprinkler or is left in bins or boxes. Small operations might have an ice-water tank in which to "stir" the vegetables for rapid cooling. Pay special attention to water quality. Unfiltered and unsanitized water can spread undesirable microorganisms.

Most vegetables and many fruits that can withstand wetting can be hydro cooled. Asparagus, celery, cantaloupes, green peas, leaf lettuce, peaches, radishes, and sweet corn can be cooled successfully with this method.

Forced Air Cooling

Forced air cooling is the best method of precooling, and it is a commercial practice used worldwide on many fruits to reduce field heat, disease development, softening, and weight loss of fresh fruit. However, the main purpose of precooling is removal of field heat from fresh produce. Forced air cooling is a powerful tool that allows perishable produce to be marketed over long distances because it can cool produce quickly after harvest. It is the primary cooling method used for fresh fruits and vegetables in California prior to placing them in longer term cold storage (Thomson et al. 2008).

In this method, cool air moves rapidly over a product to remove the field heat. Inside a cool storage room, fans pull air through the produce boxes and back into the cooling unit. When you design a cool room, provide enough refrigeration capacity and proper humidity control. These steps can prevent excess weight loss. Forced air units are affordable for many small-scale growers. Alternatively, an existing cold room can be augmented by making cooling tunnels using portable fans and tarps. Line up two rows of produce and set up a fan to draw air down the aisle between the rows. Cover the aisle with a sturdy tarp to force the system to draw air through the boxes of produce. Forced air cools most commodities effectively, but those best adapted to this method include berries, stone fruits, and mushrooms. Forced air cooling stages are shown in Fig. 7.4.

In forced air cooling system, mainly packed produce is placed in the cooling system and the box is covered with tarpauline so that direct hitting with cold air may not cause chilling injury. Therefore, slowly the heat is removed from the produce.

Fig. 7.4 A forced air coolers loaded with boxes (*left*) under loading (*middle*) empty (*right*)

Vacuum Cooling

Produce is placed in a vacuum tube and air pressure is reduced greatly. At lower atmospheric pressure, some water from the produce "boils" away as the produce uses its own heat energy to convert water to gas, thus lowering the product's temperature. Heat and moisture are removed from the vacuum tube by mechanical refrigeration. Commercial vacuum units usually cool the product to the proper storage temperature in less than 30 min. Units are available for cooling different amounts of product, from two pallets to a full truckload. Because of the high cost of this equipment, it might be more economical to do the cooling at a central location on a cooperative basis. Grower costs depend mainly on the volume cooled. Growers usually are able to recover costs by charging a fee per unit, in addition to the agreed purchase price of the produce. Lettuce and a few other vegetables can be vacuum-cooled effectively.

Icing

Crushed or slurry ice is placed directly into the produce box. This can be an effective way to precool individual boxes of certain vegetables. The produce can be cooled in a short time and the temperature maintained in transit. Broccoli, green onions, and some root crops most commonly are top iced.

Ripening Treatments

Ripening has revolutionized the world of bananas, mango, sapota, and other fruits. Ripening had a positive impact on consumer satisfaction and sales volume. A very important step in a successful fruit ripening program is to select fruits that were harvested at proper maturity stage. Fruit that was harvested immature will soften, and it will not develop a pleasing flavor. Temperature management is the key for ripening fruits and storage after ripening. All tropical fruits such as banana, mangoes, and sapota if stored at low temperature, sustained chilling injury. Ripening of mango and sapota are described here.

Mango Ripening

Mango maturity and ripeness are two different stages. Like all other fruits, mango also progresses from immature to mature stage. However, peel color is not a maturity standard in mango as it is in tomato, apple, and many other fruits. However, peel color is also taken as one of the maturity standards of mango in retail business by both sellers and consumers. An immature mango will eventually become softer, but

its flavor will not improve and neither will consumer acceptance. Thus, an immature mango will be inferior in quality and there is no postharvest treatment that can improve it. Mangoes should be harvested at physiological mature stage to get optimum quality upon ripening.

Maturity at harvest is a critical factor for development of mango flavor. A mango harvested immature will not ripen normally and development of mango flavor is almost NIL. These mangoes never satisfy consumers even though peel color has turned yellow and may attract consumers. In Indian markets, arrival of mango of early variety Safeda (Banganpali) from Andhra Pradesh is a typical example of immature mango with uniform yellow color. In normal condition, this variety is supposed to attain maturity after 15th of March every year. But it is available in the market from the first–second week of February and ripening treatment is given at terminal markets by wholesalers or sub-wholesalers. Retailers also do ripening before marketing, and in this way, they regulate market.

At the mature/unripe stage at harvest, mangoes are high in starches and acids and low in soluble sugars. During ripening, sugar content increases, mango firmness decreases, and acidity and starch concentrations decrease. Internal flesh color will develop from white or pale yellow to deep yellow or golden yellow. External skin color changes will also take place in some varieties. For example, the skin of the Safeda or Banganpali, Neelum, and Chausa variety will progress from green to a deep yellow upon ripening. Not all varieties show skin color changes during ripening. Malda or Bombai mango variety is a typical example where skin or peel color do not change upon ripening.

Ripening Procedure

Fruit should be ripened using controlled temperature and ethylene. First remove field heat (precooling of fruits up to 20–22 °C). Hold at this temperature, i.e., 20–22.2 °C (68–72 °F) and apply ethylene at 100 ppm for 24 h. After 24 h ethylene exposure, hold mangoes at this ripening temperature 20–22.2 °C (68–72 °F). Ethylene-treated mangoes kept at 20–22.2 °C (68–72 °F) will ripen in 3–9 days. Check ripening progress in the fruit for firmness and peel color until the required peel color and firmness are reached for marketing. During ripening, carbon dioxide levels should always be kept below 1.0 % by exchanging room air with outside air. Hence, open the door for once or twice for 5–10 min after every 24 h. Keep fan on continuously for better air circulation. Maintaining a relative humidity of 90–95 % will reduce potential water loss and mango shriveling due to continuous air circulation.

The ripening procedure may vary slightly on the demand, maturity level of fruits, and quarantine treatment (HWT). Ripening chamber should have high air flow (forced air) circulation inside the chamber. Generally, forced air circulation is must in the chamber or room for uniform mango ripening. Hence, maintaining uniform temperature, relative humidity, and air flow in the ripening room are three most important parameters for ripening.

Hot Water Treatment

Mangoes are grown in tropical climates. Many mango production areas have populations of fruit flies that are not allowed in European countries and Japan, the United States, and other countries. Importation of fruit from a fruit fly zone could carry the pest into these countries and threaten the domestic agricultural production. For this reason, many tropical fruits are required to go through some type of *quarantine treatment to eliminate* this risk. For mangoes, the most common protocol is *hot water treatment*. HWT is also called quarantine treatment. The fruit is submerged in hot water for sufficient time to control the risk of fruit fly. Ripening procedure after HWT is given below

- After HWT, precool the fruits 20–22 °C
- Hold at 68–72 °F (*20–22.2 °C*) *for sufficient periods* (*3–6 days*)
- No ethylene application is needed, although using ethylene on hot water-treated mangoes should not cause a problem
- *Hot water-treated mangoes kept at 20–22.2 °C* (68–72 °F) *will ripen in 3–6 days*
- Monitor progress and sample fruit for firmness until the ideal stage for marketing is reached

Handling After Ripening

Once ripen, mangoes will ideally be kept at (54–60 °F) 12–15.6 °C and 90–95 % relative humidity for no longer than 1 week.

Banana Ripening

Banana ripening is very similar to mango ripening. Maturity of banana also plays very important role of ripened fruit. This is a climacteric fruit, hence transportation is done at green mature stage and fruits are ripened at sales place. Major production site of banana is South India and consumption is in North India.

Ripening Procedure

Fruit should be ripened using controlled temperature and ethylene application. First separate hands, if bananas are in bunch. Ripening of bunch is not uniform and commercially not viable. Discard diseased, cut, damaged fruits and keep best quality in plastic crates. Always use plastic crates or bins for ripening. Now, stack the crates in the ripening chamber and remove field heat (precooling of fruits up to 20–22 °C). Hold at this temperature, i.e., 20–22.2 °C (68–72 °F) and apply ethylene at 100 ppm for 24 h. This ethylene application is called gassing. After 24 h of gassing, open the door for 5–10 min to remove CO_2 build-up. This is necessary because accumulated

Fig. 7.5 Ethylene cylinder for gassing (*left*), cooling system (*middle*), ripened banana ready for dispatch (*right*)

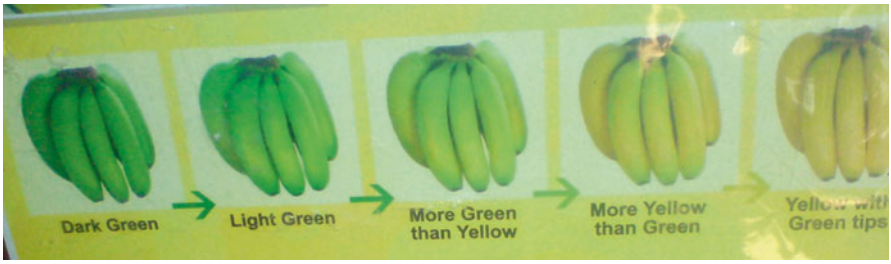

Fig. 7.6 Ripening stage based on color development in banana

CO_2 will reduce ripening process. Hold bananas at this temperature for 3 days. Bananas will ripen if kept at this temperature (20–22.2 °C) for 3–4 days. Check ripening progress in the fruit for firmness and peel color until the required peel color and firmness is reached for marketing. During ripening, carbon dioxide levels should always be kept below 1.0 % by exchanging room air with outside air. Hence, open the door for once or twice for 5–10 min after every 24 h. Keep fan on continuously, for better air circulation. However, continuous air circulation may results water loss and shrivelling. This problem may be sorted out by maintaining a relative humidity of 90–95 % with the help of humidifier.

The ripening procedure may vary slightly for better air circulation. Maintaining a relative humidity of *90–95 %* will reduce water loss and hence shrivelling from the fruits in the ripening chamber. Different components of ripening of banana are shown in Fig. 7.5 and color development in Fig. 7.6.

Handling After Ripening

Once ripen, bananas can be stored at 12–15.6 °C (54–60 °F) and 90–95 % relative humidity for 5–7 days. When to dispatch for markets depends upon the color developed after ripening. More green than yellow is the best stage for long distance journey (25–50 km); more yellow than green should be dispatched to a radius of less than 25 km. Whereas, yellow with green tips is ideal for immediate consumption.

Packaging

Packaging is considered as the first sales man in marketing language. It maintains the condition of fresh commodities during entire postharvest handling chain. A good packaging and packet is liked by all consumers. Buyers wanted to know exactly what they will get when they purchase a particular packet. Packaging also reflects the image and quality of any brand. Thus, a packet that is consistent in quality, appearance, and weight (sometimes a grade standard) throughout the season is desirable. Packages and presentation of produce in a package make it attractive to buyers. Poorly packed containers distract the consumer's eye from the quality of the produce. Attractive packing frequently encourages repeat purchase.

Packaging requirements vary from produce to produce and are based on perishable nature of the fresh produce and rate of respiration, transpiration, and ethylene production. On the basis of rate of respiration and ethylene production, there is a wide variation among fruits and vegetables (Tables 7.1). High-quality produce must be handled carefully during harvesting and packing. For packing in the field, you have to rely on skilled harvesters and packers and adequate supervision is needed. Atmospheric conditions cannot be maintained in field condition. In a packing shed, you must rely on skilled line workers and properly operating equipment. The cost of building and/or packing shed varies according to product needs and type of equipment. Though usually more expensive than field packing, packing sheds offer some advantages. Grading and packing can be done under well-supervised and less strenuous working conditions and with or without required machineries. The result often is a higher quality and more uniform pack than can be achieved in the field. Some crops, however, cannot absorb the additional costs of shed packing. Also, some products, such as berries, do not lend themselves to the additional handling required in packing sheds. If such handling is necessary, harvesters should select only clean, firm fruit that will allow extra handling.

When you choose a packaging container considering several functional criteria, the container must meet industry standards for size, volume, and strength and must allow for efficient cooling of the contents. In addition, be sure the container protects the product throughout distribution and is suitable for storing standard pallets. The package must present your product in a useful and attractive manner. Buyers usually expect new, unused containers. Sometimes, however, recycled produce boxes are acceptable for deliveries directly to a customer such as a restaurant. But keep in mind that recycled containers may have another farm's name printed on the outside, and your excellent job of production and handling may be attributed to that farm.

Some products are packaged in smaller units before being placed in the shipping carton. Apples and pears may be wrapped individually and placed on layer trays. Berries may be sold in pint or half-pint containers and covered with a clear plastic lid. Berries also may be sold in clear plastic, clamshell-type containers for easier handling. Shippers often use prepacking to provide additional protection for their product. Many retail buyers prefer prepacking of some products to reduce the amount of preparation and handling at the point of sale. With many types of fruit, such as

apples and pears, a coded sticker is applied to each piece for easy identification by supermarket clerks. Be sure to check with potential buyers to determine their labeling requirements. Prepackaged produce is more expensive to prepare and ship than bulk produce, so your pricing should reflect the added cost.

When you pack produce destined for retail supermarket shelves, use an attractive package. A package that shows off the product and has an attractive label helps promote sales. Be sure to include your farm name, business telephone number, and address (where the product is grown) to help promote locally grown products. Take advantage of any local promotions or logos that identify products as locally grown. Advertise your farm website (you really should have one) to encourage buyers to check out your full line of products and to make future ordering easier.

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Chapter 8
Packaging of Fresh Fruits

Introduction

Packaging refers to the technology and material for enclosing or protecting products for distribution, storage, sale and use (Soroka 2002). Packaging can also be defined as the art, science and technology of ensuring the safe delivery of a product to the ultimate consumer in sound condition, at the minimum overall costs (Selin 1977). According to UK institute of packaging, packaging is a coordinated system of preparing goods for transport, distribution, storage, retailing and end use.

After harvesting and assembling, the next important job for any fruit grower or trader is packaging in a suitable container before storage and marketing. The main purpose of packaging is protection of produce during transportation, storage and marketing till consumption. It is because fresh produce is highly perishable in nature and therefore, proper packaging is an essential part to reduce losses, and it employs a blend of technologies and processes (Olsmats and Wallteg 2009). Fruits and vegetables account for the highest share of food losses and are usually among the most wasted items, followed by other perishables such as bakery and dairy products, then meat and fish (Parfiit et al. 2010). Not only in India but at global level also, food packaging industry has a lot to contribute not only in addressing food losses but also in ensuring food safety as well as enhancing global food trade, which is a key to economic development of any country. Now packaging industries are in transformation phase adopting new technologies and replacing old ones (Packaging Trend-The Future Outlook 2010). During handling, physical injury and pressure damage are the major concern areas kept in mind while selecting a packaging containers for fresh produce. It is essential to minimize physical damage in order to obtain optimal shelf-life and this can be achieved by use of suitable packaging (Thompson 1996). Packaging acts as an added "P" to the "4 Ps" of marketing (product, price, place, promotion), particularly in terms of facilitating branding of a product and popularization among consumers.

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_8

There may be many objectives of packaging, but the main objectives are

1. It protects the produce from microorganisms (Bacteria, Moulds)
2. It acts as a silent salesman (Promotes branding)
3. Protection from physical injuries (impact, compression, abrasion and wounds) and adverse environmental conditions (temperature, relative humidity) during transport, storage and marketing

Characteristics of a Good Package

Fruits and vegetables are perishable commodities and therefore, packaging for these perishable items should have many characteristics as described below.

- A good package should occupy less space when empty. It will facilitate cost-effective transportation of empty boxes and convenience in storage while not in use, e.g. collapsible plastic crates and corrugated fibre board (CFB) boxes.
- A good package should be easy to assemble, fill and close either by hand or by use of a simple machine. Semi-skilled labour can also fill and close comfortably.
- A good package must provide adequate ventilation and overall protection for contents during transportation, storage and marketing.
- Its capacity should be suited to market demands. Capacity and size may depend on market demands and consumer preferences.
- The dimensions and design of a good package must be according to the available transport systems in order to load properly without leaving any chance of vibration damage.
- A good package must be cost-effective in relation to the market value of the commodity and the cost of packaging material.
- A good package should be environment friendly, reusable and biologically inactive.
- A good package should have sufficient strength in order to protect the contents against physical injury (impact, abrasion and vibrations) during entire distribution chain.
- A good package should not damage while doing special treatments like pre-cooling, fumigation etc. It should be resistance to moisture and free from any sort of smell.
- A good package should have attractive shape, size and colour and should have consumer appeal. It should also possess enough printable area and should be printed easily.
- Provide information to buyers, such as variety, weight, number of units, selection or quality grade, producer's name, country and area of origin. Recipes are frequently included such as nutritional value, bar codes or any other relevant information on traceability.

Materials for Packaging

The common materials used for packing fruits and vegetables are described below.

1. *Wood*—Packing in wooden boxes is still a common practice in developing countries including India. However, this practice is decreasing slowly and the use of CFB boxes is increasing. Now, CFB boxes have almost replaced the use of wooden boxes from Himachal Pradesh, but still continued in Jammu and Kashmir. A number of fruits and vegetables like apple, pear, kinnow, oranges and tomato are packed in wooden boxes especially for storage and long distance transportation. Due to many disadvantages of wooden boxes such as rough surface and in the absence of suitable cushioning material, fruits get damaged, deforestation, environmental issues, its use is decreasing day by day in all parts of the country. Wooden plates are still very common for making pallets for bulk handling of fresh produce. However, plastic plates are also available in the market.
2. *Jute and polypropylene*—Jute is used for manufacturing jute sacks, and plastic sacks are manufactured from polypropylene. Sacks are generally used for bulk packaging and for transporting produce to the wholesaler or trader. Sacks are used for bulk packaging of semi-hard vegetables such as potato, onion, garlic, cassava, chilli, pea and brinjal. Low-quality fruits are also packed in sacks. The major disadvantage in sacks is handling damages due to pressure damage which is maximum in sacks and therefore, fruits are not advised to be packed in sacks. However, the advantage of using sacks are their ready availability and low cost. Net bags (mesh bag) and plastic bags are manufactured from polypropylene. These bags are used for retail as well as for bulk packaging of fruits and vegetables.
3. *Polyethylene*—Polyethylene is the most commonly used polymeric film used for modified atmosphere packaging (MAP) of fresh produce. The degree to which atmospheric modification takes place in packages depends upon several factors such as film permeability to O_2 and CO_2, rate of respiration of product and the influence of temperature on both these processes (Beaudry 1999). Permeability of film depends upon the gas transmission rate of the film which in turn depends upon the manufacturing process of the film (Lamination or co-extrusion). Gas transmission rate includes the rate of change of gases mainly O_2, CO_2 and water vapour that exit from the package or enter into the package in a controlled manner such that the need for aerobic respiration is fulfilled, and desirable CO_2 and moisture levels are maintained.
4. *High-density polyethylene*—plastic crates are manufactured by using high-density polyethylene (HDPE). However, some manufacturers make use of polypropylene in the manufacture of plastic crates. Polypropylene is scratch resistant whereas polyethylene offers greater strength against impact and provides a high level of protection against degradation by ultraviolet radiation from sunlight.
5. *Paper and cardboard*—Paper and cardboard boxes are used in a big way for packaging fresh produce. Majority of the fruits are packed in paper and cardboard boxes for both wholesale and retail markets. Due to the moisture sensitivity of

paperboard, it must be coated or laminated with a polymer in order to improve its moisture barrier properties. Now, laminated boxes are also available in the market. Both transport and retail cardboard boxes are available. The retail box is used primarily for high value and more delicate fruits such as gift packs for strawberries, cherries, kiwi and oranges. Graphics on retail packages play a key role in the marketing of the product. High-quality retail boxes of packed produce may contain a clear film window for produce display and visibility. Most common and widely used cardboard box is CFB (Corrugated fibre board box) boxes. Wooden boxes are now almost replaced by CFB boxes on commercial scale. However, wooden boxes are still used in Jammu and Kashmir and Kullu district of Himachal Pradesh on commercial scale. Fruits are packed with or without liner and trays. In order to increase the stacking strength of CFB boxes, many combinations with other materials are available in the market. Most common combinations include

- Wooden box having CFB liners
- CFB box with plastic film wraps
- CFB trays with wooden corner supports
- CFB laminated or waxed
- CFB box with plastic retailer packs (strawberry boxes)
- CFB or polystyrene trays/boxes with plastic film wraps

Packaging Requirement Varies According to Purpose

Packaging requirements for fresh produce varies according to the purpose as described below.

1. If hydro cooling or ice-cooling needs to be undertaken, it needs to be able to tolerate wetting without losing strength.
2. If product has a high respiratory rate, the packaging should have sufficiently large openings to allow good gas exchange.
3. If produce dehydrates easily, the packaging should provide a good barrier against water loss.

Type of Packaging

There are three types of packaging:

(a) Consumer packaging
(b) Transport packaging
(c) Unit load packaging or pallets

Consumer Packaging

When weighed product reaches the consumer in the same type of container in which it is packed in the beginning, it is described as a consumer packaging or prepackaging. Generally, the weight of consumer packaging is less so that one can easily carry it. Few photos of consumers packaging are shown in Fig. 8.1.

Transport Packaging

Transport packaging mainly consists of packing in comparatively bigger boxes aiming transportation. It mainly consists of fiberboard or wooden boxes weighing from 5 to 20 kg or even heavier (Fig. 8.2). They need to satisfy the following requirements: be easy to handle, stackable by one person, have the appropriate dimensions so that they fit into transport vehicles and materials should be constructed with biodegradable, non-contaminating and recyclable materials. Packaging intended for repeated use should be: easy to clean and dismantle so that it is possible to significantly reduce volume on the return trip; ability to withstand the weight and handling conditions they were designed for and meet the weight specifications or count without overfilling.

Fig. 8.1 Consumer packaging or prepackaging. Grapes in punnet, litchi packed in polyethylene, shrink-wrapped apple

Fig. 8.2 Transport packaging (*left* to *right*)

Packaging of Apple Before Transportation and Marketing

Apples are packed in both CFB boxes and wooden boxes in India. CFB boxes are more prevalent in Himachal Pradesh and wooden boxes in J&K. In CFB boxes, trays are of same sizes but differ in cup size and number of fruits per tray (Fig. 8.3). For example, tray of large fruits possess 20 cups per tray and medium 25 cups per tray and small 30 cups and so on. As the number of cups increases per tray, the size of fruits decreases and vice versa. There are five trays packed in 1 box and therefore, 100 fruits are packed in large, 125 fruits in medium and 150 fruits in small box. In short and in business language, large, medium and small is called LMS and sold altogether in one price for all three grades. The lots having more medium and small boxes are priced more for South and North east market. Whereas, lots with more large boxes are sold at higher prices in Northern fruit mandis.

Banana Packaging Before Transportation and Marketing

Banana is transported either in loose (whole bunch) or packed in crates/CFB boxes after cutting into hands. Crates packing is more common than CFB boxes. Only retail modern formats are using CFB boxes and for export. Liner and foam cushioning is used in CFB boxes (Fig. 8.4) while paper cushioning is used in plastic crates. Banana leaves are used as cushioning in whole bunch transportation.

Fig. 8.3 Packing trays are shown

Fig. 8.4 Banana packing in CFB boxes with liner and cushioning with foam

Pallets

Individual boxes are assembled on wooden or plastic pallets. Pallets have fixed dimension (Fig. 8.5). Boxes are tightly held by corner post and plastic strips. This whole process is called palletization. Now, pallets are loaded in reefer container.

Packaging of fruits in India is in an early stage but progressing day by day with the advent of corporate and multinational companies. Horticultural produce are packed before transportation to mandi except coconut, pineapple and watermelon. There are four types of packaging mainly used for fresh horticultural produce.

Flexible Packaging for Fresh Produce

Many flexible packaging options exist for fresh produce in our country. These generally include sacks, bags, bamboo baskets, cartons and crates.

Sacks

Sacks are flexible containers and are generally made of woven jute fibre or woven synthetic material such as polypropylene. Sacks are generally used for transporting produce to the wholesale market. Produce is sold with sacks and the cost of the sack is added into the cost of the produce. Plastic sacks called leno bags are extensively used for packing onion, garlic and potato. Sweet orange, kinnow and oranges are packed in sacks for short distance markets (Fig. 8.6). Jute sacks are used on large commercial scale for storage and transportation of potato. Now, leno bags are

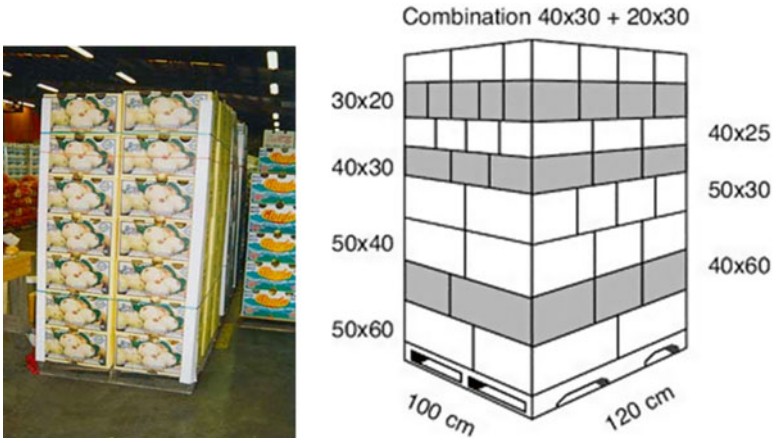

Fig. 8.5 Pallet stabilization with corner posts (white corner post) and strapping

Fig. 8.6 Potato in jute sacks, onion in leno bags, sweet orange in leno bags

preferred over jute due to its light weight, strength, good air circulation and unfavourable medium for fungal growth. Application of CIPC, an anti-sprouting agent is found more effective if potatoes are packed in leno bags. Earlier tomatoes were also packed in sacks, but now it is packed in plastic creates and transported to wholesale mandi. Here, cost of crates is not included but buyers deposit security money for plastic crates. Every time they return empty crates and take new tomato crates. Sacks are relatively inexpensive and have a low weight to volume ratio. However, sacks provide relatively little protection against damage caused by compression, puncturing, vibration and impact injuries. Sacks also have poor vapour and heat transmission characteristics.

Bags

Two types of bags, namely net bags and plastic bags are used for bulk packaging. Both types of bags are flexible containers. Net bags are generally colourful and are made of open mesh using polypropylene (Fig. 8.7). Net bags are best suited for packing relatively physically hard produce items such as apple, onions, lemons and garlic. Mesh or net bags vary in size. Plastic bags used in bulk packaging are made from polyethylene films. Plastic bags are commonly used by traders for transporting vegetables such as lemons, jamun and phalsa to wholesale markets in urban areas. The capacities of the bags vary widely from 5 to 25 kg. Typical dimensions of plastic bags used for bulk packaging are $16'' \times 24''$ with a capacity of 10 kg and $26'' \times 30''$ with a capacity of 15 kg. Net bags and plastic bags are relatively inexpensive, readily available and have a low weight to volume ratio. Although net bags allow adequate ventilation of the packed produce, plastic (polyethylene) bags require holes to reduce the buildup of heat and to avoid excessive humidity inside the package. The major disadvantage of using either type of bag is the low level of protection against damage during handling, loading and unloading, and during transportation.

Fig. 8.7 Different fruits in net bags

Baskets

Baskets are containers made of woven strips of fibrous materials. Bamboo baskets are widely used in the bulk packaging of fresh produce. Bamboo baskets are of different sizes and shapes (Fig. 8.8). Those made from strips of the hard outer rind of the bamboo are stronger than those woven from the soft inner part and can be reused on several occasions. Most bamboo baskets can be nested when empty. Bamboo baskets are semi-rigid containers, are relatively lightweight and can be produced in a range of sizes and shapes. Their hard and rough surfaces can, however, damage the produce. They must, therefore, be lined with a padding material such as leaves, old newspapers and/or rice straw, in order to protect produce from bruising. Bamboo basket is used as harvesting container for tomatoes and apples and also for bulk packaging. Now, plastic crates have almost replaced bamboo baskets in apple growing areas. In many countries, plastic baskets are also in use. Plastic baskets are an alternative packaging container to bamboo baskets. These baskets are made of woven polypropylene (PP) strips. These baskets can be repeatedly reused.

Cartons

Cartons are boxes made of either solid or CFB. Solid fiberboard consists of three or more sheets of fibre board glued together, whereas corrugated fiberboard is made of linerboard glued onto fluted sheets of fibre board by means of water-resistant adhesive. CFB provides better protection than solid fibre board. CFB boxes are rectangular in shape and come in a range of many sizes (ranging from 2 to 20 kg) (Fig. 8.9). CFB boxes are used to transporting produce such as apple, orange, pear, banana, mango, pineapple and papaya in export trade. To enhance market appeal, CFB boxes are printed with attractive colours, a brand name and a label that displays information required by the importing countries are printed. The advantages of using cartons or fiberboard boxes include low weight and thus ease of handling. Fibre board boxes also have relatively soft walls that provide a cushioning effect to packed produce. These boxes are convenience during delivery and collapsible facilitates for easily assembling and storage while not in use.

Fig. 8.8 Different types of baskets for packaging of fruits and vegetables

Fig. 8.9 Carton boxes used for the packaging of fruits, CFB boxes with five ply

Wooden Boxes

Wooden boxes are rigid containers popularly used for the bulk packaging of fresh produce. Wooden boxes are commonly used for packing apple in Jammu and Kashmir and orange packing in Maharashtra. Wooden boxes provide good ventilation but may transfer microbial contamination to produce and damage due to rough surface and improperly inserted iron nails. They are manufactured with rigid wooden planks in such a way that their corners are nailed. Spacing of the planks varies in accordance with the type of produce to be packaged. Wooden boxes are commonly used as transport containers for the domestic interstates trade of apple, orange, mango and tomatoes. Wooden boxes are relatively inexpensive when compared to plastic crates. They provide good ventilation and have high stacking strength. Furthermore, wooden boxes are preferred for storage over low-quality CFB boxes. Plastic crates are increasingly being used in the bulk packaging of fresh produce.

Plastic Crates

Plastic crates are mainly used for handling of fresh produce especially from field to pack house or to wholesale markets. It is used for long distance transportation of tomato, orange, grapes, etc. It is also used for storage of fruits such as orange,

Fig. 8.10 Plastic crates (*left*) collapsible plastic crates (*right*)

grapes, apple and pear. The use of plastic crates for the bulk packaging of fresh produce during post-harvest handling, transportation and storage is growing rapidly in developing countries due to its natural strength, ability to protect the produce and unbreakable nature of plastic crates. However, management of empty crates (storage of empty crates) and transportation cost from end user to production site is a major limiting factor for use of plastic crates. These problems were sorted out by introduction of categorized crates such as collapsible, stacking, nesting, stacking and nesting crates. Now, all categorized plastic crates are available in the market. Stacking crates are assembled by placing one crate above another as it takes less space for storage of empty crates. Nesting crates are assembled by inserting into other crates when empty. Similarly, stacking and nesting crates are stacked on top of others or nested by inserting one crate into the other. Plastic crates generally manufactured from HDPE, although some manufacturers make use of polypropylene in the manufacture of plastic crates. Polypropylene is scratch resistant whereas polyethylene offers greater strength against impact and provides a high level of protection against degradation by ultraviolet radiation from sunlight. Both collapsible and non-collapsible plastic crates are available in the market (Fig. 8.10).

Characteristics of Plastic Crates

The characteristics of plastic crates as bulk packaging containers for fresh produce are discussed briefly below.

Perforation or Ventilation Holes

Plastic crates may or may not be perforated or ventilation holes. It depends upon the intended use. Always perforated crates are preferred for handling of fresh produce. Those crates are mainly used for the field handling, transport and storage of fresh produce. They allow for adequate air flow through produce during cooling as well as during refrigerated transport or when stored in cold storage.

Ease of Cleaning and Disinfecting

Plastic crates have hard but smooth surfaces which make them easy to clean and disinfect.

Dimensions and Types of Plastic Crates for Fresh Produce Packaging

A number of fresh produce supply chains in developing countries have begun adopting plastic crates for bulk packaging during field handling as well as for the transportation of produce from on-farm packing houses to wholesale/retail markets. Commodities handled are usually high value vegetables such as lettuce, cabbage, carrots, broccoli, beans and tomato and fruits such as mango and citrus. Currently, no specifications exist for the use of plastic crates in fresh produce supply chains. Stacking crates with ventilation holes are the most commonly used crates for the bulk packaging of fruits. Stacking-nesting type crates with ventilation holes and swing bar handles are generally preferred for the bulk packaging of vegetables.

Thermocol Boxes

Thermocol is also costly packing material and difficult to store when empty. However, many perishable commodities are packed in thermocol including grapes. Almost all imported grapes are packed in thermocol boxes. It is durable, resistant to moisture and provides cushioning to fruits. Fruits are packed in polyethylene pouches and then packed in thermocol boxes as shown in Fig. 8.11.

Manner of Loading

Vehicles can be either manually or mechanically loaded. Mechanical loading makes use of a forklift. Lightweight and convenience are important features of bulk packaging materials for manual loading in order to eliminate inconvenience to workers and to mitigate the risk of dropping and damage to the produce during loading and unloading. Weight is not, however, a critical consideration for mechanical loading. Heavy bulk units on pallets are convenient when handled using forklifts. Given the large capital investment requirements of mechanical loading, it is often used by large enterprises.

Fig. 8.11 Thermocol boxes showing imported grapes (Red Globe)

Modified Atmosphere Packaging

MAP is a technology of food packaging in which the gas composition inside the package gets modified either by natural respiration of packed commodities or by manipulating (addition or removal) the gas composition. The former condition is called passive MAP and later is called active MAP. In passive MAP, the atmosphere is changed through the respiration of the commodity within the pack and in active MAP, the atmosphere is changed by pulling of a slight vacuum within the pack and then replacing the atmosphere with the desired gas mixture. Active MAP can also be developed by placing gas absorbers inside the package. These absorbers absorb O_2, CO_2 and or ethylene and change the gas composition inside the package. In both the cases, gas composition inside the package differs from that of regular air atmosphere (20.9 % O_2, 78 % N_2 and 0.03 % CO_2). This modification affects the shelf-life of a product by preserving its quality. It is important to note that gas composition differs from commodity to commodity and accordingly selection of a packing material is important.

Packaging of fresh produce in MAP requires polymeric films (polyethylene, polypropylene, etc.) of required gas permeability. There are many advantages of polymeric films including control of water loss, protection from skin abrasion and reduced contamination of the produce during handling. They also provide a barrier to the spread of decay from one unit to another. These films affect the movement of respiratory gases depending on the relative permeability of the film. This leads to the development of lowered O_2 and raised CO_2 levels within the package, and this condition reduces rate of respiration of the produce and potentially extend shelf-life. The final equilibrium atmosphere will depend on the characteristics of the commodity and the packaging film. Temperature control is extremely important with MAP, as this will influence the gas permeability properties of the films as well as the respiration rate of the product. One of the main drawbacks to MAP is the potential fall of O_2 levels to too low that anaerobic respiration may start and cause the production of undesirable off-odours as a result of fermentation. Therefore, the success of MAP packaging depends on selection of a suitable film based on the permeability (gas transmission rate) of the film and rate of respiration of the product.

For highly respiring produce such as mushrooms, bean sprouts, leeks, peas and broccoli, films like low-density polythene (PE-LD), polyvinyl chloride (PVC), ethylene/vinyl acetate (EVAC) and cellulose acetate are not recommended to use as these films are sufficiently permeable. Such highly respiring produce is most suitably packed in highly permeable polyethylene films with or without microperforation. The permeabilities of two commercial ceramic-filled PELD films were measured and compared with those of a plain PE-LD film. It was found that the ceramic films have higher oxygen (O_2), carbon dioxide (CO_2) and ethylene (C_2H_4) permeabilities, higher CO_2 to O_2 permeability ratio and higher C_2H_4 to O_2 permeability ratio (Lee et al. 2006). Table 8.1 enlists the different polymeric film with their gas permeability, and Table 8.2 enlists recommended gas mixture of MAP.

Table 8.1 Gas permeability and water transmission rate (WTR) of polymeric film available for packaging of MAP produce (Chung and Yam 1999; Day 1993; Greengrass 1993; Guilbert et al. 1996; Han 2000; Park 1999; Phillips 1996)

Film	Permeability (cm^3/m^2 day atm) for 25 μm film at 25 °C			WTR (g/m^2/day/atm) at 38 °C, 90 % RH
	O_2	CO_2	N_2	
Ethylene-vinyl alcohol (EVAL)	3–5	–	–	16–18
Low-density polythene (PE-LD)	7800	2800	42,000	18
High-density polyethylene (PEHD)	2600	650	7600	7–10
Polypropylene cast (PPcast)	3700	680	10,000	10–12
Polypropylene, oriented (OPP)	2000	400	8000	6–7
Polypropylene, oriented, PV dC coated (OPP/PV dC)	10–20	8–13	35–50	4–5
Rigid poly(vinyl chloride) PVC	150–350	60–150	450–1000	30–40
Ethylene-vinyl acetate (EVAC)	500–30,000	300–10,000	1500–46,000	15–40
Polystyrene, oriented (OPS)	12,500	4900	50,000	40–60
Polyurethane (PUR)	800–1500	600–1200	7000–25,000	400–600
Polyamide (Nylon-6) (PA)	40	14	150–190	84–3100

Table 8.2 Recommended gas mixtures for MAP (Day 1993; Exama et al. 1993)

Fruits	O_2 (%)	CO_2 (%)	N_2 (%)	Vegetables	O_2 (%)	CO_2 (%)	N_2 (%)
Apple	1–2	1–3	95–98	Artichoke	2–3	2–3	94–96
Apricot	2–3	2–3	94–96	Beans, snap	2–3	5–10	87–93
Avocado	2–5	3–10	85–95	Broccoli	1–2	5–10	88–94
Banana	2–5	2–5	90–96	Brussels, sprouts	1–2	5–7	91–94
Grape	2–5	1–3	92–97	Cabbage	2–3	3–6	81–95
Grapefruit	3–10	5–10	80–92	Carrot	5	3–4	91–95
Kiwifruit	1–2	3–5	93–96	Cauliflower	2–5	2–5	90–96
Lemon	5–10	0–10	80–95	Chilli peppers	3	5	92
Mango	3–7	5–8	85–92	Corn, sweet	2–4	10–20	76–88
Orange	5–10	0–5	85–95	Cucumber	3–5	0	95–97
Papaya	2–5	5–8	87–93	Lettuce (leaf)	1–3	0	97–99
Peach	1–2	3–5	93–96	Mushrooms	3–21	5–15	65–92
Pear	2–3	0–1	96–98	Spinach	Air	10–20	
Pineapple	2–5	5–10	85–93	Tomatoes	3–5	0	95–97
Strawberry	5–10	15–20	70–80	Onion	1–2	0	98–99

Equilibrium Modified Atmosphere Packaging

If you adjust the permeability of the film used for the packaging for the respiration rate of the product, a gas composition that is beneficial for the product can occur on its own. The goal is to maintain a concentration of oxygen and carbon dioxide that is beneficial for the product. This balanced atmosphere is influenced by the interaction between product respiration (the product "breathing") and film permeability. Because film is generally not permeable enough for such applications, the film's properties can be adapted with micro-perforations.

Active Packaging

Active packaging is an emerging and exciting area of food technology that is developing due to advances in packaging technology, material science, biotechnology and new consumer demands.

Active packaging is defined as a system in which the package interacts with the product or the headspace, in order to maintain the nutritional and sensory quality, fresh-like appearance and safety of the food product (Villa-Rodriguez et al. 2015). Thus, active packaging is based on such new technologies that continuously monitor the changing gas environment (and may interact with the surface of the food also) by removing gases from or adding gases inside a package or by scavenging. For example, a chemical reagent is incorporated into the packaging film and traps the ethylene produced by ripening fruits or vegetables. The process is called ethylene scavenging, and this reaction is irreversible. Only a small quantity of the scavengers is required to remove ethylene. This emerging technology has interesting perspectives for practical application in post-harvest management. Examples of active packaging include the use of moisture scavengers, flavour emitters/adsorbents and antioxidants.

Flexible packaging materials such as PE-LD and linear low-density polyethylene (PE-LLD) when impregnated with potassium permanganate and cinnamic acid, respectively, become ethylene scavengers. Fresh fruits and vegetables, such as mango, tomato, banana and papaya exhibit more shelf-life of 2–3 weeks when packed in such ethylene scavenging films. Similarly, oxygen scavengers are also available that can be incorporated into the packing film and level of oxygen can be manipulated.

Active packaging technology has been applied for antimicrobial purposes mostly in fruits, and using mainly essential oils or polyphenols as antimicrobial agents or additives (Villa-Rodriguez et al. 2015) basically in order to ensure product safety and quality. However, the same mechanisms or principles may be applied to increase the antioxidant potential in fruits and vegetables contained in the package (Fig. 8.12).

According to Ayala-Zavala et al. (2008), antioxidant active packaging systems can be divided into four groups according to the mechanism of action of the antioxidant compound (Ayala-Zavala et al. 2008):

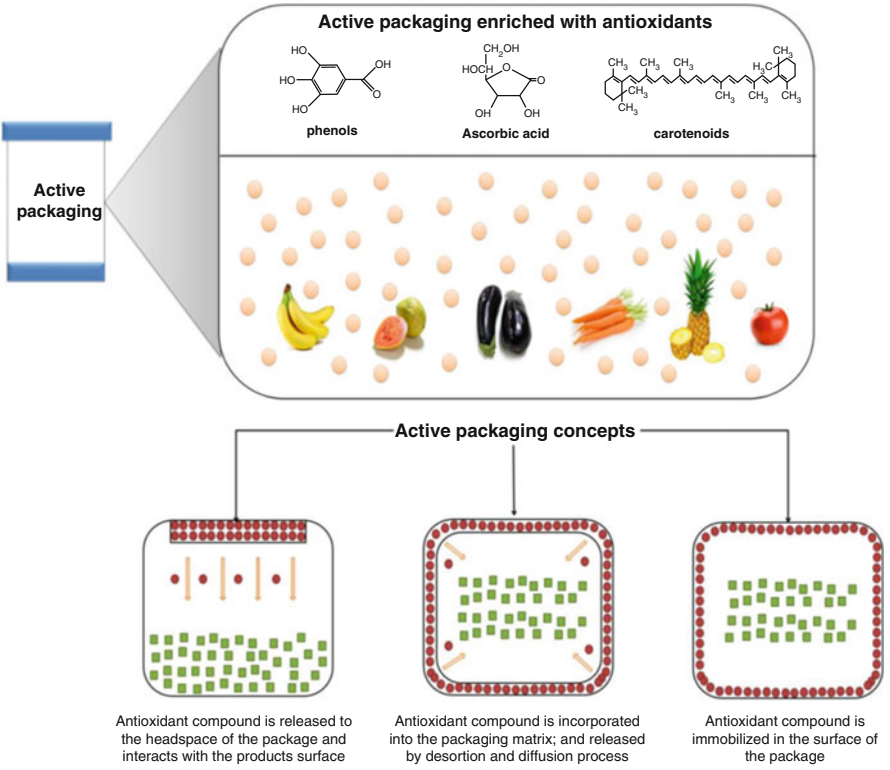

Fig. 8.12 Active packagings deliver antioxidants into the package atmosphere of fresh produce. Several antioxidant compounds may be incorporated by different concepts: (1) Sachets, (2) within the packaging matrix and (3) immobilized in the surface of the package (Adapted from Villa-Rodriguez et al. 2015)

1. The antioxidant is released to the headspace of the package in order to interact with the product surface.
2. The antioxidant compound is included into the packaging material and is released to the product by a migration process.
3. The antioxidant compound is immobilized in the surface of the package.
4. The package material has inherent antioxidant and also antimicrobial activity.

This technology can confer many preservation benefits on a wide range of ambient-stable and chilled food products. The intention is to extend the shelf-life of foods, while at the same time maintaining nutritional quality and assuring microbial safety. The use of active packaging is becoming increasingly popular and many new opportunities will open up for utilizing this technology in the future.

Smart or Intelligent Packaging

Smart or intelligent packaging automatically regulates oxygen intake and carbon dioxide out flow according to the prevailing temperature. In this way, an optimum atmosphere is maintained inside the package or around the product during storage and distribution. Thus, extending freshness and allowing shipping of higher quality products to the consumer. Smart packaging can be categorized into two types, those which incorporate integrated circuits (ICs) and those which do not incorporate integrated circuits (ICs) also known as chipless smart packaging. Packaging that incorporates diagnostic indicators are also included in smart packaging. These can be used for such functions as monitoring vibration, acidity, tilt, shock, humidity, light, heat, time chemicals, virus or bacteria as they develop or as they are contacted. Intelligent packaging can change colour to let the customer know how fresh the food is and indicate if the food has been spoiled because of a change in temperature during storage or a leak in the packaging.

Shrink Wrapping/Packaging

Considering packaging as an integral part of post-harvest management and value addition, several advancements have been made. This technique involves overwrapping of the produce with heat-shrinkable films such as Cryovac, polyolefin and LDPE of the desirable thickness with the help of machine. The shrink wrap technology for different fruits has been standardized now. There are two types of shrink wrapping such as individual fruit wrapping and tray-shrink wrapping (Sharma and Pal 2009).

For individual shrink wrapping, initially individual fruit is loosely sealed in a desirable heat-shrinkable film with the help of an impulse sealer. The produce is then placed inside the machine maintained at 120 °C. Then, upper cover of the machine is pressed for 10–15 s to activate fan, which circulate hot air around the produce, and the film shrinks tightly around the produce. In case of tray-wrap packaging, produce is first sealed in a consumer pack of suitable size and then passed through the machine. Shrink-wrapped produce is immediately removed from the machine and cooled for 2–3 h at 5–10 ° C or by rapid ventilation. Thereafter, the produce can be packed in plastic crates for further storage or transportation.

The technology delays physiological deterioration of fruits and also prevents condensation of droplets within the package. Individual shrink wrapping of the produce provides optimum gas and humidity for maintaining quality of the produce during the transit and storage. As a result, it doubles or sometimes triples storage life of the fruits and vegetables under proper storage conditions. Such unit packs also provide protection against abrasion and maintain attractive appearance of the product (Sharma and Pal 2009).

Steps Followed in Shrink Wrapping

Select healthy fruits of equal size.

⇩

Wash fruits and air-dry them under a ceiling fan.

⇩

Seal fruits and vegetables loosely in heat-shrinkable film with impulse sealer.

⇩

Pass fruits and vegetables in a machine maintained at 120 °C.

⇩

Cool shrink-wrapped fruits and vegetables for 2–3 h at 5–10 °C.

⇩

Pack fruits and vegetables in desirable containers for storage or marketing.

Advantages of Shrink Wrapping

- It is easy, user-friendly, can be very well adopted by marginal farmers and/or entrepreneurs.
- It adds very little to the cost of high-value fruits like apple or kiwifruit.
- Machine used for shrink wrapping of apples or kiwifruits can also be used for other commodities. Thus, year-round production of shrink-wrapped produce is possible.
- Shrink-wrapped produce looks attractive, hygienic and free from dust and dirt.
- It is easy to handle shrink-wrapped apples or kiwifruits during storage or transportation.
- It avoids secondary infection, which is important for long-term storage.
- It delays deterioration of the produce, and thus enhances to shelf-life.

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Chapter 9
Storage of Fresh Fruits

Introduction

The demand of fresh fruits is also increasing regularly due to the increase in health consciousness among consumers, faster growth rate of urban population, increased income of middle class family, etc. Fruits are seasonal in nature. Every year, harvesting season falls during a fixed period. Demand for apple, pear, grape and many other fruits are round the year. This demand can be fulfilled only if fruits are stored in the harvesting season and sold in off season, i.e. when the season ends. The sale beyond harvesting season is remunerative and successful business all over the world (Siddiqui et al. 2015). But this business is not successful in every fruits. There must be few important qualities related to fruits for successful store business. Such as the fruits should store well at low temperature and off season demand should be fulfilled only by stored fruits.

Stored fruits should have long shelf-life and demand in the off season. For example, apple, pear and grape are stored during glut and fetch good price in the off season sale. Other fruits like papaya and banana are produced almost round the year. Production of pineapple, pomegranate and few citrus fruits are also regulated for round the year production. It is available in some parts of the country round the year, and only transportation is required to feed where it is demanded. Sweet orange is not available during winter season (December to February), but there is no demand for this fruit during this period. Therefore, these fruits are not stored for off season sale. These fruits are stored occasionally to overcome glut period but not stored for off season sale. Mango harvesting season lasts very long (6–7 months) starting from March in South India (variety, Safeda) till August from North India (Variety, Chausa). Therefore, mango is also not stored for off season sale. However, storage of fruits is an integral part of fruit business whether it is for off season sale or for temporary storage just to overcome the glut phase.

Quality can't be improved by storage, but it can be maintained or rate of quality deterioration can be minimized up to a fixed period (Siddiqui and Dhua 2010). The cost

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_9

of fruits increases if it is stored. The handling charges (loading and unloading) and store charge per month is fixed per box for every cold storage. Therefore, the first requirement is only good quality fruits (storable quality) should be stored. The second important requirement is management of temperature and relative humidity in the store chamber. Fault in maintenance of temperature and humidity deteriorates quality.

There may be many objectives or goals of storage; here only few important goals are mentioned below.

- Regulate price fluctuation in the market on daily basis especially during peak harvesting season. More arrival reduces price in the market but purchasing for storage acts as a balance against price fall.
- More arrival create glut situation in the market and forces farmers for stress sale. Storage facility provides an option for storage and reduces the chances of distress sale.
- Storage makes perishable commodities available in the off season and thus extends the market period beyond the harvesting season.
- Since horticultural produce are perishable in nature, storage save these produce from being spoiled.
- Storage in season when cost of produce is relatively low and marketing in off season at a better price is a business and an employment opportunity for many farming and non-farming communities.

Development of Storage Systems

Like any other development, storage systems also developed from simple heap storage in the field to highly sophisticated controlled atmosphere storage system. This development happened step by step and one by one starting from simplest to sophisticate. All these storage systems are mentioned below.

Natural or Field Storage

All systems of on-farm storage are termed as *field storage or on-farm storage*. This is most simple and one of the earliest systems of storage and is still in use for many crops such as carrots, sweet potatoes, cassava, potatoes and onion. In J&K (India), store houses are built in apple orchard, and apple is stored after loose packing in wooden boxes. The house may be with or without exhaust fan. In case of fruits, tree storage is also possible only in limited crops (citrus, apple, etc.), but it is not a commercial practice till date in India.

Evaporative Cool chamber: Evaporative cool chamber works on the principle of evaporative cooling (Roy and Khurdiya 1986) and one of most important low cost storage system. The beauty of this chamber is that there is no power requirement to run this chamber for cooling fruits hence, the term Zero Energy Cool Chamber (ZECC) is used. These chambers are suitable for short storage periods only

(Fig. 9.1). Evaporation of water takes place by using heat from surroundings. This heat is used for converting water (liquid phase) into vapour (gaseous phase) which results cooling. These water vapours are then blown away by the unsaturated wind. Thus, the rate of cooling is directly proportional to the rate of evaporation of water. The rate of evaporation depends on temperature, wind velocity and relative humidity. The higher the temperature, the more would be the evaporation and cooling. Higher wind velocity or more aeration would cause more evaporation and more cooling. High relative humidity in air would cause less evaporation and less cooling and vice versa. That is why ZECC is not effective during rainy season and most effective during dry hot weather.

ZECC maintains low temperature ranging from 5 to 25 °C and depends upon the weather conditions (ambient temperature and relative humidity). This chamber is suitable for almost all fruits and vegetables except onion and garlic). An advanced stage of ZECC is commercial size cool chamber equipped with exhaust fan and wall structure is supported by cemented corners (Fig. 9.2). Four air inlet air ducts and one middle cavity are also provided for better air circulation. The cavity is filled with sand and kept wet by watering once or twice in a week. Running of exhaust fan is regulated by a timer and runs on a fixed period say 10 min on and 5 min off. Both cool chambers are developed by IARI, Pusa, New Delhi.

Fig. 9.1 Construction and operation of ZECC

Fig. 9.2 Commercial size cool chamber

Construction of Cool Chamber

The floor and wall of ZECC is constructed with bricks and river bed sand and cover with gunny bags or rice straw or khaskhas framed in bamboo sticks. The detail structure and dimension is described below.

(a) Floor—made of one layer of bricks.
(b) Walls—made of two layers of bricks with a cavity (7–8 cm wide). This cavity is filled with river bed sand. For storage capacity of 1 MT fruits, the length of the chamber may be 170–180 cm, breath may be 115–125 cm and height may be 68–72 cm. Length may be increased for higher capacity but breath and height should not be increased. It may decrease cooling effect.
(c) Cover—made of gunny bags/rice straw or khaskhas in bamboo frame.

Operation

After construction is over, whole structure is made wet by sprinkling of water. Fruits should be kept in plastic crates only. Other containers may attract fungal growth. During storage, two times watering is required daily, once in the morning and once in the evening. A drip system is also possible with the help of a water tank and perforated plastic tubes (Fig-04). Watering is required twice a day. CFB and wooden boxes are not suitable for storage in ZECC due to fungal and bacterial infection over the box. Maximum/minimum thermometer and wet and dry bulb thermometer are placed inside the chamber for recording temperature and relative humidity.

Ventilation for On-Farm Storage

The success of on-farm storage depends largely on ventilation. More ventilation results long storage period and less spoilage. Two types of ventilation are applied under field condition (a) Natural ventilation and (b) Forced air ventilation. The overhead structure of on-farm storage should be well ventilated. Produce is placed in bulk, bags, boxes, bins, pallets, etc. For effective natural ventilation, the following conditions are important.

(a) Night temperature should be very low.
(b) This system is useful for few crops that store well under natural conditions such as potatoes, onions, sweet potatoes, garlic, ash gourd and pumpkins. Apple is also stored in J&K in the orchard (on-farm).
(c) The overhead structure should have wide openings and adequate protection from animals and rodents.
(d) There should be adequate gap between the bags or boxes stored. This is necessary for air circulation and for removing heat, humid condition, and gases that

have accumulated as a result of respiration and water loss by the stored commodities.

(e) Within certain limits, it is possible to take advantage of natural changes in temperature and relative humidity by selectively opening and closing of storage ventilation. At noon, ambient temperature is very high, and relative humidity is low. However, at night the opposite condition is observed. To reduce the temperature of stored products, building's opening such as doors, windows and exhaust opening should be left open when external air temperature is low. External conditions constantly change, even during the same day. However, in comparison to air, stored mass is slower to gain and release heat.

Forced Air Ventilation

Forced air ventilation is very similar to natural ventilation except the provision of forced air circulation with the help of a fan. This system allows more efficient circulation of air and utilization of space for bulk storage. Air currents are forced through the produce. If stored materials are stacked carefully, there may be uniform distribution of air throughout the stored produce. A room can be used for storage with the facility of exhaust fan and wooden plates. Commercial size cool chamber developed by IARI, Pusa, New Delhi is based on forced air ventilation (Fig. 9.2).

Modern Storage Systems

Low Temperature Storage

Development of modern storage systems started with the invention of refrigeration. The main aim of refrigeration is to maintain low temperature, and it is one of the most important factors for extending post-harvest life of fresh produce. Low temperatures slow down product metabolism and the activity of microorganisms is responsible for quality deterioration. As a result, food reserves are maintained for longer period with a lower respiration rate, ripening is retarded and vapour pressure between products and ambient is minimized thereby reducing water loss. A refrigerated room is a relatively airtight and thermally insulated environment called *cold storage*. Therefore, cold storage is a special kind of room or chamber, the temperature of, which is kept very low as required with the help of machines.

The cold storage facilities are the prime infrastructural component for such perishable commodities. Besides the role of stabilizing market prices and even distribution of fruits and vegetables on demand and time basis, the cold storage industry adds advantages and benefits to both the farmers and the consumers. The farmers get opportunity of producing cash crops to get remunerative prices. The consumers get the supply of perishable commodities with lower fluctuation of prices.

Commercially, apples, pears, potatoes, oranges and chillies are stored on large scale in the cold storages. Other important fruits like grapes, kiwi, capsicum, broccoli and dry fruits, costly raw materials like chemicals and essences, and processed foods like fruit juice/pulp, concentrated dairy products, frozen meat, fish and eggs are being stored in cold storages to regulate marketing supply channels of these products.

Refrigeration capacity of the equipment should be adequate to extract the heat generated by crops with a high respiration rate. It is also important to control precisely the temperature and relative humidity conditions inside the refrigerated storage environment. The dimensions of the refrigerated room depend on the maximum storage volume needed. Other factors to be considered include walkways and aisles to handle the product mechanically and the additional space necessary to ensure uniform distribution of cold air. One loading and unloading dock and packaging floor space is among the urgent facilities a cold storage should have. Chamber height depends on product and stacking pattern. A chamber height of 3–4 m is sufficient for stacking but more than 6 m may be required if forklifts are utilized for stacking.

Refrigerated rooms can be made with concrete, metal, PUF or other materials. All external surfaces should be thermally insulated, including the floor and ceilings. Type and thickness of insulation material depend on building characteristics, produce to be stored and the difference in temperature required between external and internal conditions. Polyurethane expanded polystyrene, cork and other such materials can be used as insulation materials. A vapour barrier should be placed on the warm side of the insulation material. A modern cold chamber and cold storage are shown in Fig. 9.3.

Refrigeration is the process of removing heat from the room or an enclosed surface or stored commodities. The basic concept of any refrigeration unit is to lower the temperature of the room and commodity to a desired level and maintain it for a specified period.

Fig. 9.3 Cold chamber and cold storage

Refrigeration Cycle

This is a process of evaporation of refrigerant at a low pressure and low temperature followed by compression and condensation at high temperature and high pressure is called Refrigeration Cycle. This cycle is completed with the help of four main components: the evaporator, expansion valve, condenser and compressor (Fig. 9.4).

In evaporator, the pressure is kept very low so that evaporation of the refrigerant liquid to gas occurs at low temperature. This low temperature is fixed according to the stored commodities. For example, if apple is stored, the low temperature is fixed between 1 and 3 °C, but for mango it is 10–12 °C. The low temperature and their corresponding low pressure vary from refrigerant to refrigerant. For example, if low temperature is fixed at −18 °C in a cold storage where ammonia is used as refrigerant, then the corresponding pressure would be 229 kPa. This means ammonia will evaporate at this pressure in order to keep the room temperature at −18 °C. However, another refrigerant tetrafluoroethane also called 134a will evaporate at 144 kPa to maintain the same temperature, i.e. −18 °C. Liquid refrigerant absorbs heat from the product and surrounding spaces that results evaporation of liquid into vapour phase. It takes place in the evaporators inside the cooling room and necessary low pressure is maintained by the suction of compressor. Now, the vapour phase of refrigerant is sucked by the compressor and compressed under very high pressure. The high pressure may be 1150 kPa for ammonia and 772 kPa for *tetrafluoroethane*. Now, this compressed air is released to condenser, where it is cooled either by water or air based on cooling systems. This cool refrigerant is again pushed into evaporators by expansion valve. This valve controls the amount of refrigerant to be pumped into the evaporators. Now, the heat absorbed by the refrigerant in evaporators inside the cooling room is transferred to air or water in condenser outside the room, and this cycle is repeated again and again. The condenser is *called heat exchanger* and cooled either by water or air.

Refrigeration can reduce or completely stop the growth of certain pathogen and spoilage microorganisms but will not eliminate them. It is generally recognized that maintaining food at 5 °C is sufficient to prevent the growth of most common food-borne pathogens. However, some psychotropic pathogens such as *Listeria*

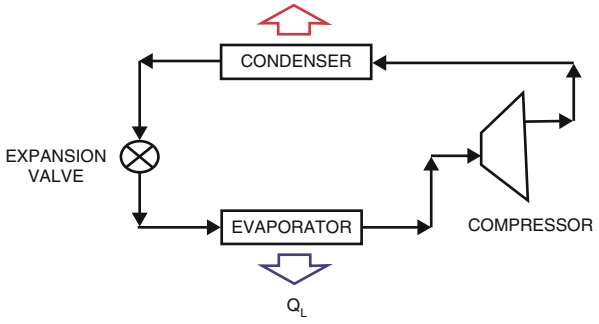

Fig. 9.4 Refrigeration cycle

monocytogenes, *Clostridium Botulinum*, and *E. coli* are able to multiply slowly in refrigerated foods. In the conventional refrigeration storage environment, three important factors must be controlled: temperature, relative humidity and air movement.

Temperature: The system should always be able to meet the demands placed upon it and controlled automatically by the use of thermocouples, pressure valves, etc.

Relative humidity (RH) should be kept high in a refrigerated storage room by controlling the refrigerant temperature. In many modern cold storage, a humidifier is also fitted to create and maintain required humidity. High RH prevents water loss that affects texture, freshness, colour appearance and overall quality of fresh produce.

Air movement in the refrigeration environment must be sufficient to remove respiration heat, gases and the heat penetrating through the door, junctions and structure of the refrigeration room. However, excessive air movement can cause food dehydration. Air circulation must be uniform throughout the room. Packages must be correctly stacked to achieve good air circulation. Optimum temperatures, RH levels, and expected shelf-life of stored horticultural products are described in Table 9.1.

Table 9.1 Important fruits and optimum temperature and relative humidity for storage

S. no.	Crop	Optimum temperature (°C)	Relative humidity (%)	Remarks
1	Apple	1–4	90–95	Small fruits keep better than larger ones
2	Apricot	−0.5 to 0	90–95	
3	Asian pear	1	90–95	Small fruits keep better than larger ones
4	Avocado	3–13	85–90	
5	Banana	13–15	90–95	Below this temperature, chilling injury occurs
6	Cashew apple	0–2	85–90	
7	Cherimoya	13	90–95	
8	Cherries	−1 to 0.5	90–95	
9	Coconut	0	80–85	
10	Custard apple	5–7	85–90	
11	Dates	−18 to 0	75	
12	Fig	−0.5 to 0	85–90	
13	Grape	−0.5 to 0	90–95	
14	Grapefruit	10–15	85–90	
15	Green onions	0	95–100	
16	Guava	5–10	90	
17	Jack fruit	13	85–90	

(continued)

Table 9.1 (continued)

S. no.	Crop	Optimum temperature (°C)	Relative humidity (%)	Remarks
18	kiwifruit	−0.5 to 0	90–95	
19	Lemon	10–13	85–90	Lemon for storage should be picked at the greenish yellow colour
20	Lime	9–10	85–90	
21	Longan	1–2	90–95	
22	Loquat	0	90	
23	Lychee	1–2	90–95	
24	Mandarin	4–7	90–95	Rotting due to fungal is not checked
25	Mango	13	90–95	
26	Mangosteen	13	85–90	
27	Melon (Others)	7–10	90–95	
28	Nectarine	−0.5 to 0	90–95	
29	Olives, fresh	5–10	85–90	
30	Orange	0–9	85–90	
31	Papaya	7–13	85–90	
32	Passion fruit	7–10	85–90	
33	Peach	−0.5 to 0	90–95	
34	Pear	−1.5 to 0.5	90–95	
35	Persimmon	−1	90	
36	Pineapple	7–13	85–90	
37	Plum	−0.5 to 0	90–95	
38	Pomegranate	5	90–95	
39	Prickly pear	2–4	90–95	
40	Quince	−0.5 to 0	90	
41	Rambutan	10–12	90–95	
42	Raspberries	−0.5 to 0	90–95	
43	Sapodilla	15–20	85–90	
44	Strawberry	0–0.5	90–95	
45	Tamarind	7	90–95	
46	Tart cherries	0	90–95	
47	Watermelon	10–15	90	

Source: Cantwell (1999), Sargent et al. (2000), McGregor (1987)

Controlled Atmosphere Storage

Controlled atmosphere (CA) storage is found the most successful storage system for pome fruits and especially for apple and pear. This system brought revolution in apple and pear fruits business globally. In normal cold storage, apple can be stored for 2–3 months comfortably, but it is impossible to keep fruits juicy at the end of 3

months. It is noticed in general in all developing countries and particularly in India that after 3 months storage in cold store, apple turns yellow (40–100 %) and becomes less juicy or loses all juice that results in mealy texture. There is no crunchy feeling upon biting the 2–3-month-old stored apple in normal cold storage. On the other hand, in CA storage, no yellow colour development takes place, juice level in the fruits is maintained and same crunchy feeling is experienced even after 5–6 months storage of apple (Apple firmness above 15 lb).

In India, CA storage technology gaining popularity and one of the corporate groups, Adani group established CA facility of 18,000 MT in Himachal Pradesh, a leading apple producing state of India. Six other companies have also set up CA stores in India for apples (Himachal Pradesh and Jammu and Kashmir) with a total capacity of approximately 40,000 MT and more units will come up in near future. Government agencies such as Container Corporation of India (CONCOR) have also established a CA facility at Kundli, Haryana, India. These companies buy apple in the season, store in CA condition and sale in off season and this has tremendously benefited the farmers, customers and companies. The total apple production of India is about 20 lakh MT (NHB-2013). India needs about 8–10 lakh MT CA storage capacity by 2015. In developed countries, the storage period of apples can be increased up to 8–9 months by the use of CA storage.

Controlled atmosphere storage generally refers to storing fruit in atmospheres containing low O_2 (1–3 %) and high CO_2 (1–3 %) levels as compared to atmospheric conditions. The main principle of CA storage is to increase the concentration of CO_2 and reduce the concentration of O_2 in a leak-proof storage chamber. CA storages are generally multiple chambers with each chamber of capacity 50–250 MT. However, it is suggested that CA storage of small chambers, up to 45–50 MT is more suitable on commercial scale. It is because small chambers take less time to loading and establishment of CA condition. In CA stores, produce is stored in large bins (250–300 kg) which are stackable up to 11–12 bins high (total chamber height up to 10–11 m or more) or in PVC crates which can be stacked in mild steel pallet frames up to 4 levels high or only crates height of 12–15' (chamber height up to 4–5 m or more). Storage in CFB box may also be resorted for short duration storage of fruits like strawberry but not recommended.

The refrigeration system is designed to maintain temperature of 1–2 °C with humidity of 90–95 % RH. Recommended levels of O_2 and/or CO_2 are automatically regulated after CA is established. In spite of cost implication, automatic regulation levels of O_2 and/or CO_2 are recommended to minimize possibility of storage disorders in stored products. Before putting CA condition, the chamber is checked for any leakage. To find out any leakage in the chamber, a simple test called pressure test is done. It is a proven fact that increased concentration of CO_2 and reduced concentration of O_2 reduce the rate of respiration and ethylene production. This condition also inhibits the action of ethylene, and hence ripening process is reduced drastically. The season of availability of fruits could be extended to a certain period through controlled atmosphere storage without affecting the eating quality.

Many workers established the fact that modification of storage atmosphere can extend storage life fruits by maintaining apple quality (Kidd and West 1932; Kidd

and West 1936). At present, the use of CA storage for the commercial storage of apples and pear has become common practice. Tolerance to CA conditions also varies between apple cultivars. The recommended atmosphere for the storage of "Royal and Red Delicious" apples in H.P. and Reefer container and Kullu Delicious in J&K is a minimum concentration of 1.5 % $O_2 \pm 0.5$ % and a maximum concentration of 1.4 % $CO_2 \pm 0.5$ % at 1.5 °C for 6–8 months. The recommended atmosphere for the storage of "Cripps Pink" apples is 1.5 % O_2 and 1 % CO_2 concentration, respectively, at 0.5 °C for 8 months (Hurndall and Fourie 2003).

After starting chamber, filling and the time taken to establish the atmospheric conditions are critical for the success of maintaining apple quality throughout the storage period. Prior to the mid-1970s, 8–10 days were often required to load a CA room, and a further 15–20 days were required to establish the atmosphere (Little and Holmes 2000; Watkins et al. 2002). This was due to the fact that the establishment of the atmosphere concentration is dependent wholly on fruits' own respiration to reduce the concentration of O_2 and increase the concentration of CO_2. This delay before establishment of CA condition is often resulted in poor quality fruit at the time of opening. However, rapid CA has since been developed and has now become standard practice. Rapid CA establishment is totally based on nitrogen flushing by nitrogen generator to reduce the level of oxygen below 5 %, which can be achieved in a shorter time frame (Watkins et al. 2002). Nitrogen generator uses multiple filter systems, sieves out O_2 and allows N_2 only. It is observed that within 24 h, the desired level of O_2 concentration may be achieved. The delay in the establishment of CA conditions meant that often fruit would have begun to ripen before the CA conditions were established. Once ripening has been initiated, the process cannot be stopped. The rapid establishment of CA conditions ensures that ripening has not been initiated. However, it is also important that the fruit is harvested at the correct maturity stage for optimal long-term storage. An established CA should be maintained at 1.4 % $CO_2 \pm 0.5$ %, 1.5 % $O_2 \pm 0.5$ % and 97.1 ± 0.5 % N_2 at 1.5 °C for Delicious group apple grown in India.

Storage temperature: Refrigerated storage at 0 °C can extend the storage life of apples by up to 6 months in some apple cultivars (Little and Holmes 2000; Watkins et al. 2002). One of the effects of reduced temperature is reduction in the respiration rate of the fruits and suppression of the respiratory climacteric, both prolong the life of the fruit (Little and Holmes 2000; Watkins 2003). Refrigerated storage can also slow down the onset of ethylene production in apples (Watkins 2003). By delaying the production of ethylene, the processes of ripening are delayed, as a result shelf-life of fresh produce increases. However, the tolerance to low temperature during storage is cultivar specific and varies from one cultivar to another. Few cultivars like "McIntosh" is highly susceptible to chilling injury at 0 °C and require storage at a higher temperature, between 2 and 4 °C (Little and Holmes 2000; Watkins 2003). Other cultivars such as "Granny Smith" and "Delicious group" are less susceptible to chilling injury (CI) at this temperature and can be successfully stored at 0 °C (Little and Holmes 2000; Watkins et al. 2002). Different components such as inside view of CA storage, N_2 generator, CO_2 scrubber and plastic bins are shown in Fig. 9.5.

Fig. 9.5 CA storage, N_2 generator, CO_2 scrubber, plastic bins

Determination of Storage Quality of Apples

Determination of storage quality is the key factor for successful storage of apple. Maturity at harvest is the most important quality attribute that must be judged before storage. On commercial scale, maturity standards of apple are judged by two methods.

Firmness

1. *By Pressure Tester or Penetrometer*: This is the most common destructive method of quality analysis followed by corporate back end companies and organized retail sectors in India. Number of fruits taken from each lot varies and depends upon lot size. In general, three apples are taken from a lot size of 10–50 crates. When lot size increases above 50 up to 100, six apples from different crates and if lot size increases above 100 crates or boxes, nine apples are taken from different crates as sample for destructive quality analysis. Samples are taken randomly from upper, middle and lower crates of the lot. Fruit firmness is measured with the help of pressure tester. Scientifically a pressure above 16 lb in Indian apple is good for storage. Adani Agrifresh Ltd., Fresh and Healthy Enterprise, Field Fresh and other direct sourcing companies never accept a lot whose pressure is less than 16 lb for storage in controlled atmosphere storage. If lots are accepted below 16 lb, then these lots are stored in a separate chamber and marked as low pressure chamber and sold after 1 month storage only. A pressure level of 14–15 is acceptable for immediate marketing but below 12 is unacceptable because fruits will get pressure marks during loading, unloading and transit. These low pressure fruits get pressed during transit and will start rotting within 2–3 days and buyers never accept such lots. Effigy fruit pressure tester (Model FT 327) is the most common pressure tester used by apple direct sourcing companies. The stepwise procedure for measuring fruit firmness has been described in Chap. 13.

   Flesh firmness (FF) is the most important quality measurement of apples that has been used to determine optimal storage maturity by private companies. But it varies among the cultivars (Watkins 2003). In Himachal Pradesh, Red and Royal Delicious are two most firm cultivars while Golden Delicious is the least.

While in J&K, Kullu Delicious and Delicion are two firm cultivars. Flesh firmness has successfully been used to measure the harvest maturity of "Delicious" apples. Similarly to TSS, FF is a useful measure of consumer acceptance of apples as textural qualities of apples are often reported by consumers to be among the top requirements for acceptability (Harker et al. 2003). Fruit firmness is directly related to consumer's acceptance and storage quality. It is important for edible quality, post-harvest handling and market value of apples (De-Ell et al. 2001). Fruit firmness, also depends on total soluble solids (TSS) contents as well as the texture of apple fruit (Weibel et al. 2004; Peck et al. 2006). Thus, the loss of fruit firmness before storage and during storage is a serious concern as it results in quality losses (Kov et al. 2005) leading to soft and mealy fruit and hence less consumers' acceptance. Fruits having pressure less than 14 are not suitable for storage. The fruit firmness varied significantly with cultivars.

2. *Maturity Standards by Experience*: The people involved in apple business, they recognize maturity standards by colour, size and firmness. They judge firmness by pressing their thumb on apple. On the basis of their experience, they have identified apple areas possess high pressure and hence suitable for storage. For example, Chango, a place in Kinnaur district and Ramnagri in J&K are very firm and people know this fact and hence prefer for storage.

By Starch Iodine Test

This is another reliable test extensively used by corporate sectors for storage of apple in CA chambers. Both the above tests are carried out side by side and only one apple is used for both the tests. After finishing pressure test, the fruit is cut in the middle, and pedicel end is immersed in the solution kept in a Petri dish and left for 1–2 min for colour development. As soon as the colour develops, it is compared with the colour chart. A reading of 2.5 is ideal for CA storage. The same reading is also ideal for cold storage. A little fluctuation is also considered. If reading is more towards colour scale 3, this can also be stored but as low pressure stock and its early (better 1 month storage) removal from the store is compulsory. A reading beyond 3 is not advisable to put in cold or CA store and should be sent immediately to market without any further delay. Stepwise procedure is described in Chap. 13.

Apple growers and traders never use this test either for maturity determination or for storage purpose. Only private firms in India using this test for storage purpose and their officers regularly visit growers' field with quality checking kits that include penetrometer and reagents for starch iodine test. The development of colour is shown in Fig. 9.6 and their description is listed in Table 9.2.

Total Soluble Solids

TSS are a quality component of apples that have also been used to measure fruit maturity and quality. However, this method is not applied on commercial scale. TSS are a measure of the soluble compounds (such as carbohydrates, salts and acids) in the

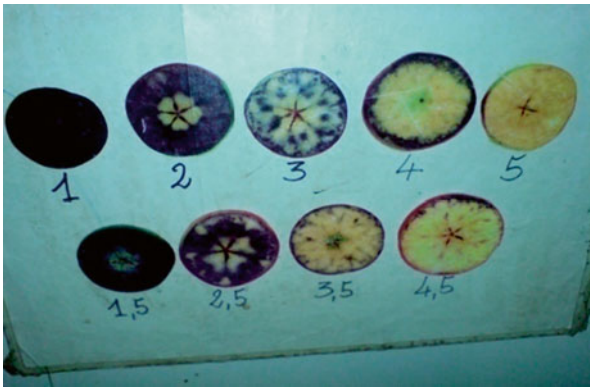

Fig. 9.6 Starch iodine test chart

Table 9.2 Description of developed colour in response to iodine dip

Colour value	Description	Remarks
1.0	*Immature*, *should not be harvested*	
1.5	This is borderline stage between immature to mature. Check other harvesting parameters at this stage like seed colour (should turn black)	Fruit should not be harvested
2.0	Perfect mature stage, ideally suitable for both CA and normal cold store	Indian apple (Red and Royal Delicious) is ready to harvest at this stage for storage in CA storage
2.5	This is also ideal, suitable for CA and normal storage. Therefore, range 2–2.5 on 1–5 scale is suitable for CA storage. This criteria is for Indian apples	Ideal for both CA and normal cold storage
3.0	An advance stage of over maturity should not be stored but only temporary storage for 1–2 months	Fresh sale is recommended. If stored, the chamber should be marked as low starch or low pressure
3.5	At this stage, senescence starts, fruits become very soft and juice begin to dry	Immediate sale in nearby cities or market is preferred
4.0	*Senescence continued*, mealy texture with no or little juice	Less commercial value, immediate sale as fresh or processor
4.5	Advance stage of senescence, mealy texture, little pressure, not juicy at all	This stage is ideal for immediate marketing or processor
5.0	*Last stage of* senescence before spoilage	Not liked by consumers, better process into jam

cell which increases during ripening, primarily from the conversion of starch into sugar (Watkins 2003). During apple maturation, sugars become the primary component of the soluble solids and consequently the TSS gives a measurement of the sweetness of the fruit. Because of this, TSS is often used as a quality component and a minimum TSS is often required for export markets. However, the concentration of acids and the ratio of TSS to acid is also an important aspect of the perception of flavour.

Factors Affecting the Quality of Fruits or Vegetables Stored in CA Storage

1. *Rapid Cooling*—Rapid cooling of fruits after chamber filling is one of the most important criteria to maintain quality in CA storage. For example, fruits should be cooled as quickly as possible after chamber filling. Cooling with forced cold air is the best method of cooling for fruits like apple and pear. Apples or pears are not injured by rapid cooling. If adequate refrigeration and air circulation are not provided, fruits may take several days to cool and thereby quality is not maintained during CA storage. The main aim of rapid cooling is to bring the temperature at 1–2 °C within 48 h. Rapid cooling is also important to reduce water loss from the produce. The main advantage of chamber cooling after loading is that the produce can be cooled and stored in the same room without the need of transfer from pre-cooling chamber to storage chamber. In order to achieve rapid cooling, the rooms need to be properly designed with adequate refrigeration, air circulation and most importantly proper stacking of bins/storage arrangement. It also saves labour cost of shifting from one room (pre-cooling room) to another room (storage room).
2. *Quick transportation to CA Site*. After harvesting, fruits intended for storage should be transported quickly to CA storage site. Delay loading into chamber causes quality deterioration and CA storage cannot improve the quality. It is found that a delay of 1 day at 21 °C after harvest takes 7–10 days off the potential storage life at 0 °C. A delay of 3 days in the orchard or in a warm packing shed may shorten their storage life as much as by 30 days, even if they are subsequently stored in CA at 1 °C. Therefore, quick transport and chamber filling are essential for quality preservation during CA storage.
3. *Quality of produce—CA storage never improves the quality of stored fruits, but it maintains the quality*. The quality of fruits in CA storage largely depends on the initial fruit quality or the quality of produce at the time of harvest in terms of maturity and free from disease and disorders. For example, apples, which are widely stored in controlled atmosphere condition all over the world and also gaining popularity in India should be harvested when mature and firm but not overripe. The fruits should be free from diseases, insect pest infestation and physiological disorders. It is necessary for maximum storage life in CA storage and also at ambient condition. Immature, overripped, diseased, defects and disorders fruits are not suitable for CA storage. Immature apple, pear and other fruits have poor eating quality and likely to shrivel during storage and overripe fruits may get chilling and CO_2 injury in CA storage. These fruits are also more susceptible to storage disorders and market value reduced drastically. The cost of storage, handling charges and cost of fruits are difficult to recover. Therefore, only good keeping quality fruits at the right stage of maturity should be stored and also must be handled carefully during all operations including picking, sorting, grading, filling and loading into the chamber. The main cause of rotting of fruits in the storage is rough handling starting from harvesting to chamber filling. The quality parameter varies among fruits. For example, apple quality parameters are firmness of apple and starch content as discussed.

Storage Life in CA Store

The storage life of apples in CA storage is influenced by many factors including cultural practices, fruit maturity when picked, delays before cold storage, storage temperature and the presence of other fruits or vegetables in the storage chamber. Some varieties are susceptible to storage diseases and disorders and therefore have a short storage life. Orchard cultural practices and climate influence storage life drastically. The absence of an ideal soil conditions influence the composition of apples and thus their storage life. Cloudy and rainy growing seasons result in a shorter life and susceptible to disease and pest attack. Fruit size and handling procedures also influence storage life. Large, over-sized fruit have a shorter storage life than medium and small ones. Rough handling shortens the expected storage period.

(a) *Storage Conditions*: For a successful CA storage, atmospheric conditions, temperature and relative humidity must be defined in terms of critical storage conditions. Other facilities like ethylene and carbon dioxide scrubber, air circulation, humidifier, etc. should be well maintained.
(b) *Temperature*: The temperature in the CA storage facility should be kept close to $+1 \pm 0.5$ °C for apple and other pome fruits. The recommended temperature may vary for different commodities. For storing at temperatures close to freezing point of the commodity, for increasing storage life, even a narrow range may be needed. The freezing point of apples varies considerably, but most types will not freeze until the flesh is below 29 °F (−1.7 °C). Freezing discolours the surface and browning can occur internally. To prevent unnecessary injury, apples should not be handled while frozen.
(c) *Humidity*: Maintaining the proper relative humidity around stored apples is very important. Apples have approximately 84 % moisture at the time of harvest, and to maintain this water content and prevent shriveling of the skin, the storage relative humidity should be 90 % or higher. With good air circulation, a higher relative humidity (95–98 %) may be maintained without fungal infection. The relative humidity (RH) in a long-term CA store facility should be kept at 90–95 %. The refrigeration system must be specially designed for maintaining high RH. Many CA chambers are fitted with humidifiers or water sprayed on the surface of each chambers. Less humidity or uncontrolled humidity levels may cause the growth of microorganism and storage disorders like surface cracking. Although higher humidity levels of 85–90 % can also be achieved by keeping low delta T in the cooling coil. But during loading periods and for RH > 90 %, humidification system is used. Several techniques are available, but it should preferably be done using water mist with 2–10 μm and uniformly distributed all over the chamber ensuring that the product does not get wet.
(d) *Loading Rate*: To achieve good storage quality, the room should be small enough to be filled in 3 days or sooner with adequate refrigeration capacity and air circulation. As a guiding principle, loading rates may vary from 3 to 5 % of the total cold store capacity, and it is critical to sizing the chamber capacity of the controlled atmosphere store.

(e) *Air Circulation*: CA cold store should be designed to provide an air flow of 165 cmh per MT of product, based on maximum amount of produce that can be stored in each chamber. This is essential for rapid cooling of the produce. However, the system should be designed to reduce air flow after the produce has reached the needed storage temperature. This is achieved by variable frequency drive and control system. It is also recommended that once the desired temperature is reached, air flow should be reduced automatically. Therefore, optimizing fan speed and operating time results in tremendous saving in electricity cost also.

(f) *Stacking*: Stacking means arranging bins or crates in the chamber during chamber loading prior to closing. Bins should be stacked in such a manner that the moving cold air can contact all the container surfaces for adequate and rapid cooling. Well-ventilated bins/crates should be used as ventilation facilitates air movement through the stored produce and speed-up the cooling rate by allowing the air to uniformly flow and cool. It is recommended that the bins/pallets must be stacked to form air channels 4–6 in. wide to direct air movement. It is also recommended that there should be adequate space between the bins/crates row and walls to allow refrigerated air to move through the sides of wall. Since, air takes the path of least resistant, in proper stacking of bins, blocks are provided in the main air channels. Chambers should not be partly filled as it may result in poor air distribution that could affect the cooling rate. CFB cartoons are not recommended for storage in CA stores; however, there are reports of storing fruits and vegetables in CFB cartons too but not recommended for long-term storage. The CA storage stacking arrangement should be well designed to move the air uniformly through the stored produce. It is therefore recommended that CA store chamber/facility is designed for storage in bins/PVC crates. Loaded bins should be handled with fork lift. Generally, the PVC bins available in the country are of 300 kg capacity each of size $1200 \times 1000 \times 780$ mm which can be stacked up to the height of 9 bins.

(g) *Lowering the Oxygen Concentration*: An airtight door is sealed either by grease or sealant. Airtight CA room has been filled with fruits. Prior to filling the chamber, pressure test is carried out in order to test the airtight condition of the chamber. A pressure ranging from 10 to 20 mm is applied and pressure drop is recorded after every 5 min till 20 min. A positive pressure at the end gives good result. Pressure should not be zero after 20 min. The oxygen in the room is lowered to the desired concentration generally by flushing the room with nitrogen gas from an external tank or from an air separator called nitrogen generator, which blocks all gases except nitrogen. It is a well established fact that the more quickly the low oxygen atmosphere is attained after chamber filling and cooling, the better will be the condition of the CA apples after storage. Rarely, oxygen is lowered by fruit respiration as it results in poor quality at the end of storage.

(h) *Maintaining the Desired Gas Concentrations*: The desired oxygen concentration is maintained by adding little air to the CA room each day, if the atmosphere is analysed manually, or several times each day if the atmosphere is automatically analysed and controlled by a computer and sensor connections.

Excess carbon dioxide is removed from the atmosphere by chemical reaction with lime, adsorption onto activated carbon, permeation through silicone elastomer or hollow fibre membranes, or by slow flushing of the CA room with nitrogen gas. Removal of ethylene gas from the storage atmosphere by chemisorption or by catalytic oxidation has found limited commercial application for firmness retention of Empire apples and control of storage scald on Bramley's Seedling apples.

(i) *Lighting Condition*: Light is not a major requirement.

General Consideration of Running a Controlled Atmosphere Storage

Before the start of the season all the chambers shall be tested for leakage and cleaned. Fumigation shall be carried out in the presence of quality in charge and record for same shall be maintained for future use and recommendation.

Arrival at Site

1. Allocation of consignment number/Gate in number
   Responsibility: Gate keeper or security in charge

   - The vehicle with apple crates reaching the gate shall be allotted Gate In or consignment number by the security person/gate keeper.
   - The security person shall direct the vehicle to the unloading dock or to the shaded parking area as per his consignment number and or grading speed/ unloading speed.

2. Quality Checking and Unloading Operations at Dock:

   - Responsibility: Quality In Charge or Shift In Charge or Unloading Assistant or Quality Assistant or Lab Assistant or any assigned person.
   - Lab assistant helper shall collect the samples randomly from the crates in the vehicle at the unloading dock for destructive analysis as per the sample plan (Annexure I).
   - The sampling should be done from the crates located at top front, middle and back of the vehicle. Fruits of small, medium and large size shall be drawn for assessing various internal defects and destructive quality parameters in the laboratory/designated area.
   - The average fruit firmness and Starch Iodine test or Starch Pattern Index (SPI) values for acceptance should be in accordance with specifications (Annexure II).
   - The data of destructive analysis shall be recorded (Annexure III).
   - Destructive Analysis Report, Information slip and Consignment Note shall be sent to Quality Assistant at the Unloading dock by the Lab boy or helper for

confirmation to Unloading Assistant. Based on the acceptance or rejection, unloading assistant will act.

- Material not confirming the specifications (for pressure and SPI) shall be treated as rejected and Data Operator will issue outward gate pass for the same.
- However, this rejected material may be accepted for Fresh Sale (FS) based on the consent of grower. If grower agrees on the terms and conditions, this material shall be necessarily packed and despatched for seasonal sale or fresh sale.
- Information slip for accepting the consignment shall be communicated to Unloading Assistant for systematic unloading of the lot with proper identification of all lots at the floor.
- The accepted material (for pressure and SPI) is unloaded from vehicle and sample for external defect analysis shall be drawn as per the sample plan.
- Quality check report along with Consignment Note shall be handed over to Data Operator for Quality Data Entry.
- The Data Operator shall create a vendor number with father's name of grower, no. of crates, place or area of grower, etc.
- Material not confirming the specifications for external defects shall be treated as rejected and Data Operator will issue outward gate pass for the same.
- However, this rejected material may be accepted as Rejection on Arrival (ROA) on consent of grower and Business Head and handled as per ROA procedure of the company.
- Sometimes, ROA Consignments may be accepted on recommendations of Business Head. If accepted, material shall be sorted on Greefa Machine at very slow speed and more number of people should stand at quality selection belt to ensure that all defected apples must be removed as Rejection on Line (ROL). Quality report of deviated consignment shall be generated (Annexure IV).
- Quality In Charge shall audit the external defect analysis on unloading dock. Two consignments in shift shall be audited from already accepted material at 6 h interval (Annexure V).

Pre-sorting Operations

Responsibility: Quality In Charge, Shift In Charge, Greefa Pre-sorting Machine Operator.

- Quality In Charge will initiate the calibration process with a team comprising Pre-sorting Machine In Charge, Procurement In Charge, Sales Team Member and validated by Terminal Manager for calibrating the machine for colour and size. This shall be recorded in Annexure VI.
- However during daily operations, in case of any deviation of sorting (mixing of colour and size), Machine Operator will stop the machine immediately and rectify the same with the help of site engineer. The pre-calibrated colour and size values shall be used for further sorting operation.

- In case of major machine breakdown or product change, the colour and size parameters shall be revalidated as per procedure mentioned above (Annexure VI).
- Greefa Pre-sorting Machine maintenance and cleaning shall be done as per cleaning and maintenance SOP by Pre-sorting Machine In Charge for smooth grading operations. Quality In Charge shall monitor the cleaning on weekly basis and record the same (Annexure VII).
- Zero Weight value without apple, colour and size of Greefa Pre-sorting Machine shall be verified daily by Quality In Charge (Annexure VII).
- Shift In Charge shall ensure that Information slip reaches the Machine Operator for entry of Name, Consignment Number and Number of crates in the Pre-sorting Machine before running the consignment for Pre-sorting.
- Shift In Charge shall ensure that different consignments of growers do not get mixed.
- The manpower on quality selection belt and speed of the machine should be adjusted in such a way that ROL material is completely sorted out.
- The speed of machine should be optimum to avoid any size and colour mixing in bins.
- While running small-sized material on the machine, the speed shall be kept slow to avoid crowding of apple on singulator and cups and dropping below the brushes on the floor.
- Empty crates with bubble sheets shall be placed below the brushes to avoid apple damage, falling on the floor. At the end of each shift, the crates shall be emptied and the material shall be used for fresh sale.
- After Pre-sorting, the report generated from the Pre-sorting Machine along with Information slip and ROL Slip containing ROL weight shall be sent for PRN Generation.
- PRN shall be generated in duplicate. One copy will be given to the grower and other will be sent to accounts for payment.
- After each shift, information regarding total lots and total material run on machine and ROL generated shall be recorded in Annexure VIII.
- Shift In Charge shall ensure proper bin filling for smooth operation without quality issues related to apple cutting by bin filler head. However, outlay may be changed depending on different grades received at time considering the maximum bin filling speed of 6 bins/h.

Quality Verification in Bins

Responsibility: Quality In Charge, Shift In Charge

- During Pre-sorting, Shift In Charge shall ensure proper manpower and speed of the machine so that no ROL material goes into the premium quality material bins.
- Quality In Charge in his working shift at every hour interval will check a premium grade bin filler and collect randomly 40 samples of apples. These samples will be inspected for major and minor defects. If major defects in the bin are ≥2.5 % and/or minor defects ≥10 %, Quality In Charge will immediately point

this out to the Shift In Charge and workers at quality selection belt who in turn will ensure that the material shall be sorted out and does not go into the bins.
- Quality In Charge will check randomly 40 pieces of apple from 5 bins of the preceding shift to check for major and minor defects.
- Monitoring report for both hourly bin audit and preceding bin audit shall be prepared. The data recorded is to be entered in SAP.

Chamber Filling

Responsibility: Shift In Charge, Quality In Charge, Refrigeration In Charge, Fork Lift Operator

- Bin should be checked visually for filling. If the bins are not properly filled, addition or removal of Apple shall be done.
- CA Quality bins shall be stored in CA rooms. SKUs which are termed as CA quality are of sizes L/M/S/ES of more than 80 % colour and 55–80 % colour.
- All other SKUs like EEL/EL/EES of above 80 % colour and 55–80 % colour and all sizes EEL/EL/L/M/S/ES/EES of less than 55 % colour are termed as Non-CA quality. These bins shall not be stored in CA rooms generally; however, they may be stored in business interest and only after getting approval from competent authority.
- EL/EEL size SKU of Non-CA quality material for all colours shall be stored for short-term storage, i.e. max up to 3 months.
- Non-CA quality, which is not stored in CA rooms, shall be packed as per packing quality specifications and sent to market.
- Shift In Charge is to ensure that filled bins for CA from bin filler are sent for storage immediately.
- However for Kinnaur apples, dip treatment shall be followed (Annexure IX).
- The temperature of the chamber shall be maintained at 2 °C.
- The bins of 80–100 % colour material shall be stored in different chamber and 55–80 % colour produce in other chambers.
- Bin loading pattern at room shall ensure maximum filling quantity in one room per day to 40 MT of apple (Maximum 145 bins).
- Stack plan of each filled chamber shall be prepared and circulated to all concerned.

CA Condition Setup

Responsibility: Instrumentation/CA In Charge, Quality In Charge, Refrigeration In Charge

- After the chamber has been filled, the door shall be closed and all the locks shall be tightened.
- Bring the temperature of the chamber to 2 °C.

- After lowering the temperature to 2 °C, the sides of the doors shall be sealed using silicon sealant.
- Fill the chamber with water.
- Start pull down of the chamber using nitrogen generator and bring the oxygen level to 3 %.
- CA conditions shall be established as per Annexure X.
- CA condition setup record shall be maintained by Instrumentation In Charge as Annexure XI and verified by Quality In Charge.

Rejection on Line and Fresh Sale Handling

Responsibility: Shift In Charge

- The ROL and FS material shall be packed as per the packing quality specifications and sent to market. However, this material may be stored in business interest and only after getting approval from Business Head.
- In that case, FS/ROL material for all colours shall be stored for short-term storage in CA rooms, i.e. max up to 3 months.

Rejection on Arrival Handling

Responsibility: Quality In Charge, Shift In Charge

- Maximum external defect for ROA accepted shall be 20 %.
- The consignment will be immediately sent for weighing and the weight receipt shall be sent to SAP operator for PRN Generation.
- Material shall be sorted on Greefa Machine at very slow speed and more number of people at quality selection belt to ensure that all defected apples may be removed as ROL.
- Quality In Charge shall verify that the consignment has been sorted properly (Annexure XII).
- CA Quality bins shall be stored in CA rooms.
- Non-CA quality, which is not stored in CA rooms, shall be packed as per packing quality specifications and sent to market.

Data Recording and Reporting

- All annexure (different nos.) shall be used for data recording in registers and report sheets as per described in (Annexure XIII).

- A daily report shall be prepared by Quality In Charge (Annexure XIV) and sent to Quality Head with a copy of same submitted to Terminal Head, Procurement Head, HP Operation Head and Business Head.

Annexure I: Sampling Plan

Sampling Plan for Destructive Analysis of Apple Lots

No. of crates/boxes (*N*)	No. of crates/boxes to be sampled (*n*)	Min number of fruits to be picked	Total sample size
Up to 75	4	1 per crate/box	6 fruits
75–150	5		8 fruits
>150	7		8 fruits

Sampling Plan for External Defect Analysis of Apple Lots

$$\text{No. of Crates to be sampled} = \sqrt{N-1}$$

where N = Total no. of crates in the consignment

Annexure II: Specifications

External and internal defects to be monitored while checking a lot during arrival

S. no.	Defects	Tolerance
1	Colour	Fruits having colour on 55–80 % and above 80 % surface area (characteristic for the variety). Fruits do not meet this requirement shall not exceed 10 % per lot
2	Size	Extra extra small: 60–62.5 mm: 200 count
		Extra small: 62.6–67.9 mm :175 count
		Small: 68.0–71.9 mm: 150 count
		Medium: 72.0–76.9 mm: 125 count
		Large: 77.0–85 mm: 100 count
		Extra large: 85.1–88 mm: 80 count
3	Shape	Fairly well formed. Mis-shaped fruits are not allowed

(continued)

(continued)

S. no.	Defects	Tolerance
4	Development	Fully developed (should not have pale red colouring on surface) fruits are allowed
5	Hail damage	Free of fresh or unhealed hail damage
6	Sun burn/spray burns/superficial scald	Slight sunburn which merges into skin colour allowed in not more than 2 % per crate/box
7	Russeting	Russeting up to shoulders allowed in 30 % of fruits per crate/box. One mark of one rupee coin size in a scattered form beyond stem cavity allowed in 5 % fruits per crate/box
8	Skin puncture	Max. 1 hole of skin deep provided the diameter of hole should not be more than pin head size and the holes are clean. The count of such fruit shall not exceed 2 % per crate/box
9	Dark brown marks produced by branches	Such marks should not exceed 1 cm^2 surface area. The count of such fruit shall not exceed 1 % per crate/box
10	Fly spec	Thinly scattered not exceeding 1 cm^2 surface area. The count of such fruit shall not exceed 2 % per crate/box
11	Sooty blotch	Sooty blotch which is thinly scattered covering not more than 2 % of the surface area allowed in not more than 2 % of fruits per crate/box
12	Black rot marks	Not allowed
13	Pressure marks and bruises	One or two hard pressure marks of 1 cm^2 surface area maybe allowed in 2 % fruits per crate/box
14	Scab	Not allowed
15	Shriveling	Not allowed
16	San Jose scale	Not allowed
17	Crack/injury	Not allowed
18	Bitter pit	Not allowed
19	Rotten spots/fungal infection	Not allowed
20	Internal browning/ external browning/ bruising	Not allowed
21	Internal breakdown	Not allowed
22	Fruit firmness (lb)	Greater than 16.0 lb
23	Starch index	Shimla: between 2 and 2.5 on 1–5 point scale
		Kashmir: 2–2.5 on 1–5 point scale
		Kinnaur: between 2. 25 and 3.25 on 1–5 point scale

Note: The overall count of fruits with above-mentioned defects should not exceed 8 % of the count in a crate/box

Annexure III

ARRIVAL QUALITY CHECKING REPORT AT C.A. STORE

Date:	

Gate In No :		**Grower's Name:**
Total No of Boxes/Crates :		Please specify Crates or Boxes....

Destructive analysis

No of Boxes/Crates Sampled:			

External Defects Analysis

S.No.	**Fruit Firmness (lbs)**			**Starch Index**	**Internal Defects / Other Parameters**	**Flag**	**Sample Size (No.)**	**Conforming Qty. (Nos.)**	**Non-Conforming**		**Defects Observed**	**Flag**
	First Side	**Second Side**	**Average**						**Qty. (Nos.)**	**%age**		
					Less Pressure						Russetting	
					SIP Beyond Tolerance						Hail Damage	
					Bitter Pit						Sun Burn	
					Water Core						Skin Puncture	
					Core Rot						Cracks	
					Internal Browning						Pressure Marks	
											Fly Specs	
											Shriveling	
											Sooty Blotch	
											Scab	
Average											Scale	
Range												
Q.C. Passed :-	**OKAY / NOT OKAY**						**Q.C. Passed :-**		**OKAY / NOT OKAY**			

Remarks:

Lab Asstt.

(Signature):

Q/C Asstt.

(Signature)

Annexure IV: Quality Report of Deviated Consignment

Date	Time	Consignment number	Defect as per quality check report (%)	Number of crates	Machine run quantity (MT)	Rejection on Line	Bin audit		Signature Q I/C
							Defects (%)		
							Major	Minor	

Annexure V: Visual Defects Quality Audit

Date	Time	Consignment number	Defects as per quality check report (%)	Deviation (%)		Remarks	Signature Q I/C
				Major	Minor		

Annexure VI: Greefa Pre-sorting Machine Colour and Size Calibration and Revalidation

Date			**Unit**	
Characters	**Specification**	**Calibrated value/revalidated value**		**Remarks**
Colour	80–100 %			
	55–80 %			
	<55 %			
Size	Super large			
	Extra large			
	Large			
	Medium			
	Small			
	Extra small			
	Extra extra small			
Terminal head			Procurement in charge	
Quality in charge			Greefa Machine in charge	

Annexure VII: Greefa Pre-sorting Machine Verification Record

Date	Colour	Size	Zero weight verification	Cleaning verification	Greefa I/C signature	Q I/C signature

Annexure VIII

Daily apple handling report

Date	Shift	No. of consignments	Machine run quantity (MT)	Rejection on Line quantity (ROL) (MT)	Percent ROL generated	Signature shift I/C	Signature Q I/C

Bin quality audit report

Date	Time	Shift	Consignment number	Colour grade	Size grade	External defects (%)		Corrective action taken	Signature shift I/C	Signature Q I/C
						Major	Minor			

Annexure IX: Procedure for Post-harvest Dip Treatment of Kinnaur Apples

Kinnaur apple in bins shall be treated for post-harvest dip before putting into CA chamber. The procedure is as follows:

- Dumper and Dump tank of the Greefa packing machine is to be used for giving dip treatment.
- Water is to be filled in the dump tank and Bavistin @ 500 ppm (50 g/100 L) shall be added.
- Ensure that solution should be in circulation using the circulation pump at 10 % speed.
- The bins with Apple are to be dipped in this tank by the dumper in manual mode.
- The bin shall be dipped up to only a 3/4th depth in the tank.
- The top layer which does not get dipped in solution shall be sprayed by use of a knap sack sprayer or a foot pump sprayer. The solution for the spray is to be used from the dump tank.
- The retention time of the bin shall be 30 s.
- When the level of water reduces in the tank and the pump is unable to circulate, top up shall be done.
- Top up shall be done by measuring the quantity of water with the help of dip rod. Bavistin shall be added for this top up quantity of water.
- The solution should not be topped up more than three times. After three top up, drain the solution and prepare new solution as mentioned earlier, for further dipping treatment.

Annexure X: Controlled Atmosphere Storage Conditions

•	Temperature	1 ± 0.5 °C
•	Relative humidity	87–92 %
•	Carbon dioxide	1.4 ± 0.2 %
•	Oxygen	1.8 ± 0.2 %

Annexure XI: Chamber CA Setup Record

Chamber no.	Date and time of chamber loading	Date and time of chamber completion	Date and time of chamber sealing	Date and time of start of pulldown	Date and time of end of pulldown	Time of pulldown	Signature CA room in charge	Signature refrigeration in charge	Signature quality in charge

Annexure XII: Rejection on Arrival (ROA) Quality Sorting Report

Date	Time	Consignment number	External defect (%)	Number of crates	Machine run quantity (MT)	Rejection on Line	Signature Q I/C

Annexure XIII

Quality formats to be used as:

Annexure I	Sample plan
Annexure II	Specification
Annexure III	Sheet
Annexure IV	Register
Annexure V	Register
Annexure VI	Sheet
Annexure VII	Register
Annexure VIII	Register
Annexure IX	Kinnaur apple dip treatment procedure
Annexure X	CA conditions
Annexure XI	Sheet
Annexure XII	Register

Annexure XIV: Daily Quality Mandi Information System (MIS)

Date:	Unit:

1. Total lots received

Total	Accepted	Accepted under deviation	ROA	Rejected

2. Daily apple handling report

Shift	Total	Machine run quantity	ROL
1			
2			

3. Summary of raw material quality check

No. of consignments audited	Deviation (%)

4. Super grade material in bins (estimated)

Shift	External defects (%)		Total
	Major	Minor	
1			
2			

5. Rejection on Arrival (ROA) sorting summary

Shift	Total consignments	Percent ROL	Percent CA material	Percent FS material
1				
2				

6. Daily chamber CA condition setup report

No. of rooms under filling	No. of rooms under CA setup	No. of rooms CA achieved	Rooms filled pending for CA setup

Remarks

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Chapter 10
Prevailing Marketing Channels and Marketing Systems

Introduction

Fresh produce is marketed through a range of different channels and marketing systems in India, similar to other developing countries. These channels include the traditional markets, wholesale markets, super markets, retail shops, middlemen, and street vendors. Wholesale markets play a key role in supplying fresh produce to sub-wholesalers and retailers. Harvested fresh produce is brought to wholesale markets, and after sale mainly by auction or on fixed price, is loaded for district markets, and from there again forwarded to traditional markets, small traders, supermarkets, and street vendors. The sale process at the majority of wholesale markets begins at around 4 AM and end at 3 PM on the same day.

In wholesale markets, there are few specific places for retail shops where consumers can also purchase small quantity. Except Sundays and National holidays, all days are functional for wholesale market and large volumes of produce are traded in a single day in wholesale markets. However, in India, maximum volume of fresh produce is sold directly to consumers through unorganized sectors including roadside shops, weekly mandi (hats), daily markets on municipality land, and fruits and vegetables stalls in multipurpose markets. The organized retail shops, super markets, and hyper markets are picking up slowly mainly in metropolitan cities and big towns only. Doorstep delivery by hand carts (Thela) is also a mode of sale in semi-urban areas.

The marketing of agricultural products in India has traditionally been controlled by the state and regulated by the Agricultural Products Marketing Committee (APMC) Act. These acts require all agricultural produce to be sold only in government-regulated markets (called "mandis"), which have poor infrastructure and are typically characterized by a long chain of middle man or intermediaries. These intermediate people including commission agents of wholesale markets create long marketing chain, delays products to reach consumers, and charges high margins in an arbitrary manner. They pay scant attention to grading, sorting, storage, and take little care in handling the product during loading, unloading, and

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_10

transport (Pandey et al. 2010). Their focus remains on sale and takes their commission as soon as sale is over. These agents are license holder provided by APMC.

The licensing of traders in these regulated APMC markets gives them upper hand over farmers and buyers. In many fruit markets of India, 1 % of the sale value is charged as APMC Charge. It is a major entry barrier for progressive farmers and entrepreneurial traders (Coulter 2004). Postharvest loss due to poor postharvest management and lack of infrastructure is approximately 30 % of the value of Indian fruit and vegetable production or almost US$3 billion (Pulamte 2008).

Organized fresh food retailing through supermarkets is still in developing stage and largely confined to a few big cities. Wholesale traders and commission agents hold the market and they have channels at various levels who give them advance knowledge about expected arrival. But they fail to say about quality arrival. Buyers, on the other hand, are not able to get information about expected arrival. For this reason, most buyers, including food processors and retailers, do not know in advance what to expect from the supply lot (Minten et al. 2009). The demand and supply play an important role in determining price of fruits like any other fresh produce.

Fresh produce market may be divided into six categories:

1. Local markets
2. Wholesale markets
3. Terminal market (Main mandi of a city or district)
4. Farmer's markets
5. Co-operative markets
6. Retail markets

Local Markets

Local markets are well prevalent everywhere in India and known by various names like Haat, Hatiya, Subzi Bazaar, etc. It is weekly in villages, but may be twice per week in few villages. However, in towns and cities it is everyday. Local markets are the main option for village people. No bulk purchasing and auction sale is performed in local markets; only local traders and few producers sale their produce.

Wholesale Markets

Wholesale market offers buyers to purchase produce in bulk quantity involving commission agents, loaders, and commission agents of other state's wholesale market, distributors, semi-wholesalers, retailers, and producers (Fig. 10.1). Number of buyers and their purchasing willingness driven by the demand in their respective areas generally set the daily wholesale price. If demand in terminal markets or markets of other states is more and supply is less, the price of fruits will shoot up and

Fig. 10.1 A typical wholesale market in India

vice versa. Also, whenever the supply of a particular commodity is higher than the demand, price falls to very low levels, and producers will find it more difficult to make any profit. This is the period when buyers purchase purposefully for storage and for off-season sale. Many commission agents also store fruits in cold store for off-season sale. Wholesale market is not functioning properly due to various reasons. The reasons are summarized here

(a) *Nonexistent of infrastructure at the wholesale markets*: The basic facilities in any wholesale markets are sorting, grading and packing shed, shops, auction shed, cold storage, ripening chamber, precooling facility, well-maintained road, cleanness, etc. The major wholesale markets of India lack the basic facilities and few have cold storage facilities in the premises. In an era of liberalization, privatization, and globalization, the existing market infrastructure of wholesale market is not up to the mark. A lot of efforts and attentions are required in this direction. It is a known fact that state government and respective mandi board alone cannot build modern market infrastructure of the international standard. Therefore, the modern market infrastructure may be built up with the public–private partnership and with the aid of central government.

(b) *Sorting*, *grading, and packing*: These operations start in the farmer's field and continued till reaches retailer's shop. Sorting, grading, and packing are routine work of every fruit shop of a wholesale market. They do this job for many purposes or reasons. However, the main reason is placing good quality fruits at the top layer and rest of the fruits at bottom layers, removal of diseased and damaged fruits, and for better presentation. This is sometimes called repacking.

(c) *Insufficient cold storage*: Cold storage facility is the most important facility of any wholesale market. This facility should be inside market premises, but in India, most of the cold stores are outside market premises.

(d) *Large amount of wastage*: It occurs due to lack of basic facilities, mainly cold storage, ripening chamber, precooling facility, etc. According to many reports, the postharvest losses at various level are very high. It is a well-documented fact that most growers who sell through wholesale markets (APMC markets) overpack the boxes, with some growers even packing close to 30 kg in a box designed to hold only 20 kg of apples. This overpacking is mainly to save costly packing and transportation cost. This practice adversely affects the quality of the apples. In the subsequent stage, transporters frequently loaded 25 % more

apple boxes on their trucks than recommended, resulting in additional damage during transit. Further, during the peak harvesting months, India's largest wholesale mandi, Delhi's Azadpur market, receives more than 600–800 trucks of apples per day during the peak season, where sale capacity is only 400–500 trucks each day during that period. As a result, apples remained packed hours under the hot sun in non-refrigerated trucks prior to auction. The apples were further damaged at APMC markets as the boxes were unloaded, auctioned, and reloaded manually for further transportation to various consumer markets of different states. All these practices add wastage at wholesale level.

(e) *Very less rewards for quality produce*: Quality is a major criterion for fresh produce marketing and price realization. However, the reward is not proportionate to quality offered by producers. This is due to less transparency in sale transaction by the commission agents and lack of quality consciousness among the buyers.

(f) *Traders dominate the chain*: Indian fresh produce is dominated by traders and commission agents. This holds true for many fruit markets, particularly wholesale markets. Producers bring their produce at the shop of commission agents for sale or auction. Agents perform the sale transaction and at the end provide a slip called Bataque (sale slip), indicating sale price, commission, mandi fee, loading unloading charges, etc. per box. After deducting all expenditure like loading–unloading, commission, APMC fee, etc., the net amount is given to the producer either in cash or by cheque.

(g) *No transparency in pricing*: In the presence of farmers, price of fruits and/or vegetables are fixed under a piece of cloth in many cases. In this system, farmers cannot understand the actual price of his produce. He is informed about the price what buyers are offering, but that not holds true in most of the cases. In absentia, the sale price informed to the farmers is less than the actual sold price. The agents give many reasons for low price sale such as more arrival, less demand, low-quality fruits, and damaged fruits and boxes.

(h) *Unhygienic and dirty*: Most of the wholesale markets of India are not clean. In every corner or even on the center of the market, accumulation of rotting fruits and vegetables can be seen. There is a provision of cleaning but is not followed strictly. After harvesting their crop, the farmers of Himachal Pradesh pack their apples in cardboard boxes and transport them by small trucks to the mandis, traveling an average of about 20–30 km from their orchard. A commission agent in fruit market works with the farmers by acting as a liaison between the farmers and buyers. There are major inefficiencies in this supply chain model. From the grower's perspective, the major disadvantage is that he or she does not know beforehand the prevailing price of apples at the mandi. Cell phone communication is the only means of price discovery for the farmer. This information is often unreliable and insufficient for determining where, when, and at what price to sell the product. Once the farmer arrives at the mandi with the produce, he or she discovers the price. In most cases, the farmer must sell at whatever price the apples get at auction by the commission agent. Farmers are left with few options for two principal reasons. First, storage opportunities are

not available due to the absence of cold chain infrastructure. This means that farmers must sell their fruit immediately following harvest. Second, farmers lack financial training and do not understand that transporting their apples to the mandi and incurring the transportation costs generally puts them at the mercy of whatever price the commission agent offers. Farmers simply cannot afford to pay the cost of transportation more than once. Before the APMC Act reforms, farmers were not only dependent on commission agents to sell their apples, but also to get loans in the absence of a formal credit mechanism. Reliance on a commission agent makes the entire transaction very asymmetric where the farmer has very little power relative to the commission agent. With little power in the hands of farmers, cheating in the weighing of the apples has become standard practice and farmers are not in a position to demand otherwise.

Fresh Produce Market (Wholesale Market)

Many terminologies are used in Indian fresh produce wholesale market. The most frequently used terminologies of major wholesale mandis of India are described below.

Major wholesale mandis of India: APMC Azadpur (New Delhi), Kothapet (Hyderabad), Koyambedu (Chennai), Hathua market (Kolkata), and others.

Mode of sale: They are auction, fixed sale, and price fixation between Arhatiyas (commission agents) and buyers either by open price known to all buyers or under a piece of cloth (Handkerchief or towel) known to only one buyer at a time. In case of fixed sale, there is no bargaining and ups and down. In auction sale, highest price bidders are eligible to purchase, whereas in price under cloth produce are sold to high price bidders and buyers whose payment record with the CA is good. The price may not be the highest similar to the auction sale. In many cases, produce are divided into 3–4 buyers if their coated price is same.

1. *Auction* (*Boli lagana*): A system of sale where 2–4 boxes of one lot are opened for display and commission agents (Arhatiyas) start seeking a price for the whole lot and the person who coined the highest price can purchase the whole or part of the lot depending on his capacity to purchase. The Arhatiyas have the sole authority to distribute the lot to more than one people or can give to a single person. *This is simply a mode of transfer of farmer's produce to buyers without any value addition*. For this, the commission agents charge his commission (5–10 % of sale value, varies from mandi to mandi) + unloading and handling charges (per box/bag basis) + APMC fee (1 % of sale value; in few markets no APMC fee is charged, e.g., Tamil Nadu). All above charges are deducted from the sale value and farmer receives a sale bataque in which all the values are written and net amount is paid to farmer by cheque or case. In many mandis, commission is not charged from farmers but charged from buyers (e.g., Chandigarh market), but other charges are deducted from farmer's sale.

Remarks: Generally, auction is carried out for B-grade produce in Azadpur mandi (Delhi). A-grade produce is sold under cloths. Corporate buyers are not directly involved in auction, but they purchase from service provider or commission agents directly. Service provider purchase for them and for this they charge a service charge of 3–4 %. Employ of the company of firm can take their own decision to refuse or accept any purchase based on quality parameters of the company. This is a prevalent malpractice in Indian fresh produce wholesale market. In many cases, company people are also involved with service provider. This is one of the reasons that Indian corporate retail marketing is not flourishing well.

2. *Price fixation under cloth* (*Hath Dena*): It is a system of sale where price of commodity is fixed by the movement of fingers of both buyer and seller under a piece of cloth without any talking. Farmer or any third person can't understand at what price the commodity is sold. Only buyer and seller know the price.

   Remarks: Most common in North Indian markets like Azadpur mandi (New Delhi) and Chandigarh (Punjab). This method involves more risk of cheating for the farmers by commission agents. By this method, commission agents favor few buyers who are good in payment or have long relationship with commission agents (CA) or if he is a sure buyer or always buys from a fixed commission agent. A-grade produce is mostly sold by this method.

3. *Loader* (*Ladani*): Ladanis/Loader (purchase at wholesale rate by auction, fixed price rate or price fixed under handkerchief by wholesalers and do loading for wholesalers of distant markets of North and South in the form of either Batak or Commission sale). Here, value addition takes place in the form of repacking and rope binding of each box.

   Remarks: Many commission agents also act as loader. Where two or more brothers are involved, one brother acts as a loader. They mostly send to South and East markets.

4. *Batak*: Batak is a piece of paper on which all costs are written such as cost of fruits + loading + Local transport if any + Ladani's commission 3–5 % of total cost. Sometimes freight is also included in the batak. The Arhatiyas of distant markets (Terminal markets) are bound to pay the batak amount irrespective of his sale price. In this case, ladanis or loader is in win–win situation free from any risk of low price sale at distant market. All loaders prefer this mode of fresh produce business.

   Remarks: Batak business is very common in India where small shopkeeper is working in large numbers. Batak money is paid within 7–10 days to Loaders.

5. *Repacking*: Repacking is nothing but opening a box and rearranging fruits or vegetables in such a way that the best fruits in all respects should be placed on the upper layers of box and less quality fruits in the inner layers. In this way the quality of fruits decreases from top to bottom and the least quality are placed at the bottom layer. During repacking, diseased and damaged fruits are discarded. Repacked boxes fetch more price than non-repacked. In many cases repacked boxes are wrapped tightly with plastic ropes to provide extra strength during

subsequent handling. The person who does repacking is called packer in the mandi. They are trained in repacking and they charge per box.

Remarks: Repacking is essential for loading to distant markets like south markets (Hyderabad, Chennai, Bangalore) because it gives assurance of quality. The weight of heavy packed or overpacked boxes are also reduced to normal weight in order to reduce touching, pressure marks, and damage during transit.

6. *Commission sale*: In case of commission sale, all costs (cost of fruits + loading and unloading costs + Local transport if any + Freight to destination market + Commission of commission agents at destination mandis) are borne by ladanis only. Here, commission is charged by commission agents and a sale batak is prepared for net amount payable to ladanis or commission agent (in many cases, commission agent also acts as ladanis). In this case, commission agents at terminal markets are in win–win situation free from any risk of low price sale. All commission agents prefer this mode.

   Remarks: Commission sale is same as auction sale; the only difference is that this sale is confined only among traders or loaders and not farmers.
7. *Mashakhor*: Mashakhors are group of permanent buyers and purchase good quality small lots for local sale. Minimum one box they can sale. They never sell in kilogram (kg). After purchasing, they repack all boxes and one or two boxes are opened for display. They mainly sell on cash payment, but credit sale is also common.
8. *Part load and Full load*: Part load means one vehicle carrying fruits and vegetables (horticultural produce) of many shops of a particular area. During loading, driver of vehicle receives written document of material and address of each shop. It is the duty of the driver to deliver right quantity to right owner. In general, local small shopkeeper use part load delivery but now part loads are also sent to distant markets such as Hyderabad, Chennai, and Bangalore. Full load means full vehicle load for one shop only. Farmers mostly use part loads for sending their produce in the market. Small and marginal farmers always use part loads, whereas big farmers use full load.
9. *Forwarding agents*: Forwarding agents work in growing areas. Their main function is arranging vehicles every day. Farmers bring their produce at the door step of forwarding agents for loading and sending to markets. In few cases forwarding agents collect produce from farmers' field and bring at loading site. They charge all expenditure (Loading and freight) and extra charge/box (Rs 4–7/box as forwarding charge). Forwarding agents give a challan to grower and one challan to commission agent.

   Remarks: Forwarding agents only facilitate logistic arrangement for different mandis. They also have contacts with commission agents of mandi. In many cases, farmers do not travel with their produce.
10. *Dhara*: The term "Dhara" is mainly used for apple sale when all grades (LMS, ES, EES) of apple of a particular lot are sold at one price. In some cases, pittoo is also included in Dhara. Prevalent apple grades are large, medium, small (LMS), extra small and 210–240 counts (EES, 6 layer) and 310 counts. Large,

medium, and small are always sold at same price. Whereas, extra small price is Rs. 150–200 less than the LMS and 210–240 counts price is again reduced by 100–150 from extra small and Rs. 200–300 from LMS. 310 counts again are reduced by Rs. 100 from 210 to 240 counts. This is a general practice, not a fixed rule. Sometimes 310 counts are not included in dhara.

Remarks: Growers always demand for Dhara sale and loaders calculate grade-wise rate quickly. If number of extra small and 210–240 counts (EES) boxes is less than buyers prefer dhara purchase.

11. *Mandi grade*: Mandi grade is a general term used by farmers and traders for apple packaging. To increase the weight of box, framers pack large size fruits in medium trays, medium size fruits in small trays, and small size fruits in extra small trays and so on. This system is called one grade up packaging and thus increases the weight of boxes. *All boxes have 20 kg capacity only, and therefore, touching, pressure marks, and damage due to overfilling is more than normal.*

Remarks: Mandi packaging is highly preferred by buyers due to heavy weight of the boxes. Buyers (loaders and commission agents) do repacking of these boxes, remove few apples per box, and make extra boxes for more profit.

Major Wholesale Markets of India

In every state, one major wholesale market exists and fulfills the demand of other district markets. However, state-wise markets are not well known rather zone-wise markets are more frequently used and popular. There are five zonal markets like markets of North India, South, East, West, and Central India. Markets of North India play major role followed by South, West, and East. Major markets are listed below:

- *North*: Delhi, Ludhiana, Chandigarh, Jammu, Sahibabad, Lucknow, Varanasi, Kanpur, Allahabad
- *East*: Kolkata, Siliguri, Guwahati, Bhubaneswar
- *South*: Chennai, Bangalore, Hyderabad, Vijayawada, Coimbatore, Mysore
- *West*: Mumbai, Pune, Goa
- *Central*: Jabalpur, Indore, Raipur

Market Profile of North India

North Indian markets are major demand hub for many fruits and vegetables such as apple, pear, peach, plum, pineapple, apricot, almond, grapes, mango, guava, banana, potato, onion, garlic, tomato, watermelon, musk melon, imported fruits, carrot, chilli, and litchi. Almost all fruits and vegetables are sold from Azadpur.

Delhi (Azadpur)

- Delhi (Azadpur) is the biggest market in North India in terms of arrival, number of shops, and per day sale volume. It acts as both consumption and transit center (loading center). More than 60 % of apple, pear, plum, banana, onion, and apricot are transhipped from here to Punjab, Haryana, J&K, South, East, and West markets. During the peak season, on an average, 400–450 trucks of apple, 350–400 trucks of potato, 60–100 trucks of onion, and banana rack (40 bogies train) arrival per day are common. A large number of buyers from different parts of the country are gathered in)Azadpur mandi during temperate fruit season, especially apple season. Himachal Pradesh and J&K are two major suppliers of temperate fruits.
- Temperate fruit crops start in the month of May and July when Plum, peach, apricot, and early apple varieties (Red Gold, Tyde Man from Himachal Pradesh and Hazrat Bali and Razzak Bali from J&K) arrive in the market. Apple season continues till November.
- After apple, grape season starts in mid-November or first week of December from district Nasik (Maharashtra) and continues till March. Then arrival of cold store grapes starts in the mandi and lasts till June. Wholesaler and traders mainly store grapes in Nasik itself and then transport in the months of April, May, or June. Grapes from this mandi are sent to Delhi NCR, Punjab, Haryana, parts of UP, and J&K.
- Potato also arrives in the market in January mainly from UP (Agra, Farrukhabad, Shamshabad, Khandoli, Hathras, and Aligarh, popularly known as potato belt). From Azadpur mandi, potatoes mainly are sent to Delhi NCR and J&K. Chips quality potatoes are not available in the mandi.
- In December itself, kinnow mandarin from Abohar (Punjab) and Sri Ganganagar (Rajasthan) arrives in the market. The season lasts till first week of March. There is not a tendency to keep kinnow in cold store because of two reasons; first, there is no place for off-season sale as Nagpur mandarin arrives in the mandi in January first or second week and second is that the shelf life of stored kinnow is merely 3–5 days. Fungal infection in stored kinnow is also more than that in fresh kinnow. Kinnow mainly is sent to Delhi NCR and South, East, and West markets on a limited scale or part load. Nowadays, South, East, and West markets are fed directly from the growing belts. It reduces the handling costs of the fruits and provides more profit to growers.
- In the month of February, mango arrival from)south (Var. Safeda) starts followed by from North (U.P.). It is a universal truth in fruit business that most of other fruit prices reduce or their demand decreases as soon as mango starts hitting the market. Retailers shifted towards more to apple purchase. Major mango varieties sold in this market are Dashehari, Langra, and Chausa. Lucknow Dashehari is the best quality sold in the mandi. However, Malihabad region of UP is famous for mango. The season of this wonderful fruit lasts till July. Once rainy season starts, mango demand decreases drastically.

- Onion arrival also starts in December and continued) to January from Rajasthan and from January to March from Nasik. J&K and Himachal Pradesh receive major parts of onion supply from Azadpur mandi
- Citrus arrival (Sweet orange) from Hyderabad and Warangal, Nagpur mandarin from Maharashtra, and kinnow from Punjab and Rajasthan. Kinnow season is from December to first week of March. Kinnow and sweet orange are not stored in cold storage. Whereas, little quantity of Nagpur mandarin is stored in cold store for one month.
- Potato from Agra, Hathras, Shamshabad, and Kannauj starts from January till April and then cold storing of potato starts.

Chandigarh

- Chandigarh market is also fed by similar source as Azadpur mandi. Commission agents (CA) from south and east visit this mandi every year during apple season for purchasing, loading, and forwarding to south and east markets.
- Commission agents at Chandigarh have business relationships with commission agents of other mandis, especially south, central, and east where they send medium- to low-grade commodities for sale through open auction. Within 10 days, they receive money in their account after sale process is over.

Ludhiana

- Ludhiana is the next major market after Chandigarh for fruits and vegetables which caters to nearby adjoining areas and meets the demand of the city.
- It is a very good market for onion that comes directly from Maharashtra and Rajasthan.
- Many commission agents dealing in smaller quantities source materials as part loads from other commission agents sitting in Delhi, Varanasi, Lucknow, Hyderabad, Jammu, etc. During the season of apple and grape, commission agents put fruits in cold storages and during off-season they sell them. Cold-stored fruits generally fetch more price in off-season.

Sopore

Sopore is a famous mandi for apple. It is situated in Baramulla district of J&K. Local traders play important roles in dealing and have connections with wholesaler of Punjab, UP, and other states. They do purchase from this mandi and send to other mandis of other states. For initial purchase, they borrow many from traders of other mandis, and at the end of the season, they settle their accounts. By and large, traders from other states directly visit farmers' orchards and after negotiations purchase their produce (Packed boxes). The rate is fixed per peti/box (16–18 kg). Generally,

wooden boxes are used for apple packing, but CFB boxes are also in use. The Kashmir packing is not similar to Himachal Packing where 20 kg CFB boxes are used. For storage, only wooden boxes are recommended. CFB boxes of J&K are of poor quality and 3 ply. Therefore, it loses its strength during storage and damage of apple is obvious.

Jammu

- Jammu is not a very famous mandi of North, but it acts as a connecting link between J&K and rest of India. Major quantities of banana, grapes, onion, potato, citrus, and all tropical and sub-tropical fruits arrive here from Delhi, Chandigarh, and Ludhiana in trucks as full or part loads. There is a good demand of all fruits, vegetable (potato, onions, garlic, etc.), and spices crops during peak harvesting season.
- Some quantities of fruits are also sourced directly from production centers.

East India

- In East India, Kolkata, Guwahati, and Siliguri are the major fresh produce markets where demand for apple, grapes, mango, pomegranate, potato, onion, garlic, and imported fruits is high. Kolkata is the number one market in terms of arrival and sale and it also supports other two markets, mainly Guwahati and Siliguri.

Kolkata

- Kolkata has a separate market only for fruits. There are large quantities of apples (Delhi, Ludhiana, Chandigarh, Himachal, and J&K), grapes (Maharashtra and Karnataka), mangoes (A.P. and locally grown), pomegranates (Maharashtra), potatoes (locally), onions (Maharashtra), and other imported fruits (Mumbai and Chennai) during the season and off-season.
- Except imported fruits, in most of the cases, commission agent or his man or a man he selects from production areas locally goes to the production belts, hires a vehicle, and every day visits farmers' field, selects the produce, purchases it from the farmers, and sends to the market after packaging. Cost of sorting and grading is paid either by farmers or by CA, but cost of packing material is always paid by CA or traders. These packed boxes are sent to mandi by trucks where they are sold through open auction or fixed price or under a piece of cloth.
- Also some commission agents from Delhi, Ludhiana, Chandigarh, Andhra Pradesh, Karnataka, and Maharashtra send apple, peach, pear, plum, pomegranate, grapes, sweet orange, and apricot to Kolkata mandi where these are sold

through open auction system and traders send the money usually within 10–12 days of business after deducting all expenditures including their commission.
- Pack size and weight differ from fruit to fruit such as apple comes in 20 kg boxes, but weight may be up to 25 kg. Similar case is with pear. Grape comes in packaging of 5 kg cardboard boxes and also in crates of 20 kg capacity. Pomegranate is packed on the basis of counts. Sweet orange is packed in loose packaging. Kinnow again on the basis of counts (42,45,72 counts).
- Kolkata also caters Bangladesh mainly in grapes, onion, orange, and apple.

Guwahati

After Kolkata, *Guwahati* is the next most important mandi of East India. During the season, apple and pear arrive mainly from Delhi, Chandigarh, and Kolkata. Grapes and Nagpur mandarin come from Kolkata, Siliguri, and also from Maharashtra directly. Khasi mandarin comes from Meghalaya and sweet orange from Hyderabad. Seeded grapes arrive from Bangalore and kinnow again from Delhi, Kolkata, and Siliguri.

- There are facilities for cold storage of apple, but other fruits are mostly not stored.
- Arrival of grapes is in cardboard boxes of 4 or 5 or 8 kg and also some quantity arrives in plastic crates carrying 20 kg grapes.
- This market mainly caters to the demand of city and also major markets of North East and other nearby small towns.
- It is auctioned as well as sold at fixed prices, thus commission agents in this market also act as wholesalers. To other areas, it is transported by buses called night trippers during the night.

Siliguri

- It is a big market in West Bengal where large quantities of North-cultivated fruits such as apple, pear, and kinnow and West-cultivated grapes, pomegranate, and Nagpur mandarin arrive from Himachal, J&K, Punjab, and Maharashtra directly during the season. Also, good quantity of grapes arrives from Bangalore and sweet orange from Hyderabad during season.
- This market has very good potential for imported pears, smaller count Fuji apple, Indian apple, and off-season grapes.
- This market mainly feeds lower Assam and also good quantity of grapes is purchased by traders from Nepal and Bhutan. This also acts as transit point for Gangtok and Darjeeling hills.
- No cold storage facilities are available in the market, and therefore, all fruits are auctioned on the same day they arrive in the market.

Organized Retails

Organized retailing in F&V is quite advanced in many developing countries of Africa, Asia, and Latin American countries—Kenya, China, Brazil, and Argentina. India is a late starter in the area of organized retailing in fresh F&V when corporate entered in the business of fresh produce. The FDI in retails in F&V is not encouraged because Government policy of FDI entry in multi-brand retailing is possible in JV only; as a result, only Del monte Bharti entered as JV. Indian retailers were not very active until recently to incorporate F&V with other grocery items. Nowadays, supermarkets are increasing, but are confined to only big cities.

Entry of big retail names—Reliance, Bharti, ITC, Aditya Birla Group, Adani Group with the brand names Reliance Fresh, Field fresh, Choupal Fresh, MORE, Namdhari's Fresh, FARM-PIK. The organized retails are listed in the Table 10.1.

Current situation of F&V marketing: Indian fresh produce marketing is at a very primitive stage like many other developing countries, such as:

- Non-existent infrastructure at the wholesale markets: It is a common feature in almost all wholesale markets.
- The common facilities of packing, grading, sorting, and cold storages are totally absent with few old model cold stores. This results in large amount of wastage ranging between 20 and 40 %.
- Fragmented production, leading to fragmented supply chains from production site to marketing place.
- No rewards or very little reward for quality produce for growers if their lots are small and physically absent during auction. The commission agents make more profit out of quality rather than the farmer.
- Traders dominate the chain in fresh produce marketing irrespective of the commodities and places. Ninety percent of the produce moves to retailers via traders called commission agents or Arhatiyas. All CA agents possess a shop, license for

Table 10.1 Major organized retails of India dealing with fruits and vegetable

S.no.	Name of group	Company/brand name	Area of operation
1	NDDB	Safal	Delhi NCR, Bangalore
2.	RPG	Food World	South India
3.	RPG	Spencer	South, Central, and East India
4.	Reliance	Reliance Fresh	All over India
5.	ITC	Choupal Fresh	North, South, and Central India
6.	Aditya Birla	More	All over India
7.	Heritage	Fresh@	South India
8.	Future Group	Food Bazar	North, South, and Central India
9.	Bharti Wall mart	Easy Day	North, South, and Central India
10.	Mahindra & Mahindra	Mahindra Shubhlabh	North
11.	TATA	Khet Se	North and South

Source: Ahmad et al. (2014)

auction, and sale in that particular market issued by the APMC of that state. The local traders, farmers, assemblers, forwarding agents, and all types of middle men bring their produce with advance information to CA agents. Upon reaching the vehicle in the mandi, CA employees take responsibility of unloading and displaying sample during auction.

- Generally, auction starts when buyers assemble in sufficient numbers, but time of auction varies from mandi to mandi and state to state. But in most of the mandis, it starts at 8–10 AM.
- In majority of the cases with few exceptions, pricing is done under a small piece of cloth by moving and catching fingers. In such cases, what price is fixed is known only to buyer and CA; later on this is conveyed to the growers.
- When auction takes place openly and price fixed by the highest bidder, price reduction is a common phenomenon and the term used here is called *Claim*. It is nothing but a type of cheating either by buyers and/or CA. The buyers make a claim that grower cheated me in quality. I offered the price for the quality I saw in the sample boxes during auction, but rest of the boxes are not of the same quality; therefore, the auction price must be reduced to a level, then only I will accept the lot otherwise I will return. In most of the cases, CA also put pressure to accept the buyers' claim or keep the produce for next-day auction. Growers find themselves helpless and accept; they cannot wait for more days because their produce are just like dead bodies—every passing day, the quality will decrease and also there is no guarantee that next-day auction will be more profitable.

1. Farm to Fork Complete Chain—Reliance, ITC, Aditya Birla Group, Wal mart, Heritage, etc.
2. Wholesaling—Adani Agrifresh Ltd., Metro, Unifruity
3. Distributorship—Adani Agrifresh Limited, Unifruity
4. Front end—Food Bazaar, Big bazaar, Spencer, etc.
5. Back end—Adani Agrifresh Ltd.
6. Exports with EUREPGAP Certification—Namdhari's Fresh, Field Fresh, Fresh Trops, etc.

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Chapter 11
Supply Chain and Marketing Channels of Fruits

Introduction

An agricultural supply chain can be defined as the entire set of production, distribution and marketing processes by which the consumer is supplied with a desired product (Woods 2004). Fresh produce is marketed through a range of different channels in many developing countries including India. These channels include the local market, wholesale market, supermarkets, retail shops, middleman and street vendor. Wholesale markets play a key role in supplying fresh produce to sub-wholesalers and retailers. Harvested fresh produce is brought to wholesale markets and after sale mainly by auction or on fixed price is loaded for district mandis, and from there forwarded to local markets, small traders, supermarkets and street vendors. The sale transaction at majority of wholesale markets begins at around 4 AM and end at 3 PM on the same day. Except Sundays and National holidays, all days are functional. Large volumes of produce are traded in wholesale markets. Supply chain of fresh fruits is important because it determines the producer's share in consumer's rupee. The farmer's share of the price paid by the consumers is studied by many workers. According to Anantia (2008), the share of producer in consumer's price depends upon the types of marketing channels. On an average, the share of producers varies between 33 and 75 % in case of fruits and vegetables. Another survey by Government of India (2001) reported that the farmer receives only one rupee out of every Rs. 3.50 paid by the consumer, whereas the retailer receives Rs. 0.75, the wholesaler Rs. 0.50 and rest of the amount Rs 1.25 goes to commission agents and traders. Marketing channels differ from produce to produce and from state to state. Always more than one marketing channel exists for each produce. Few of the supply chain of fruits are described here.

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_11

Apple

Apple is mainly grown in Himachal Pradesh, Jammu and Kashmir and Uttarakhand. Supply chain of this fruit is more or less same in all three states except corporate buyers like Adani group, Fresh and Healthy Enterprise, Reliance fresh, etc., where channel totally differs from rest of the buyers.

Corporate buyers—Most of the corporate buyers purchase directly from the farmers in the orchard after fixing price and quality. However, corporate like Adani Agrifresh Ltd. purchases apple in plastic crates at the storage site or collection centre. The rate per kilogram of apple of different quality, colour and sizes is announced by the company at the beginning of harvesting season. This price is valid for few days (1 week), and again it is changed or remained same based on market trend. The same purchasing procedure with slight modification is also adopted by other companies. This gives an option to farmers in price realization of his produce. Now, farmers have an option to sell either in mandi or to corporate buyers. The company also appointed hub operators for distribution of empty plastic crates. The empty crates are made available to each hub operators and producers collect crates from their hub operators. All crates are lined with bubble sheets. This acts as cushioning material. Farmers bring their produce at the storage site in these crates and after quality checking, the lot is accepted or rejected. Accepted lot, unloaded and sorting grading is completed by highly modern grader (colour and weight grading by image processing). The channel is mentioned in detail below as flow chart.

Farmers → Apple in plastic crates to CA centre → Sorting grading (best quality stored in CA) and rejection (B-grade) and low pressure apple channelled to market within 2–3 days → Empty crates again sent to hub operators → Farmers collect empty crates from the nearest hub operator and bring apple in crates and this cycle is continued.

Semi-direct company buyers: Retail companies such as Reliance, Mahindra Shubhlabh Spencer and TATA Khet se have appointed their own agents in Himachal Pradesh. These agents buy from farmers on behalf of their company and compete aggressively in the field for larger volumes of good quality apples. Since most of the growers produce small quantities of apples, the purchasing company needs many buyers to handle the large volume of purchases. Moreover, since the packing and grading of apples is not standardized, a great deal of time is spent finalizing the deal with farmers. This makes it difficult to monitor and control the entire operation of apple procurement. Semi-direct company buyers purchase approximately 30 % of overall apple production.

Direct company buyers: At present, the direct company buyers include Adani Agrifresh Ltd. and Fresh and Healthy Enterprise Ltd. of the Container Corporation

of India (CONCOR, Ministry of Railways, India). Unlike commission agents and semi-direct company buyers, direct company buyers work throughout the year to train farmers in scientific cultivation practices and post-harvest management. These training sessions are organized by company personnel, who send experts hired by the company to periodically visit villages and invite farmers to participate in training sessions free of cost. Both Adani Agrifresh Ltd. and Fresh and Healthy enterprises own CA storage facilities, which are technically far superior to conventional cold storage.

In conventional supply chain, growers are not bound to follow the best harvest and post-harvest practices, especially harvesting at proper maturity stage, product handling and packing. Back end companies never purchase bulk quantities directly from the mandis. It is observed that most growers who sell through APMC markets over packed the boxes, with some growers packing close to 30 kg in a box designed to hold only 20 kg of apples. The desire to save on costly packing adversely affected the quality of the apples. In the subsequent stage, transporters frequently loaded 25 % more apple boxes on their trucks than recommended, resulting in additional damage in transit. Moreover, during the peak production months, India's largest mandi in Delhi's Azadpur market would receive more than 800 trucks of apples per day, although it was designed to handle only 400 trucks each day. As a result, apples become warm and ripening process speeds up in non-refrigerated trucks. The apples were further damaged at APMC markets as the boxes were unloaded, opened and reloaded manually for further transportation to various consumer markets.

Market channels of back end companies: Most of the back end companies, sale their fruits through distributor systems. Adani Agrifresh Ltd. appointed distributors all over India. All distributors are well-established traders of different mandis. Few back end companies directly supply to organized retail buyers also.

Supply Chain During Season

(a) Farmers → Company pack house or storage site → Sorting, grading and filling in crates/bins/boxes at site → Storage of good quality apple or transported to distributors on fixed price or for auction sale → unloading at distributor's shop → Distribution to wholesaler and sub-wholesaler by distributors
(b) Farmers → Harvesting → Sorting, grading and packing in CFB/wooden boxes local mandi → unloading at mandi → Auction by trader → Wholesale/sub-wholesaler → Retailer → Consumers
(c) Farmers → Harvesting → Sorting, grading and packing in CFB/wooden boxes → Loading in trucks for distant markets → unloading at mandi → Auction by trader → Wholesale/sub-wholesaler → Retailer → Consumers
(d) Farmers → Full orchard sold to traders or middlemen → Harvesting by traders/middlemen → Sorting, grading and packing in CFB/wooden boxes → Storage by trader/sale at fruit mandi → unloading at mandi → Auction by trader → Wholesale/sub-whole salers → Retailers → Consumers

Marketing Channel During Off Season

(a) Stored apple ----- washing, brushing and packing ---- Loading and transportation of A-grade to distributors on fixed price for distant markets and B-grade to the nearest market for auction ---- Unloading at distributor's shops.
(b) Stored apple ----- sorting, grading and packing ---- Loading and transportation mandi for auction or fixed price sale ---- Unloading at mandi.

Litchi

Litchi is mainly grown in Bihar, West Bengal, Punjab and Uttarakhand. The marketing is mainly governed by traders and middlemen. Only few back end companies purchase litchi to supply organized retail shops and their appointed distributors.

(a) Litchi ---- Harvesting in bunch ---- Transported to Pack House ----- Sorting/ Grading ----- sulphuring ---- Packing ------ Cooling ---- Loading into Reefer Van ----- Transportation to distributors
(b) Litchi ---- Harvesting in bunch ---- Packing in wooden boxes ----- Loading into truck or train ----- Transportation to mandi for auction

Banana

Banana mainly transported from Maharashtra (Jalgaon) to different mandis of the country.

(a) Banana → Bunch harvesting → Transported to Pack House → hand cuttings → Bavistin treatments → Packing in plastic crates → Loading into trucks → Transportation to mandi
(b) Banana → Bunch harvesting → Bunch loading → Transportation to destination mandi → Auction
(c) Banana → Bunch harvesting → Bunch loading → Transportation to destination mandi → Auction

Kinnow

Punjab and Rajasthan are two major producers of Kinnow fruits. Procurement and sale channels are very similar to Litchi and apple.

(a) Kinnow ---- Harvesting with fruit clippers ---- Assembling in plastic crates transported to Pack House ----- Sorting, grading, washing and waxing ----- Packing in CFB boxes------ Loading ----- Transportation to fruit market

(b) Kinnow ---- Harvesting with fruit clippers ---- Assembling in plastic crates transported to Pack House ----- Sorting, grading, washing and waxing ----- Packing in wooden boxes ------ Loading ----- Transportation to fruit market
(c) Kinnow ---- Harvesting with fruit clippers ---- Assembling in plastic crates transported to Pack House ----- Sorting, grading, washing and waxing ----- Loose packing in plastic crates ------ Loading ----- Transportation to fruit market

Mandarin

These fruits are popularly called orange or Santra and supply chain is similar to Kinnow fruits.

(a) Orange ---- Harvesting with fruit clippers ---- Assembling in plastic crates transported to Pack House ----- Sorting, grading, washing ----- Packing in wooden boxes/CFB boxes ------ Loading ----- Transportation to fruit market
(b) Kinnow ---- Harvesting with fruit clippers ---- Assembling in plastic crates transported to Pack House ----- Sorting, grading, washing and waxing ----- Packing in wooden boxes ------ Loading ----- Transportation to fruit market
(c) Kinnow ---- Harvesting with fruit clippers ---- Assembling in plastic crates transported to Pack House ----- Sorting, grading, washing and waxing ----- Loose packing in plastic crates ------ Loading ----- Transportation to fruit market

Mango

This is the most popular fruit of India. Post-harvest handling and supply chain are more or less similar to other fruits.

(a) Farmers ------- Harvesting ------- Desapping by few progressive farmers ------ Sorting, grading and packing in CFB/wooden boxes ------ local wholesale mandi -------unloading at mandi ------- Auction by traders ------- Loading in trucks for distant markets -------- unloading at distant markets -------- Auction by traders ------- Wholesale/sub-wholesaler → Retailer → Consumers
(b) Farmers ------ Orchard sold to traders or middlemen ------ Harvesting by traders/middlemen ----- Sorting, grading and packing in CFB/wooden boxes ------ Storage by trader/sale at fruit mandi ------ unloading at mandi ------Auction by trader ------ Wholesale/sub-wholesaler ------ Retailer ------ Consumers

There are basically two types of sale channels in fresh fruits namely (1) Direct sale channels and (2) Indirect sale channels.

1. *Direct sale channel*—In direct sale channel, farmers produce reaches to customers directly without any intermediate person. As customers' demand for locally grown produce increased, more farmers are selling their products directly to

customers. Farmers receive maximum profit under this channel. Following channels are more prevalent in our country.

(a) *The Retail outlet* (*Owned by producer*) → *Consumers*—Prevalent in many parts of the country
(b) *Street selling/Road side* (*Producer shop*) → *Consumers*—Prevalent in many parts of the country
(c) *Municipal markets/outlets* (*Producer shop*) → *Consumers*—Prevalent in many parts of the country
(d) *Farmer's market* (*Producer shop*) → *Consumers*—Prevalent in Himachal Pradesh, A.P. etc.
(e) *Farm stall* (*Owned by producer*) → *Consumers*—Prevalent in few parts of the country
(f) *Selling to Restaurant and Hotels* → *Consumers*—Prevalent in metropolitan cities

2. *Indirect sale channels*—In this system, farmers' produce reaches to customer via various marketing channels such as

(a) *Producer* → Terminal/Wholesale market → Auction by commission agents → Distributors/Retailers
(b) *Producer* → Intermediaries (Local traders) → Retail outlets → Consumers
(c) *Producer* → Retail outlets (Supermarkets) → Consumers
(d) *Producer* → Local trader → Wholesalers → Semi-wholesalers → Retailers → Consumer
(e) *Producers* → Cooperatives collection → Distributors → Retailers → Consumers

Prevalent marketing system in India—Marketing channels also depends on the type of marketing systems. A number of marketing systems are found in this country based on locality and type of produce to sale. These are mentioned below:

1. *RURAL HATS*—This is prevalent mainly in villages, small cities and outside the big cities. It occurs once in a week or twice and sold not only fruits and vegetables but all necessary items.
2. *MUNICIPAL HATS/STRIPS OF LAND WITH FRUITS SHOPS*—This is prevalent mainly in small and big cities. It is almost permanent shops without permanent structure and regulated by municipal authorities. Here, only fruits, vegetables and flowers are sold.
3. *WHOLESALE/TERMINAL MARKET*—In every big or small cities, there is a wholesale market with or without auction. In big cities, wholesale market feeds nearby small cities and villages. Here, produce are sold both by auction and negotiation. Wholesaler, sub-wholesaler, forwarding agents and big retailers are major customers of any wholesale market. The products are sold in lots may be of two to five hundred boxes or even more. Side by side all other shops like insecticides, pesticides, boxes, liners, retailing shops of fruits and vegetables, etc. can be seen. Price fluctuation in retail markets mainly dependent on wholesale price of wholesale market.

4. *TEMPORARY ROAD SIDE SALE*—This is prevalent everywhere in India except in villages. It is temporary shops mainly unauthorized. It is most commonly seen near road side or on pedestrian paths.
5. *FARMER'S MARKET*—This is not much popular in this country and only few states started this type of marketing, e.g. Himachal Pradesh. Farmers bring their produce and sell by themselves with or without the help of any third person. A marginal commission is sometimes paid to helping person.

Factors Affecting Fruit Marketing

There are many factors affect fresh produce marketing. Few factors are listed below:

(a) *Consumption pattern*—Consumption pattern in India differs to a great extent. In some states, small size fruits and vegetables are preferred (North East states, Bihar, W.B., Orissa, etc.) while in some states big size fruits and vegetables are preferred (Punjab, Haryana, etc.). Accordingly, more prices are paid if produce are sold in their preferred consumption areas. Small size apple fruits have very little price in Punjab and Haryana but highly priced in Bihar and West Bengal due to consumption pattern.

(b) *Production quantity and price during season*—In general, price during season remains low and buyer keeps produce in cold store for sale in off season at high price. In this way, a higher margin is possible and in adverse condition, there will not be a big loss. This is a general practice followed every year. However, if season price is very high, off season price may or may not be higher than season price. In few years, people who stored in the season lost heavily. Traders store mainly apple in all major terminal markets of India during season. If price in the season is high, then traders store less quantity due to fear of low price during off season. Heavy rain, land slide and unavailability of vehicle at major producing states during season also hinder storage in wholesale and terminal markets. The price in off season generally remains on higher side but not always. It mainly depends on the price of imported fruits and the presence of or absence of auspicious occasions like festival season, marriage season, etc.

(c) *Presence of competitive crops*—The presence of substitute crops affects demand and sale volume of main crops. For instance, the demand of apple in off season in Andhra Pradesh largely is affected by the arrival of local mango. Off season sale of apple in south markets are very profitable but sale volume and demand decreases, as soon as mango variety, Safeda hits the market. Also sometimes prices of Indian apple and imported apple decreases drastically due to more arrival of mango. Similarly in case of Maharashtra, grape harvesting season coincides with imported and stored domestic apple. This largely affects the sale volume of apple.

(d) *Buying power of consumers*—Buying power of the customer greatly influences the fruit sale volume. This is the main reason behind higher sale in metropolitans than in second tier cities.
(e) *Extent of perishability of crops*—This also influences the price of the product. More perishable items are generally sold at higher prices in the beginning, and then price reduces as quality deteriorates, e.g. strawberry, grapes and litchi.
(f) *Import/Export volume*—The effect of import volume depends upon dollar rate and FOR price of the fruit. If dollar rate increases, import quantity decreases and vice versa. It is because landing cost of the product becomes very high. Apple constitutes about 90 % of total import volume of fruits and rest 10 % includes kiwi, citrus, pomegranate and grapes. Domestic production of apple greatly influences the import market. If domestic production is high, selling price remains low throughout the season. A large quantity of apple is stored by traders and wholesalers for off season sale. This keeps the price of apple under a level.
(g) *Length of marketing channel*—In general, price of fresh fruits and vegetables increases with increasing marketing channels.

Prevalent Business Models in Fruits in India

One can find a number of business models in fresh produce marketing in India. The major models are illustrated here

1. *ORCHARD PURCHASE AT FLOWERING/FRUITING STAGE* (*Kinnow*, *Litchi*, *Mango, etc.*)—This is a common practice all over India but more prevalent in Kinnow, litchi and mango. A local trader or middleman or trusted men of traders is compulsorily involved to take care of orchard after buying. The whole orchard money never paid to the farmers but paid first token money then 50 % and final at the time of full harvesting. There is date fixed for harvesting by the farmers and obeyed by the purchasers in most of the cases.
2. *ORCHARD PURCHASE OF STANDING CROPS*—This is similar to flowering stage purchasing except maturity of the fruit. Here, mature fruits ready to harvest are purchased directly by the traders, and spot payment is given. Here also harvesting date is fixed by the farmers. If fruits are not harvested within the stipulated period, grower may harvest and sale without the consent of buyer.
3. *PRECONTRACT SALE–MONEY BORROWED FROM TRADERS*—Farmers take money in advance by traders and wholesalers and in return give their produce for sale during season. The traders take commission for this sale and other charges (loading, unloading, labour, etc.). This practice is very common in Himachal Pradesh and J&K.
4. *LOCAL TRADERS ACTS AS MIDDLEMEN*—Local traders actively participate in fruits and vegetable business. They generally supply to wholesale traders sitting in the wholesale mandi. They work on commission basis. All financial helps are provided by the traders.

Emerging Marketing Trends in Fruits and Vegetables

- *ASSURED MARKET ON FIXED PRICE–CONTRACT FARMING*—Contract farming in India is increasing day by day. This is a common practice in potato chips making companies (PepsiCo, Haldiram and ITC) prefer contract farming. The price of potato is fixed for one season, and the same price is paid to the farmers irrespective of prevailing market price.
- *COLLECTION CENTRE*—Another business model adopted by Adani Agrifresh Ltd, Fresh and Healthy Enterprises, Harshana Naturals, etc. is direct procurement by all sections of farmers starting minimum with 10 crates (50 kg approx.). These companies supply plastic crates with or without bubble sheets directly to their crate vendors in each growing areas or from his storage site. Purchase is also done in packed boxes. Farmers collect crates directly from the vendors or site without any payment and bring their produce to the collection site. At the site, quality is checked and if found OK, the lot is accepted.
- *SERVICE PROVIDER* (*Corporate Purchase*)—Few big traders or organization having basic infrastructure facilities like grading packing unit, pre-cooling and cold storage facilities works for big companies and provides good quality produce on packed out models. This model includes cost of produce, cost of grading, packing, pre-treatments if any, pre-cooling if needed, all labour cost with or without cost of packing materials.
- *REVERSE MARKETING*—This is newly introduced marketing by Adani group of companies in Himachal Pradesh. The company sells all inputs like fertilizers, pesticide, plastic crates, etc. to farmers and purchases their commodity in the season. This type of marketing develops a strong relationship between farmers and the company.
- *ONE-STOP FARMER SOLUTION SHOP*—This type of marketing where all inputs required by farmers is available in one shop only.

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Chapter 12
Mode of Transportation of Fresh Produce

Introduction

Fresh horticultural produce is transported in two ways within the state and three ways between the states. The most common mode of transport within the state is utility vehicles (1–6 MT load capacity) and Trucks (8–16 MT). Trucks, train, and aeroplane are three medium of transport used between the states. Among the three major transport media between the states, trucks (8–16 MT) are the most common and most important followed by train and least is air transport. Non-refrigerated trucks move most fresh produce between the states. Ship transport is almost negligible in India. Limited Reefer van is operational during summer months for high-value domestic produce and imported fruits. However, the refer van operation and demand for fresh produce are increasing.

Organized retails and fresh produce handling companies prefer refer van for transportation to distant markets. Rail transport is restricted only for few commodities (banana, onion, and mango). Air services are very limited and used for highly perishable products from North to South. Sometimes litchi is transported from Kolkata to Chennai by air. Type of markets (metropolitan, urban, suburban) and the distance of market location from the source largely determine which modes of transport should be used. The buyer usually selects the type of transportation and pays for it directly after delivering the produce. In some cases, sender might pay the transportation cost and the same cost is included in the cost of the products. While deciding any mode of transportation, the following points must be considered.

- Product perishability
- Value of the product
- Season (Summer, winter, rainy)
- Travelling period
- Preference of the buyer
- Volume to be transported
- Freight charges (Cost of transportation)

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DOI 10.1007/978-3-319-21197-8_12

- Market destination
- Sale volume of the targeted market

It is a thumb rule in fresh produce transportation that more perishable produce should not be sent to distant markets in ordinary trucks. It will spoil during the journey period itself. Value of the produce, season, and distance of markets are the most important criteria for selecting a particular mode of transport. If the value of the produce is very high (apple red, capsicum, grapes, cherry, etc.), business people prefer refer van transport in summer months for South Indian markets (Andhra Pradesh, Tamil Nadu, Maharashtra, Gujarat, etc.). Preference of the buyers also matters in selection of mode of transport. Few buyers of metropolitan cities prefer refrigerated van irrespective of the high freight charges. The most common vans used for fresh produce transport are listed below.

Utility Vans

The most widely used means of transporting fresh produce to mandis within the state is utility vans (Mahindra Pik-up, Tata 407, Jeep, Camper, etc.). Utility van of different load carrying capacity is used. More than 90 % of the fresh produce grown in orchard is shipped to mandis by utility vans. Many growers have their own utility van. These vans are easily available and can reach inside the orchard for loading. It is more popular where transportation distance is near, i.e., within a radius of 30–50 km from production site.

Truck (Non-refer)

The most widely used means of transporting fresh produce in developing countries is non-refrigerated trucks, which is used to transport fresh produce from any growing area or market to all distant markets (Fig. 12.1). More than 90 % of the fresh produce grown in northern states of India is transported by trucks to southern states and vice versa. There are no specialized trucks for carrying fresh produce.

Fig. 12.1 Transportation by trucks (non-refer)

The trucks used for transporting cereal crops, furniture, and cement bags are also used for transportation of fruits. However, a separation is created by bamboo or wood in the body of trucks for transporting grapes. Grapes are highly perishable in nature, and therefore, buyer or seller fixes a cash reward to drivers in order to secure early and timely delivery in the mandi.

There is no exemption of toll tax in India for fresh produce transportation. Traditionally, truckers who carry fresh produce between two markets confirm return loads before loading. The most common procedure to obtain a truck for out-of-state shipment is through a transport agency. Many shops of transport agencies are available nearby mandis in all states. Agency people always monitor the availability of trucks. Truckers (truck drivers and their owner) consult transport agency to obtain a load. Usually, brokers of the agency handle the billing document called bilty (A printed document of transport agency in which truck number, name of driver, name of produce and number of boxes, weight of the produce, buyers' name, insurance if any, and freight cost are mentioned) and it is handed over to drivers and sufficient money also given for oil consumption, toll tax, etc. The driver collects freight from the buyers.

Several truck brokers are available in nearby markets of each growing area. Not all trucking transactions involve a broker. Growers can also contact with local truckers to move his or her product to regular buyers on a fixed freight basis. Some big growers have their own truck. In some cases, the buyer provides trucks. The transport industry is very competitive, and profit margins are slim. Truck owners prefer to take full loads. It is because partial loads generally are not profitable. To avoid partial loads, truckers take more than one buyer's load going to the same market or nearby markets. Partial loads, if going to the same destination, are manageable. Often, buyers themselves arrange mixed loads. Some transport agencies specialized in consolidating small loads by running regular on the same routes along interstate highways between major cities. Depending upon the destination, the produce might stay a longer period in trucks than with anyone else in the distribution system.

Refrigerated Vans/Trailers

Refrigerated trailers are necessary for perishable items like fruits. Trailer's refrigeration system is not dependent on engine. Before loading, check that the trailer is precooled, cleaned, and free from any bad smell. For example, a refer van used for fish transportation should not be used for fruits. It is because fishy smell may be incorporated into fruits. Temperature monitoring devices called data logger can also be installed inside the container to record temperature during transportation. If there is a quality problem when product is opened on arrival, recorded temperature during transit might be an important reference.

Transportation by Reefer Van is usually used for more expensive items than that by rail or ship but less expensive than air. Internal air circulation is essential for maintaining prescribed temperature in the reefer containers. Cold air is constantly

circulated through the stored produce in order to remove heat generated by the produce. This cold air is blown in at the bottom of the refrigerated unit through the ducted floor called T-floor and then drawn off below the container ceiling. The circulating fan maintains the cycle.

The following precautions and corrective steps must be taken before loading into a refer van

- Check if the refer van is precooled (generally 1–2 °C)
- Check for any foreign smell, air passage blockage, and cleanness ducted floor
- Check digital display unit for correct temperature display
- Load only a precooled material from the dock
- Loading should be as fast as possible
- Use good-quality boxes having good stacking strength and moisture proof
- Avoid mixed load if possible or install ethylene scrubber to protect ethylene-sensitive crops
- Do not turn off the refrigeration unit during standing and at night during journey
- Set cut off temperature according to the commodities loaded

Fruits Transported by Refer Van

The floor of van (container) should be cleaned, sanitized, and precooled to the desired temperature prior to loading. The purpose of precooling is to bring the inside temperature of the container to the desired temperature and to compensate the rising temperature during loading. If the inside temperature of the container is very hot, the produce may be warmed and quality deterioration is sure. However, during loading, temperature will raise up to some extent. Failure to precool may result in heat transfer from the container's body to the produce, which will warm the fruit. Reefer units should be turned off during loading. Running the reefer unit while loading results in accumulation of ice on the evaporator coil. Transportation to distant markets from stores has proven to be a critical step for apple, pear, kiwi, cherry, plum, etc. After February, refer van transportation becomes necessary to feed southern markets. Mixed load are generally not recommended in a refrigerated truck because of different temperature requirements for different commodities.

Rail

Rail service is used primarily for transportation of banana and onion from Maharashtra to Azadpur wholesale fruit and vegetable market (mandi), New Delhi, India. During peak harvest season of banana in Maharashtra grower's cooperative, a full train load is hired on regular basis to Azadpur wholesale fruit and vegetable market, New Delhi. Full train loads during peak season are necessary for banana. For highly perishable commodities, one or two AC bogies are also hired for specific

periods. Litchi may be taken as an example where AC bogies are hired for transportation of litchi from Muzaffarpur, Bihar, to Maharashtra.

Air

Airlines are used exclusively to ship a few high-value and extremely perishable products to domestic and export markets. It is the most expensive mode of transportation. Berries and cherries are the products most commonly shipped by air. Most berries, strawberries, are sold at a price high enough to compensate for the higher transportation cost. Produce is loaded in suitable small containers for placement in the aircraft. Using disposable insulation and dry ice inside the container also can help maintain lower transit temperatures. Be sure to check with the airline for regulations on the use of dry ice. Permanently insulated containers also are available for produce shipping.

Ship

Ship is not a very common mode of transport in India. It accounts less than 1 % for fresh produce transportation. However, all imported fruits from other countries are transported by ship only. Ship carries refrigerated containers of size 35 or 40-ft, each with its own electric refrigeration powered by the ship's engines. Some containers are equipped with modified atmosphere systems to increase the shelf life of produce. Dry containers without refrigeration are also used for hard commodities, although refrigeration is recommended. Containers of fresh produce are shipped by Chennai and Mumbai port to South East Asian countries and Europe.

Mango Transportation

Trailers or refer vans are used for mango. It should be cleaned, sanitized, and precooled to the desired shipping temperature prior to backing up to the dock. The purpose of precooling is to bring the interior surface of the trailer to the desired carrying temperature. If the interior of the reefer container is hot, the produce may be spoiled and quality deterioration is sure. Failure to precool may result in heat transfer from the trailer body, which will warm the fruit. Reefer units should be turned off during loading. Running the reefer unit while loading may cause icing of the evaporator coil. Transportation to the stores has proven to be a critical step for mangos because of lack of proper control of temperature conditions and potential rough handling.

Commodities are generally transported to the stores in a mixed load refrigerated truck cooled to the lowest temperature needed for an item in the load. Quite often, this is colder that mangoes can stand without getting damaged. Ripe mangoes can tolerate temperatures below 50 °F (10 °C) during transportation better than unripe mangoes. For long transportation time from facility to stores, transportation temperatures below 54 °F (12.2 °C) should be avoided. Additional measures, such as wrapping the mango pallets in plastic and placing them in the warmest part of the truck, can help to minimize chilling injury during transportation.

Transportation is a connecting link between producers and consumers. It holds key factor in postharvest quality maintenance of all fresh produce. Most fresh produce in India and other countries of the world is transported from farmers' field to nearby market or wholesale market and from wholesale market to terminal market up to final retailers' shops in open and non-refrigerated vehicles. Only few reputed firms use refrigerated vehicles for transportation and distribution in summer months only, starting from March to May/June in India. It is mainly due to the increased cost of transportation by refer van. In open truck vehicles (Non-refer), produce is always susceptible to a loss of quality. Ambient temperature alone spoils the produce. Other means of transport include rail transport (A/C and non A/C), air, and ship. All imported fruits are transported in A/C containers by ships only. In every country, a dedicated port is assigned for receiving and dispatch of fresh produce containers. In India, a large number of fresh produce containers are received at Mumbai and Chennai port.

After harvest, a number of vehicles (trucks, tractors, trains, boats, ships, utility vehicles, etc.) are used to transport the product from field to either packing houses or wholesale or retail markets. These vehicles are not equipped with refrigeration units and thus the produce decays faster, compared to that in refrigerated vehicles. If the produce is treated with edible wax or chemicals or additives after harvest, it can withstand little longer distances in open vehicles (non-refer), without much damage. Refrigerated vehicles (trucks, trains, ships, airplanes, etc.) contain installed refrigeration units with sufficiently low temperatures to maintain freshness in fresh produce. These types of vehicles are sealed with insulation material inside the walls of the container, which maintains the inside container temperature at desired level and thus preserves maximum quality.

Fruits and vegetables must be classified in order to separate those susceptible to cold temperatures (mango, banana, tomato, etc.) and those that are not (apple, pear, cauliflower, peppers, etc.). This eliminates the possibility of product damage (chilling and freezing injury) when cooling at low temperatures during transport. Refrigeration temperatures can vary from 0 °C (32 °F) to 13 °C (55.4 °F) and RH from 70 to 95 %. Refer van transport is an example of temporary refrigerated storage. Mixed loads cause incompatibility problems in transport also because packaging dimensions are different for different produce and it is not fully stackable. It is, therefore, not advisable to transport mixed lots for long distance. However, for short distance, there may not be any problem.

There is usually little or no humidity control available during transport and marketing. Thus, the packaging must be designed to provide a partial barrier against movement of water vapor from the product. Plastic liners designed with small per-

forations to allow some gas exchange may be an option. The rate of quality deterioration depends on many factors mentioned below:

(a) Road condition and duration of transportation
(b) Pattern of loading
(c) Stacking height
(d) Refer and non-refer transportation

Road Condition and Duration of Transportation

Both road condition and duration of transportation affect quality of fresh produce. In hilly tracks and rough road surface, more touching and bruising take place as compared to smooth surface. Longer duration during transportation also affects quality. Refer van should not be hold unnecessary. It not only increases the cost of produce, but also affects quality.

Pattern of Loading

Pattern of loading also plays crucial role in maintaining quality of fresh produce. Here pattern of loading means number of packed boxes in one layer (stacking height). In case of fresh produce, stacking height depends on extent of perishable nature and strength of packing materials. If produce are more perishable or box strength is weak, stacking height is kept low and vice versa.

For example, height of grape boxes is kept low or it is packed in five ply corrugated boxes or thermocol boxes. This precaution must be taken to preserve postharvest quality of this highly perishable commodity. *While loading*, *another important criterion is interlocking between the boxes*. Loading and unloading fruits and vegetables directly affect quality of fresh produce. It can be done either by hand or with the aid of a forklift. Forklift is used for palletized boxes and shipping containers only.

Generally, fruits and vegetables are stacked on pallets to ease the loading and unloading process and to prevent damage to the product. Exported crops arrive at the unloading port in bulk containers and are unloaded directly into the storage container with the aid of conveyor belts connected from the vehicle to the container.

Another important consideration while loading is interlocking systems of loading. In this system, a little space is left in each layer on alternate basis (once in left side and once in right side). This facilitates air movement through the produce and provides strength to the boxes during transportation. Exposure to sun while awaiting loading at local mandis or transport can reduce quality drastically. The exposed portion turns black or brown and starts decaying. It is advised for non-refer transport to move continuously while under sunlight and stop and park vehicle under a tree shade especially during sunny days.

General Dos and Don'ts for Transporting Perishable Commodities

- Do not overload the vehicles; by avoiding overloading, one can reduce compression damage.
- Always stack heavier produce at the bottom of the load.
- Don't climb on the boxes while loading and unloading; where climbing is unavoidable, put your legs on the corner of the box (the strongest portion of any CFB box).
- Use strong packages with moisture proof lamination; more than half of the staking strength of corrugated fiber board may be lost during a 5-days journey in high humidity environment.
- Avoid rough handling during loading and unloading.
- While stacking boxes, make sure that corner of the boxes should fall on the same line as most of the strength of a corrugated box is in the corners.
- Prevent or minimize vibration damage by using air suspension system.

Chapter 13
Commercial Quality Assessment of Important Fruits

Introduction

The primary goal of any fruit quality assessment team is to ensure that only those consignments should be received that confirms correct maturity stage and that is free from major disease and insect infestation. For example, apple should not be affected with sooty blotch and apple scab. Both the diseases are highly unacceptable in the market especially during off-season sale. At the receiving dock, visual observation and few tests are carried out. On the basis of these primary tests, quality assessment team can assure the acceptance or rejection of any consignment. The received consignment may be stored after sorting and grading for off-season sale. Rejected fruits after sorting are sold in the local market or nearest possible market in the season itself and only good quality fruits should be stored for off-season sale or export. The quality assessments of few important fruits are described here.

Mango Quality Assessment at Receiving Dock

The most important visual observations used at the receiving dock for maturity and free from external defects are full development of shoulder (Fig. 13.1) and free from any physical damage, disease, insects, pests, etc. The internal flesh color with firmness largely defines maturity of mango. The following quality parameters are strictly judged by the quality officer before accepting the lot.

- Mangoes should be mature (firm), but not ripe and soft
- It should be free from any mechanical damage and disease infestation
- There should not be mixing of varieties. Mixed lots are likely to be rejected
- Shape and size of a mango in any consignment should be uniform up to 90 %

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DOI 10.1007/978-3-319-21197-8_13

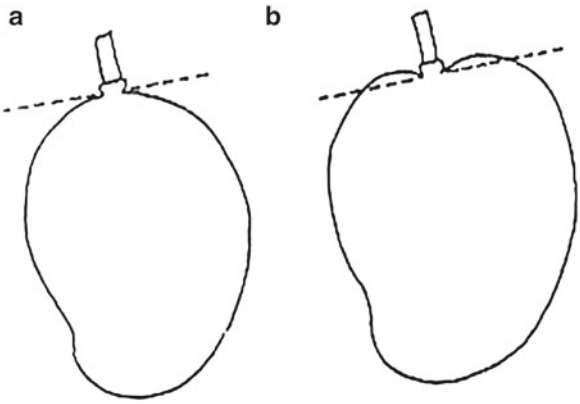

Fig. 13.1 Immature (*left*), mature (*right*)

- Maturity at receiving can be judged by testing more than one parameter, including flesh color, firmness, total soluble solids (TSS), and fruit shoulder shape (Fig. 13.1a, b). Figure 13.1a denotes immature mango and Fig. 13.1b mature mango. Always use a combination of maturity standards holds true for all fruits
- Latex flow (mango sap) over the fruit should be minimum
- Check TSS with refractometer and firmness with pressure tester

Maturity/Ripeness Indicators and Assessment of Quality: Procedure

- Remove a thin patch of skin along the cheek portion of the mango
- Be consistent in the amount of skin removed for each tested sample
- Place the mango on a firm surface for testing pressure
- Using a penetrometer with an 8 mm (5/16″) tip, measure the fruit firmness
- Repeat the process on the other cheek and record the average
- Avoid hitting the seed during the test
- A table top mounted penetrometer is more accurate and consistent than a handheld penetrometer (Fig. 13.2)

Total Soluble Solids (*TSS*) increases as the fruit matures on the tree and continues to increase during postharvest ripening. It is referred to as °Brix or percentage and should not be used as the only measure of maturity, but it can be a useful supplement to other indicators. It is measured by hand refractometer (Fig. 13.3).

- Remove the peel and collect a small piece of pulp
- Keep it in a muslin cloth and squeeze
- Apply a drop of the mango juice to the prism of the refractometer and take a reading
- Ensure that the refractometer is clean and has been reset to ZERO
- A refractometer range (0–32 °Bx) is most commonly used for fruit juice and pulp
- Refractometer works on the principle of refraction of light (Light passes from on medium to another medium)

Fig. 13.2 Handheld penetrometer

Fig. 13.3 Refractometer (*left* Erma and *right* Atago)

- Temperature of juice affects the reading. A temperature of 20 °C is supposed to be ideal. Any deviation from this temperature may be corrected as per International Temperature Correction Table and expressed as °Brix. However, on commercial scale, such correction is not required.

Internal Flesh Color

It is one of the most reliable indicators of maturity/ripeness. Immature mangoes will have white or very pale yellow flesh. With increased maturity, the yellow flesh color begins to develop from the seed outward. After harvest, as the mango ripens, the depth of color increases.

External Skin Color

It is generally NOT a reliable indicator of maturity, quality, or ripeness. Cultivars such as Malda remain green on the outside, even when fully ripe. It is a common misperception amongst consumers and sometimes retailers that red skin is an indicator of mango quality. In fact, the red color is a varietal trait that can be impacted by the position of the fruit on the tree. It is not related to eating quality.

Apple Quality Assessment at Receiving Dock

The primary goal of apple quality assessment is to ensure that only storable lots or consignments should be received that confirms correct maturity stage, pressure, free from any disease, physiological disorder, and insect infestation. At the receiving dock, visual observation and few destructive tests are carried out. The penetrometer reading or flesh firmness coupled with starch iodine test defines maturity and storable quality of apple. The following quality is strictly judged by the quality officer before accepting the lot.

- Apple should be mature (firm), but not ripe and soft
- It should be free from any mechanical damage, physiological disorders, disease, and insect infestation
- Shape and size of apple in any consignment should be uniform up to 90 %
- Maturity at receiving can be judged by testing more than one parameter, including seed color, firmness, TSS, and starch iodine test. Always use a combination of maturity standards for better result
- Check firmness with pressure tester or penetrometer. Take two readings in opposite side of 3–4 fruits per consignment of 10 crates. If number of crates increases, accordingly sample size for testing will increase
- Pick sample from upper layer, middle layer, and bottom layer. A sample should represent whole lot or consignment.

Maturity/Ripeness Indicators and Assessment of Quality

- Peel a thin patch of skin/peel from the middle portion of fruits and insert Probe of penetrometer up to the ring mark on the knob as shown in Fig. 13.4. First, peel one side, take reading, and then repeat on other side of the same fruit.
- Be consistent in the amount of skin removed for each tested sample.
- Place the apple on a firm surface for testing pressure. Hold the fruit tightly while testing the pressure.
- Hold the pressure tester in the right hand and fruit in left hand with a support of any firm surface and puncture the fruit at a constant speed.

Fig. 13.4 Penetrometer box (*left*) with two plungers and peeling knife (*middle*) and testing (*right*). Note ring marks on the plunger (*middle*)

- Now mounted table top pressure tester is also available and should be used for more number of samples and with more accuracy. The proper speed of penetration is about 2–3 s.
- Use *11 mm tip* (big tip in the penetrometer box) and penetrate to a depth of 7.9 mm or up to the ring mark on the plunger tip. Penetrometer box with tips and peeling blade is shown in Fig. 13.4.
- Repeat the process on other side of the fruit and calculate the average reading of all samples. The average reading will give the best result.
- A table top mounted penetrometer is more accurate and consistent than a handheld penetrometer.
- Record the reading in lb-force. A pressure of 16 lb or above is considered good for Indian apple. A pressure of 18 lb and above considered good for CA storage. In imported apple, a reading of 22 lb and above is supposed to be ideal for CA storage. Fruits should not be stored for more than 2 months if firmness (Pressure) is below 16 and above 14 lb (14–16 lb). If pressure is below 14 lb, the consignment is not recommended for CA storage. In normal cold storage also, the same principle is applied.
- Take care not to take the firmness readings on the top of the elevated portions of the five lobes of the fruits as these readings may be wrong.
- Discard firmness readings, which are too low or too high. This may be either due to faulty machine or wrong procedure.
- The fruits should be at uniform temperature to avoid variations arising out of temperature.

Precautions: We Must Take Little Precautions During Measuring Pressure Test

- Do not use fruits with sunburn for pressure testing.
- Operate the plunger at a constant speed.

Fig. 13.5 Mounted hand pressure tester

- Applying pressure too fast will give false readings. Too slow is also not recommended.
- After testing is over in an orchard or 20–30 samples, clean the tip of the plunger with a tissue paper.
- At the end of the day remove the plunger tip, wash it and dry, and then store in the box.
- All determinations for a given lot should be made by one person to minimize errors.
- Use handheld in the orchard and mounted pressure tester at storage site (Fig. 13.5).

Total Soluble Solids

It is not a major maturity standard in case of apple. However, it is observed that a TTS value of 12 and above gives an indication of maturity. TSS increases as the fruit matures on the tree and continues to increase during postharvest ripening. To determine TSS, the same procedure is applicable as in the case of mango.

Determination of Total Soluble Solids

- Remove the peel and collect a small piece of pulp
- Keep it in a muslin cloth and squeeze (a lemon squeezer or garlic press is useful here)
- A small cut portion with attached peel may also be squeezed to get one or two drops of apple juice
- Apply one to two drops of the apple juice on the prism of the refractometer and take a reading
- Ensure that the refractometer is clean and has been reset at ZERO

Internal Seed Color

It is one of the most reliable indicators of maturity/ripeness of apple. Immature apple will have white seed. As maturity advances, the white seed color begins to turn black. An apple with black seed confirms full maturity. Growers mostly use seed color and skin color as maturity indices.

External Skin Color

It is also a reliable indicator of maturity, quality, or ripeness. However, the development of color depends on variety, chilling requirement, and height of the orchard. Huybrechts et al. (2003) reported that peel color also acts as a maturity index for some cultivars of apple and can be used to determine the maturity of the fruit. Peel color is also used for grading in many countries before storage or marketing (Watkins 2003).

Cultivar such as Granny Smith, peel color remains green, even when fully ripe. It is a common misperception amongst consumers and sometimes retailers that red skin is an indicator of apple quality. In fact, development of red color is a varietal trait and depends on many factors such as position of the fruit on the tree, orchard location, and cultural practices. It is not related to eating quality but sale price of apple largely depends on peel color. More red peel color fetches more price and vice versa.

Starch Iodine Test

Starch Iodine test is a reliable test used for judging maturity and quality for apple and pear. This method is widely used by many fresh produce companies like Adani Agrifresh Ltd., Fresh and Healthy Enterprises, Harshna Naturals, Reliance Fresh, Future groups, etc. This test is mainly used for judging storage quality of apple.

The method involves cutting the fruit from middle portion horizontally in two halves and dipping the half portion containing pedicel end into a solution containing *4 % potassium iodide and 1 % iodine* (Potassium iodide solution). The cut surfaces stain to a blue/black color in places where starch is present. Starch converts into sugar as maturity advances. The developed black/blue color is compared with a chart and based on the value the quality of apple is judged. As fruit advances towards ripening, more starch is converted into sugar, and the blue/black area becomes less prominent (Fig. 13.6). Ripening usually takes place from the core of the fruit towards the skin. All important stages of apple maturity in Granny Smith are shown in Fig. 13.6, and the description about the color stages is listed in Table 13.1. This is also applicable in almost all apple cultivars. The procedure is described below.

- Cut the apple at right angles to the core midway between the stem and calyx end.
- Starch iodine test is one of the important tests for determining the maturity of apples and assessing their suitability for long-term CA storage.
- Dip pedicel end cut surface in iodine solution.
- Dip one piece of apple in the iodine solution for 2 s, remove and drain away any excess solution, and rate the fruit after 2 min. The entire process is depicted in Fig. 13.2.

Fig. 13.6 Starch iodine color chart for apple (Reid et al. 1982)

Table 13.1 Description about the color development stages

Color development	Descriptions	Remarks
0	This is immature fruit, harvesting should not be done at this stage	
1	This is border line stage between immature and mature. Check other harvesting parameters at this stage like seed color (should turn black)	Indian apple (Red and Royal Delicious) is ready to harvest at this stage for storage in CA storage
2	Perfect mature stage, ideally suitable for both CA and normal cold stores	Best suited for CA stores
3	Over mature, not suitable for CA and normal storage or temporary storage for 1 month or less	This stage is ideal for immediate marketing
4	Over mature, an advance stage over 3. Not suitable even for distant market sale	Immediate sale in nearby cities or market is preferred
5	Towards senescence stage, mealy texture with no or little juice	Less commercial value
6	Advance stage of senescence, mealy texture, little pressure, not juicy at all	Not liked by consumers

- Rate the fruits using the five-point scale provided in Fig. 13.3.
- Red Delicious fruits with starch index rating of 2.25–3.0 are good for Controlled Atmosphere Storage.

Precautions

- The potassium iodide—iodine solution is light sensitive and has to be stored in an amber colored bottle in dark.
- Try to prepare fresh solution every month for assessing the starch levels.
- The solution is toxic to humans and animals. Ensure to dispose the tested apples and thoroughly wash the material used for testing.
- During the process of preparation of the solution and testing, make sure the area is well ventilated to avoid the effects of toxic iodine fumes.
- Wash hands after completion of the test.

Banana Quality Assessment at Receiving Dock

Banana quality assessment is generally done in the field where separation of hands from loom (whole bunch) is necessary. Hand separation and treatment with fungicide is carried out in the farmer's field. The hands are packed in plastic crates for transportation. The quality team should ensure that only those bunches should be harvested

that confirm correct maturity stage. Roundness of fingers (Fig. 13.5a, b) is the most important maturity criteria for banana. Other maturity indices include drying of inflorescence or flowers at the tip of the fingers, color and size of fingers. At the receiving dock, only visual observations are carried out. However, the following quality should be strictly judged by the quality officer before accepting the lot for ripening and further handling.

- Banana should be mature (firm), but not ripe and soft
- It should be free from any mechanical damage, physiological disorders, disease, and insect infestation
- Shape and size of banana in any consignment should be uniform
- Maturity at receiving can be judged by angularity of fingers, dried inflorescence, etc. Always use a combination of maturity standards for better results
- After ripening treatment, the development of color will provide quality and marketing strategy as shown in the color development guide (Fig. 13.6) and description of the color is provided in Table 13.2

Table 13.2 Description of the color development stages for handling of banana

Indicator numbers	Quality parameters	Descriptions	Remarks
1	*All green*	Firm and hard fruits with very low sugar content. Before retailing, ripening treatment is suggested	Appropriate stage for long distance transportation
2	*Light green*	Fruit becomes less firm as starch begins to convert into sugar. Ripening process has begun and fruit generates heat which must be removed to control ripening	This stage confirms beginning of ripening process
3	*More green than yellow*	Fruit softens as starch converts into sugar continued. Heat generated in ripening chamber must be removed	Long distance retail delivery recommended
4	*More yellow than green*	Indicates proper color for retail display. Many consumers prefer to buy at this stage	This is firm yellow stage
5	*Yellow with green tips*	Proper color for retail display provides good consumer acceptance	This is soft yellow stage
6	*Full yellow*	Soft fruit with good flavor. Fruit should be on display shelf and not in storage	On the same day, consumption is recommended
7	*Yellow with brown flecks*	Brown flecks indicate high sugar, mealy texture, and fungal infection	Senescence started

Grape Quality Assessment at Receiving Dock

Grape quality assessment also starts at the field, where disease free and properly mature bunches are selected. In general, more than one harvesting is applied in case of grape. The best quality is harvested in the first harvesting. It is mostly done for export. The remaining quality is harvested at once or twice. The major quality criteria are bunch weight, berry size, free from disease, disorders, and TSS. Other maturity indices include color and size of berry. At the receiving dock, only visual observations are carried out including measurement of TSS. However, the following quality should be strictly judged by the quality officer before accepting the lot for ripening and further handling.

- Individual bunches should not be less than 250 g.
- Bunches should be free from powdery mildew and mealy bug.
- All those consignments are rejected if powdery mildew or mealy bug is noticed irrespective of size and TSS.
- Physiological disorders like hard berries, pink berries, yellow berries, water berries, etc. are also checked.
- Water berries are more problematic than any other disorders. Therefore, lots with water berries should be straightaway rejected.
- Determination of TSS is same as described above. Care should be taken that the TSS of last berry, i.e., the berry at the tip position of the bunch should be selected for testing. If this berry's TSS is OK, then full bunch is supposed to be OK.
- Size of berry is very important. Size graders are available and are called grape size graders.

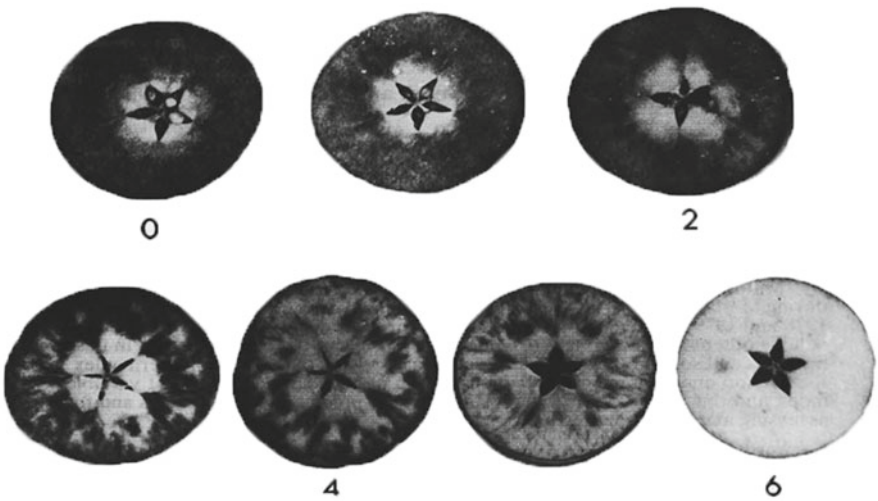

Fig. 13.7 (**a**) Mature. (**b**) Immature

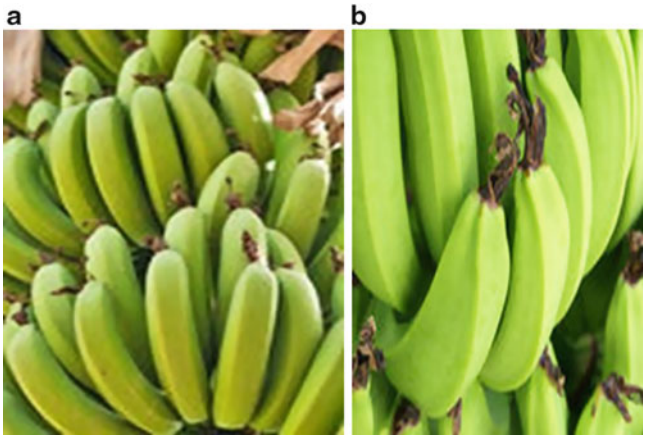

Fig. 13.8 Color development guide for handling banana

- Selection of orchard is also as important as receiving quality at dock. Bunches infested with powdery mildew and mealy bug should not be selected.
- Bagging is an important cultural operation in quality grape production. Orchard without bagging should never be selected for export.
- At least 2 days before harvesting debagging is necessary.
- Harvesting should be completed by 10.0 AM in the morning and cushioned crates should be used to bring the harvested produce. Generally, newspaper or bubble sheets are used as cushioning material.
- Berry droppings are also a major problem in grape handling. It is tested by holding one berry taking whole weight of the bunch. Bunches are also sometimes shaken. One or two droppings are allowed.

Kinnow Quality Assessment at Receiving Dock

Kinnow quality assessment also starts at the field, where orchards are selected. The orchard should be disease free, and plants should not be very old. Kinnow fruits should have properly matured. Harvesting is done with fruit clippers, and a close cut is given leaving only a small portion of pedicel. The major quality criteria are size of fruits, absence of rusetting, firmness, thickness of peel, and absence of disease. At the receiving dock, only visual observations are carried out including physical damage. However, the following quality should be strictly judged by the quality officer before accepting the lot for further handling.

- There should be small portion of pedicel.
- The peel should not possess scratch at pedicel end.

- Fruit should be free from stem end rot.
- Size of the fruit is very important. Size grading is attached with washing and waxing units.
- Uniform waxing is most essential as it reduces water loss and provides glossiness to the fruits.
- Plastic crates are used for harvesting and subsequent handling to the pack house.

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Chapter 14
Non-destructive Quality Analysis of Fruits

K. Prasad

The time-dependent variations in the physiological, textural, compositional and sensory characteristics associated with the fruits open a vast area for research possibilities in order to meet the consistent demand of associated professionals involved from handling to delivering fresh or processed form of fruits to the consumers (Siddiqui and Dhua 2010). Some of the characteristics associated with fruits are having profound correlation over the physiological changes happening during fruit maturation, ripening and senescence (Siddiqui et al. 2014b). Variations in the environmental parameters thus affect the basic metabolic activities of respiring and transpiring fruits, and it is not surprising to expect great variations in post-harvest characters and behaviour of fruits. Fruits are classed on the basis of plant parts used and also on the respiration behaviour. The structural features help in deciding the handling, suitability and performance of the fruits on machine. Whereas, the respiration behaviour of fruits describes the ways in which this important commodity should be harvested, handled, transported, treated and stored effectively (Siddiqui et al. 2014a).

Fruit Characteristics

Botanically, fruit is a matured ovary with or without seeds. Eucarp is the fruit that results after fertilization, where ovary forms fruit and ovule changes into seeds. Seedless fruit is formed without fertilization and known as parthenocarpic fruit. The fruit, pseudocarp, develops from other floral parts like thalamus, perianth or bract in fusion with the pericarp, a mature wall of ovary. The ovary of the flowers grows into a fruit and is called as true fruit, but other floral parts that develop into a fruit is classed under the category of false fruit. The fruits in general may be among the simple, aggregate or composite fruit. The fruit consists of three distinct portions such as epicarp, mesocarp and endocarp. The epicarp forms the outer skin surface of the fruit and shows distinct variations among fruits, fruit type of different

M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8_14

varieties and at different physiological stage. The fleshy middle edible portion is often termed as mesocarp. The endocarp is the central portion of the fruits, which may be thin and membranous in case of orange and hard or stony in case of mango.

The associated variations in the characteristics of fruits limit the consumers' preference for their final utility. Limited emphasis has been paid to screen the processing suitable cultivar. Enormous challenges are placed before the processor to develop the quality processed produce from the existing fruit cultivars having variable maturity levels. Sorting and grading of the fruits are often advised to introduce uniformity in the fruit quality as part of standardization of quality and fresh marketing. The characteristics which determine the raw material suitability for intended purpose may be classed under external or internal quality attributes or sensory, hidden and quantitative attributes. Sensory attributes include size, shape, defects, colour, taste and aroma. Nutritive values and the presence of harmful and toxic substances which are not assessed by senses are categorized under hidden quality attributes. Fruit crop yield and finished product yield are the quantitative attributes deciding the quality of fruits.

External Quality Attributes

Size and Shape

The size and shape are other important characteristics of fruits important for selection of raw material for processing purposes. Uniformity in size and shape facilitates effective handling and processing operations such as peeling, coring, slicing or filling. Size and/or shape-dependent sorting is thus effective in reducing the material wastage, rapid processing at reduced processing cost for the production of high quality fresh or processed produces. The size of the fruits varies in the range of light to very heavy depending on the fruit structure (Table 14.1). Variations in the shape of the fruits pose the difficulties in lending on machine for various mechanical operations. Aspect ratio, sphericity and taper ratio are the important parameters considered while developing automatic fruit processing line.

Table 14.1 Classification of fruits on the basis of size

Size	Weight range (g)	Fruits
Light	<50	Cashew nut, strawberry
Medium light	50–250	Guava, banana, orange
Medium	250–500	Mango, plantain
Medium heavy	500–1000	Avocadvo
Heavy	1000–5000	Papaya, pineapple
Very heavy	>5000	Jack fruit, water melon

Colour

Colour is the most important quality attribute to assess the quality of fruits both in fresh and processed form. Colour of fresh fruit is often associated with the extent of ripeness and thus considered as an indirect indicator of texture, flavour, nutritive value and so the wholesomeness. Chlorophyll is the derivative of dihydroporphyrin, chelated with centrally located magnesium atom mainly responsible for the green colour of the fruit in immature state. Chlorophyll is present in the chloroplast in association with carotenoid, lipid and lipoprotein. Diminishing masking effect of chlorophyll on carotenoid pigment possibly by the mechanism of chlorophyll breakdown to colourless entity is generally reflecting the appearance of carotenoid and other characteristic pigment present on the skin of the fruit during the process of fruit ripening (Fig. 14.1).

The change in the colour during ripening of fruits should yield full, intense and uniform colour on the entire fruit skin for better quality fresh produce and used as the prime quality assessment characteristics. Changes in the surface features of the ripening banana are shown in Fig. 14.2.

Defects

Defects are the imperfections found to be associated with the fruits may be due to genetic or phenotypic reasons. The unfavourable environmental conditions, excessive moisture loss due to process of transpiration, mechanical damage, insect attack

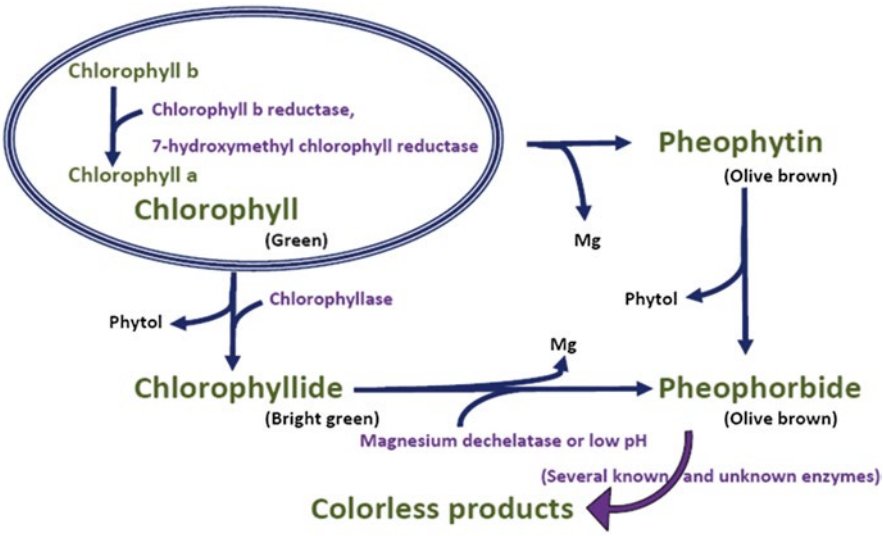

Fig. 14.1 Chlorophyll degradation mechanism

Fig. 14.2 Ripening of banana

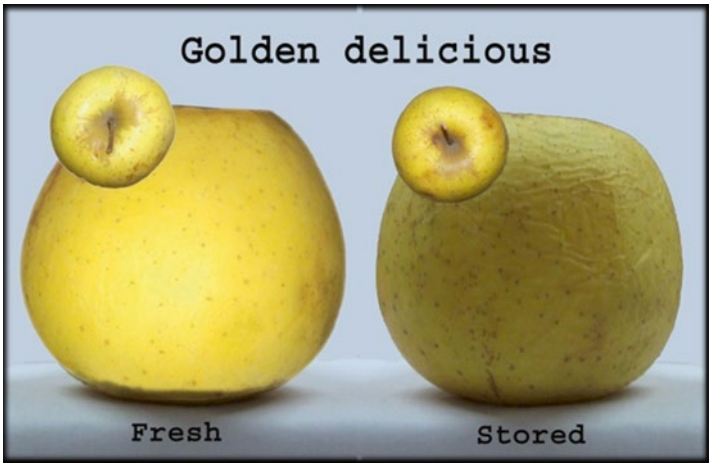

Fig. 14.3 Fresh and stored golden delicious apple

or microbial invasion affect the quality and appearance of the fruit. The shrivelled appearance of stored golden delicious apple is compared with the fresh one (Fig. 14.3). Harmful foreign materials such as soil, stone, glass particles or injurious chemicals are also considered as fruit defects.

Internal Quality Attributes

Flavour

Tropical fruits are known for the intense and attractive flavour, which retains even after processing. The crop season further affects the flavouring characteristics of fruits. Summer fruits are generally richer in flavouring constituents when compared to winter fruits. The monsoon oranges are more acidic and have less attractive colour than winter oranges, while guava is sweeter with better flavour in winter than in rainy season. Sweetness, sourness, bitterness and astringency are the taste components when mingled with the aroma components yield characteristic flavour to the fruits.

Texture

Texture is the important rheological feature of the fruit and measured using texture analyser, pressure tester, etc. Firmness is an important textural parameter of the fruit; on the one hand, it describes the stage of fruit maturity and on the other hand reflects the presence of fibrous or other polymeric material responsible for the firmness of the fruit. Fully ripe but firm fruits are suitable for canning purposes, whereas the over ripe fruits are not suitable. Thus, the desirable textural characteristics are of utmost important feature for describing the suitability of fruit variety and with specific physiological stage for the purpose of utilizing fresh or for processing.

Nutritive Value and Toxicity

Being under the class of protective food, the fruits are supposed to be the important source of micro-nutrients such as vitamins and essential minerals, apart from the available macro-nutrients provided as essential components of human diet and served as table commodities as food of choice. The chemical composition is thus important and is hidden attribute of fruits describing the quality. Succulent fruits become more nutritive as they approach maturity and optimum ripeness. Deep yellow or orange coloured flesh reflects more of carotene content as compared to pale flesh. The excessive use of toxic chemicals even persist in the fruit as residual chemical and affect the quality of the fruits apart from the health hazard associated personnel.

Post-harvest Physiology

Premium quality of fruits is obtained on harvesting at proper stage of maturity. Immature fruits yield erratic ripening whereas over mature fruits become susceptible to damage during handling and transportation; they are prone to decay resulting in poor quality having less marketability. Harvesting is the term that applies to the process of detaching the fruit from the plant. Fruits on removal from the parent plant are deprived of their normal supply of nutrient. Most of the tissues remain capable of transforming the constituents still present in them. The diversity in the metabolic shift which is commodity specific is manifest in the process of ripening and rotting and leading to other physiological disorders. Storage longevity of fruits is thus mainly dependent on the intensity of physiological activities during post-harvest period. Ripening is the process of physical and biochemical changes taking place in the fruit after cessation of growth till the onset of senescence or decay. Fruits are generally harvested at the horticultural maturity for off-the-tree ripening to avoid the damage caused by birds, insects, etc. During ripening, important changes in the respiration rate, transpiration rate, texture, carbohydrate, flavour pigment, organic acid, tannin and enzyme activity are evident. Respiration rate increases to attain maximum at climacteric peak followed by the steady decline during senescence are the basic feature associated with tropical fruits unlike continuous decline in respiration rate in non-climacteric fruits (Fig. 14.4). The ratio of CO_2 to O_2 is the term used for respiratory quotient used to deduce the nature of substrate used in respiration, completeness and types of process either aerobic or anaerobic. Loss of water from the fruit if more than 5 % through the process of transpiration reflects the fruit

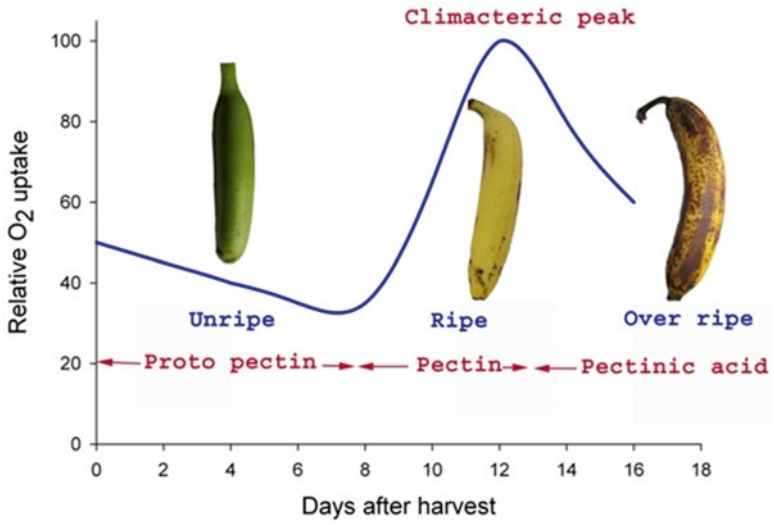

Fig. 14.4 Climacteric pattern of respiration with changes in fruit

surface shrivelled enough and the fruit becomes unattractive with the loss of eating quality. Wax coating, application of cling film and proper packing could successfully retain the freshness of the fruits by reducing the moisture loss due to transpiration.

Softening or decrease in fruit firmness during ripening is the important textural change. The turgor pressure due to hydrostatic pressure generated by absorbed water in parenchymatous cell helps in maintaining the desirable fruit crispness. The cell wall made up of cellulose fibrils in a matrix consisting of pectic substances, hemicelluloses, proteins and lignin further assists in maintaining the characteristic textural properties. The enzymatic change of insoluble protopectin into soluble pectin finds the role in softening of fruit apart from the loss of turgor pressure during storage of the fruits.

Chlorophyll, anthocyanin, flavonoids, leucoanthocyanins, tannins, quinines and carotenoids are the plant pigments that undergo changes during post-harvest storage due to extrinsic as well as intrinsic factors. The change in the colour may be correlated with the other associated quality attributes. The amount of organic acid gradually found to be decreased during ripening in most of the fruits following the process of respiration. The reduction in the polyphenolic content is associated with the developing fruits. While activity of most of the enzymes may positively be correlated with the respiration rate of fruit subjected to ripening.

Considering the above variations and the requirement, the process of ripening may be enhanced or retarded artificially. Colour, gloss and other optical characteristics are distinct and even dependent on the stage of maturity, which is helpful in deciding accurately the physiological stage of maturity before applying either the growth regulators, inhibitors or modifying the environmental conditions for the intended purposes.

Sorting and Grading

Sorting or grading of fruits is the utmost important step for improving the acceptability and for meeting the quality standards laid by the buyers, industry or governmental agencies. Some of the difference in quality of fruits is either due to genetic, environmental or horticultural factors. The basic aim behind sorting is to grade the fruits into premium qualities separated with culled fruits. Primary properties applied in sorting are shape, size, degree of ripening, colour, extent of physical injury, etc. Sorting and grading should be viewed to include all such operations that segregate the raw materials with a mixture of attribute into distinctive groups of uniformity in a particular characteristic. Grading of fruits thus improves marketing efficiency, reduces the disputes over quality between sellers and buyers, enhances farmer's bargaining power, eliminates resorting and repacking in intermediary, and could effectively eliminate the practice of topping or camouflaging. Sorting is an important unit of operation applied mainly to segregate undesirable with acceptable and outstanding individual pieces to ensure the quality uniformity.

Quality Characteristics

Quality is the term referred to as the degree of preference or excellence of any produce, which reflects the sensory, chemical, nutritive, engineering and microbiological characteristics or defects. High quality produce always succeeds, and the firm maintaining the quality is mostly recognized. Objective of production, handling and distribution of fruits is to meet the needs of consumer and thus enhance turnover as a result of quality practices (Kalia 2010; Harrison 2003).

Various methods are applied to determine the quality characteristics of fruits to meet the set legal, voluntary, industry or consumer standards (Gunasekaran and Irudayaraj 2001). Conventionally, the methods applied to assess the quality attributes may be subjective, which may be based on the judgement of examiner or objective basically based on the standard scientific approach of evaluation, which are primarily unique. The non-destructive quality assessment techniques are becoming popular in present days for the firms that involve in quality assessment and sorting or grading of post-harvest produce (Jha 2010).

Non-destructive testing method of evaluation is the process of determining particular characteristics without affecting the ability of fruits to fulfil their intended use. An understanding of quality post-harvest produce is thus essential for the cultivators, processors, transporters, distributors and importers for onward effective utilization. Advancement in sensors for measuring several attributes at a time on subjected every piece of fruit serve the purpose of high speed sorting through the use of non-destructive approach. The application of soft computing technique such as fuzzy logic, artificial neural network and multivariate statistical classification procedures with appropriate control mechanism to physically place the individual piece into proper category by artificial intelligence is based on mechanical system of present day demand (Prasad 2012).

The available non-destructive technique being the objective method of quality assessment is of high accuracy and reproducibility. Whereas, the subjective method based on sensory method of quality evaluation techniques simultaneously reveals several quality attributes but with less precision as well as reproducibility. Thus, possibility of precise quality assessment for superior or inferior fruits within the lot may not be possible through subjective technique precisely. To estimate any quality attribute through non-destructive approach, appropriate correlation must be established among the instrumental measurements, sensory responses and perceived quality or acceptability with the results of non-destructive parameters.

Quality Assessment Techniques

Post-harvest produce could be assessed either by subjective or sensory methods or by analytical or objective methods (Ranganna 2007). Sensory-based methods have their own limitations in assessing the quality of hazardous materials (Jha 2010). Whereas, objective method of quality evaluation may either fall under destructive

or non-destructive categories. Manual sorting based on sensory aspect is labour intensive, costly, subjective, slow and mostly unreliable. Sorting of larger quantity of fruits involves rapid, online, non-destructive analysis to ensure quality characteristics.

Many non-destructive techniques are developed to assess the quality characteristics of fruits and those are classified according to their underlying physical principles. Visual inspection, X-ray imaging, computed tomography, infrared spectroscopy, ultrasonic testing, electromagnetic testing, magnetic particle testing, acoustic emission testing, magnetic resonance imaging (MRI) and complex impedance spectroscopy are some of the non-destructive approaches in quality assessment techniques. Concerted efforts are required to put in for accelerating the development of own commodity-based non-destructive approach in developing post-harvest sorting and grading mechanism to save huge post-harvest losses. Important non-destructive techniques related to applications of electromagnetic radiations through imaging and image analysis with associated theories and applications are covered in this chapter.

X-Ray and Computer Tomography

Non-destructive quality evaluation through imaging employs the properties of electromagnetic waves, which are partly but not completely transparent to the subjected object. Electromagnetic radiation, combination of oscillating electric and magnetic component mutually perpendicular sinusoidal wave propagate in space with the speed of 3×10^8 m/s. The nature and applicability of electromagnetic radiation depends on the associated wavelength (Fig. 14.5).

X-Ray is an electromagnetic radiation having the wavelength ranging from 10 to 0.01 nm with the frequency of 30×10^{15} to 30×10^{18} Hz. Wavelength of X-rays is greater than γ rays and shorter than UV rays. Artificially controlled production of ionizing radiations is extensively used in medical diagnostic radiography and also in computed tomography (CT). The bombarded electron approaches faster and close to the nucleus, deflected and leaves less quickly with losing some of its energy and release as soft X-ray, which form a continuous X-ray spectrum with low photon energy. Usually, tungsten or more crack-resistant alloys of rhenium (5 %) and tungsten (95 %) are applied but molybdenum is found suitable for generating the soft X-rays for specialized purposes in order to diagnose the soft tissues. In X-ray diffraction crystallography, copper or cobalt target is used (Jha et al. 2009a, b; Prasad et al. 2010b, 2012). Approach of multiple projections is applied to assess the internal structure or defect present in any object. The formed projections in thin cross sections of the object with the scanned X-ray beam are precisely detected and organized to provide the structural integrity in the form of image in computed tomography. The formed image thus becomes the direct reflection of original object on applying computed tomography. The applicability of X-ray is reported for the quality evaluation of different foods. X-ray penetrates the exposed objects depending on attenuation, primarily dependent on density (Tollner et al. 1992).

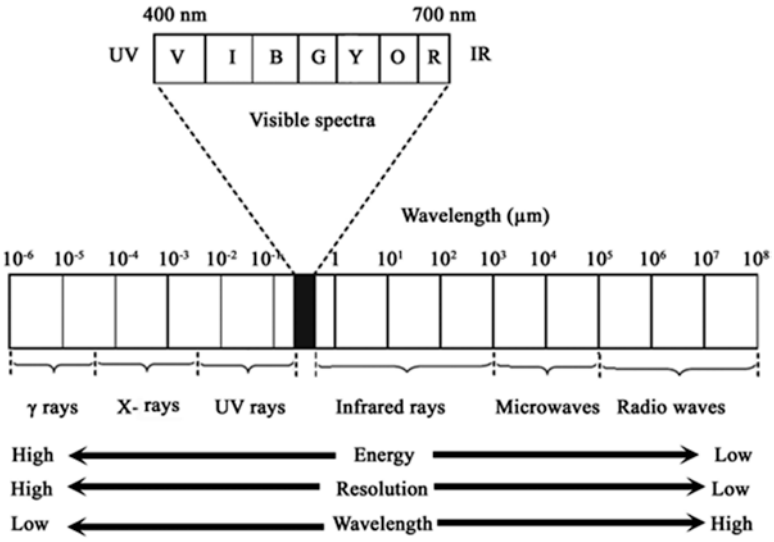

Fig. 14.5 Electromagnetic spectrum

Applications X-Ray and CT

Conventionally, two-dimensional radiography is mostly used whereas line scanning is used for assessing the products by getting either two-dimensional or three-dimensional images for checking of objects through computed tomography (Lim and Barigou 2004). For total quality evaluation, X-ray and CT information should be clubbed with other investigation techniques. Exhaustive information is available for its application in the determination of size distribution, thickness and porosity measurement (Lim and Barigou 2004). Physiological changes are associated with the growth, maturation, ripening and senescence of fruits (Fig. 14.4). X-Ray could be used to assess the extent of cell breakdown and physical damage which has the adverse effect on quality of the fruits (Zaltzman et al. 1987). Similar to the detection of hollow heart in potato (Nylund and Lutz 1950; Finney and Norris 1978) other fruits' quality or internal injuries could be identified by this method. Similarly, changes in densities of tomato during maturation (Brecht et al. 1991), peaches (Barcelon et al. 1999) and lettuce (Lenker and Adrian 1971; Schatzki et al. 1981) as reported could be used for other fruits. To detect the split pit in peaches, olive and cherries during the process of ripening is reported (Han et al. 1992; Tollner et al. 1992; Keagy et al. 1996). X-ray absorption differs depending on the density and moisture content and by employing this technique, moisture content in apple is determined (Tollner et al. 1992) with internal defects and bruises in apples, damages in papaya (Suzuki et al. 1994), and granulation in oranges (Johnson 1985). Digitized

X-ray imaging is reported for the internal injury of fruits (Yang et al. 2006). Pore-size distribution of different apple cultivars is reported using this technique (Mendoza et al. 2010). In packaged sorting of freeze damaged citrus fruits, using X-ray is reported (Abbott et al. 1997).

Visual Inspection and Image Processing

Consumers are consistently attracted towards fruits or vegetables which have characteristic visual appearance, texture and nutritional value. Images could be obtained in both visible and non-visible range. The image acquired in visible range extends from 10^{-4} to 10^{-7} m wavelength. Visual appearance illustrates the external quality of fruits followed by other attributes like aroma, flavour, taste, sweetness, sourness, firmness, and nutritional value of fruits. Grading of fruits by visual inspection lack consistency and occasionally due to shortage of labours work may impediment which result in company loss. Numerous research papers show that adoption of image processing technique helps to escalate the efficiency and consistency of grading fruits and vegetables as well as reduce human error. Non-destructive testing used to elaborate the relationship between peach maturity and colour using machine vision. Image processing is applied to characterize shape and orientation of strawberry. Classification of cucumber with the help of neural network system and image analysis has been worked out. Tomatoes are graded on the basis of maturity, shape and surface defects using machine vision system. Computer vision algorithm is developed to anticipate seven ripening stages of banana. Colour attribute is often obtained and examined using RGB, HSV and CIELAB colour spaces and applied in predicting the ripening stages of bananas and found above 94 % prediction accuracy. Image analysis is becoming popular as non-destructive evaluation as it is suitable for online monitoring for real-time sorting and grading applications.

Steps of Image Analysis

Image analysis system applies the process of image acquisition, processing and interpretation to extract the desired data to evaluate the quality of subjected fruits. Extracted features of image are further processed using soft computing or multivariate technique for quality assessment. Camera as image acquisition system used as analogous to eye, computer software program resembling the function of human brain applied to facilitate processing of acquired image in preset histogram equalization, segmentation and analysis leading to quality evaluation (Gunasekaran 2001; Prasad et al. 2010a, 2012).

Application of Visual Inspection

Non-destructive methods for measuring various quality parameters applicable on optical method based on direct imaging. The reflected, transmitted, absorbed or scattered light is recorded and considered as fingerprints in characterization of pigmented fruits. During growth, maturation, ripening and senescence of fruits external as well as internal attributes varies.

Dimensional Characterization

The dimensional parameters through image analysis have successfully been assessed for caronda fruits (Prasad et al. 2010a). Apple (*Mauls domestica*) of cultivars Red delicious, Golden delicious, Maharaji, Ambri and American trel were assessed for dimensional and optical characteristics (Sheikh 2012). Each fruit was analysed for dimensional characteristics for the linear dimensions. Length (*L*), width (*W*) and thickness (*T*) were measured as reported (Fig. 14.6) elsewhere and verified using a digital calliper with an accuracy of 0.01 mm (Mitutoyo Corporation, Japan). The derived parameters such as geometric mean diameter, aspect ratio, sphericity and packing coefficient were also determined.

On the other hand, if the size of the fruit is small then useful magnification should be employed for clear cut visualization, processing and further characterization of materials (Prasad et al. 2012). The leaf powder in similar fashion was dimensionally assessed (Singh and Prasad 2013). Using image analysis technique, the particle size and particle size distribution characteristics have been analysed and reported elsewhere.

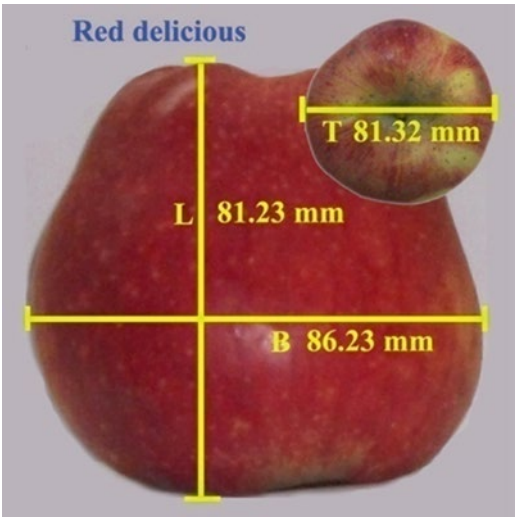

Fig. 14.6 Dimensional characteristics of apple

Fruit Firmness Estimation

Firmness is a significant quality and textural attribute of fruits that can alter the desire of purchasing. It also decides the harvesting period as well as shelf life of the fruits. Firmness can be evaluated by compressing or puncturing the horticultural products with particular probe which is a type of destructive testing. Modulus of elasticity of banana decreases as banana peel colour change from light green to yellow. The appropriate correlations have been found to have the reproducible textural parameter as ripening changes the starch content into sugar. Similar, observations for the textural characteristics has been found in case of mango.

Quality Grading Based on Colour

In many tropical and subtropical fruits, colour value is changed with maturity and ripening. Colour value indicates the maturity stage of any fruit whether unripe, ripe or over ripe. In case of banana, green colour indicates unripe stage, yellow peel colour as ripe stage and brown spot indicates over ripen stage (Fig. 14.4). Different colour model is used to define the colour of fruit like CIE $L^*a^*b^*$, RGB (red, green, blue), XYZ and CMYK (cyan, magenta, yellow, black) with the help of computer vision. CIE $L^*a^*b^*$ is correlated to human vision system. CIE $L^*a^*b^*$ gives consistence colour. With the help of image analysis, colour intensity of the fruit's skin is examined more precisely and automatically. Instruments like colorimeter and chroma meter are employed to evaluate the skin colour of fruits, but it may misguide the individual as these instruments promote small portion to view and inspect, which limit the area of study and provide insufficient information. Such limitation can be avoided using image processing technique where region of interest could be selected from the image for colour and dependent characteristics measurement. Mean colour intensity value is used to classify the maturity stage of banana where highest mean intensity value is reported for the over ripened banana and lowest mean intensity value is reported for unripe banana. Depending on the correlation analysis, the non-destructive image analysis based on colour has been thus reported as the best before using the concept in the ripening banana (unpublished data).

Optical properties of apple cultivars were assessed in terms of RGB value found to vary from 171.3 ± 18.1 to 209.8 ± 40.1, 71.5 ± 33.4 to 189.8 ± 43.5 and 56.3 ± 8.17 to 85.2 ± 28.7, respectively. Among selected cultivars, the colour value of fresh Golden delicious apple was found to have significant difference in colour attributes (Fig. 14.3). The acceptability of the fruits depends on the uniform external colour, gloss with the absence of defects, dents, browning and bruising. Thus, the external characteristics especially the colour may play the critical role in quality characterization in online system based on non-destructive evaluation based on optical method.

Ultrasonic Imaging

Ultrasound is longitudinal wave having the frequency more than the upper audibility limit of sound, i.e. 20 kHz. Low power ultrasound has been explored as analytical and high power ultrasound for processing purposes. Interest of low power ultrasound is increasing due to its use as non-destructive, non-intrusive and non-invasive technique (Prasad et al. 2000). Ultrasound on passing through biomaterial causes the wave to attenuate due to absorption, scattering or reflection. Absorption of wave energy arises due to chemical relaxation, structural viscosity and volume viscosity and rotational isomerism (Singh and Prasad 1997).

Imaging techniques using ultrasonic have been applied extensively in a situation of spatial heterogeneity of food materials. The absorption and reflection of ultrasound in the material and at boundaries are basically used in characterization. Attenuation or loss of energy occurs owing to the absorption and scattering of sound in and from the material.

The attenuation can be expressed by the equation:

$$I_x = I_0 e^{-2ax}$$

I_0 = Initial sound intensity
I_x = Intensity at depth x
e = Base of natural logs
x = Depth in tissue
a = Amplitude absorption coefficient

The absorption coefficient "a" increases as frequency of sound increases. The possible sound penetration depth is inversely related to applied frequency (Fig. 14.7). Investigation at more depth lower frequency of ultrasound must be used.

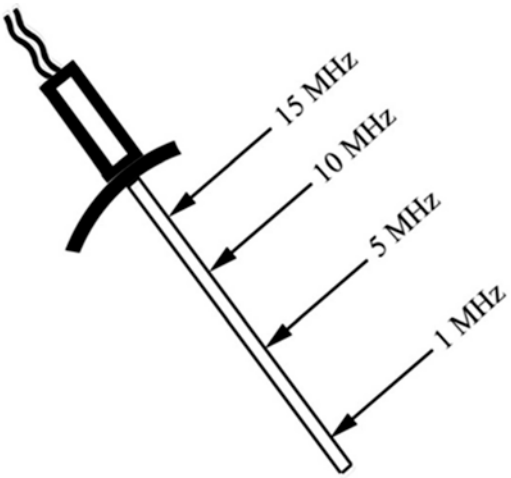

Fig. 14.7 Penetration depth as function of frequency

Absorption of ultrasound in the material is expressed as

$$S = \frac{20 \log\left(A_0 / A_x\right)}{x}$$

S = Absorption
A_0 = Amplitude at zero depth
A_x = Amplitude at depth x
x = Depth in tissue

Accordingly, sound absorption in tissue is approximately 1 dB loss/cm/MHz. Acoustic impedance (Z) is the characteristics reflecting the amount of sound energy reflected from or transmitted through different materials is determined using density (δ) and velocity (v) of the sound passing through the material.

$$Z = \delta v$$

Ultrasound passing through the subject continues until it faces boundary of another material of different impedance. Thus, materials of different acoustic impedance establish an acoustic boundary in determining the characteristics of the materials (Coupland and McClements 2001). Percent of ultrasound wave reflected can be calculated as per the following equation:

$$R = \left[\frac{Z_2 - Z_1}{Z_2 + Z_1}\right]^2 \times 100$$

R = Percent of sound beam reflected
Z_1 = Acoustic impedance of first material
Z_2 = Acoustic impedance of second material

Amount of sound transmitted through the material can be calculated as:

$$T = \frac{4 Z_2 Z_1}{\left(Z_2 + Z_1\right)^2} \times 100$$

T = Percent of sound beam transmitted

The total reflected and transmitted ultrasound at the boundary must be equal to 100 %.

$$R + T = 100$$

The material resolution is an important characteristic for ultrasonic imaging. It demonstrates acoustic boundary that lie either parallel (axial resolution) or perpendicular (lateral resolution) to the propagated ultrasound beam. Higher frequencies result in the shorter wavelengths and thus distinguish the smaller objects with increased resolution (Fig. 14.8).

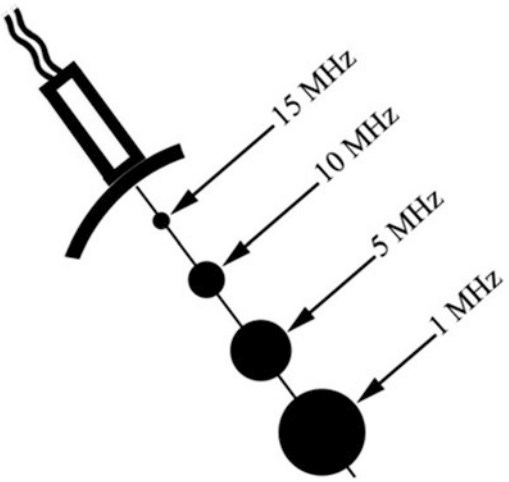

Fig. 14.8 Resolution as function of frequency

Application of Ultrasound

The features of non-invasive, precise, rapid and potential for real-time application pave the way for the low power ultrasound, a versatile non-destructive evaluation tool in quality assessment of raw or processed fruits (Povey and McClements 1988; Mittal 1997). Optically opaque materials could also be assessed for the quality with limitation if food is aerated, as air is highly attenuated. The effect of the porosity substantially increases the air space. Ultrasonic technique has been found to be having good potential for non-destructive evaluation of pre- and post-harvest quality assessment of fresh fruits. Fruit development is associated with change in chemical and mechanical characteristics. This change could be observed with the use of changes in the ultrasonic properties.

Ultrasonic imaging technique closely resembles other precise method applied for the characterization of fruits (Sarkar and Wolfe 1983). Vegetables being irregular in shape and high intercellular air cells restrict the versatility of the result with high reproducibility. Hollow heart of potato has successfully been assessed in non-destructive ways (Yanling and Haugh 1994). This technique could also be used for texture measurement during the growth and development of fruits of apple, banana and avocado (Mizrach 2008). Feasibility of ultrasonic sorting for the mealiness levels and distinguishing the bruised from unbruised tissue in apple was explored. The physicochemical properties of mango, firmness of melon and sugar content were evaluated.

Magnetic Resonance Imaging

The hydrogen nuclei containing a proton are naturally abundant in plant material, which has the property of nuclear spin and imparts magnetic properties to nucleus in image formation. Random orientation of protons present in materials results in no net magnetic field but placing under strong external magnetic field (B_0), protons spin and align themselves in particular direction either parallel or anti-parallel to the applied magnetic field. Parallel direction is at lower steady-state energy and a small excess of protons is seen aligned in this direction. The microscopic magnetizations of these excess protons sum up into a net magnetization vector (NMV) or longitudinal magnetization (M_0). The strength of this longitudinal magnetization determines the maximum available signal strength, which linearly increases with the strength of B_0, providing the primary reason for the use of higher field strength. Application of radio frequency (RF) pulse yields in absorption of energy. This pulse is also termed as excitation pulse. Absorption of this applied energy results in an increased number of high energy spin up nuclei. Applying the right amount of energy results in the number of nuclei in the spin up position equals down position. The transverse magnetization vector processes in transverse plane thus producing in a time varying magnetic field. This induces current signal forms basis for image formation in MRI.

Applications of Magnetic Resonance Imaging

It is a non-destructive and non-invasive technique to get two- or three-dimensional MRI images. Extraction of morphological characteristic is the main goal in case of first category of MRI imaging, where phase contrast is not desirable. Cost involved in the nuclear MRI in not a practically feasible technique despite providing the high resolution images of internal structures of intact fruit (Clark and Burmeister 1999). Nuclear MRI for the horticultural produce has been reviewed extensively (Clark et al. 1997; Faust et al. 1997; Abbott et al. 1997; Mariette 2004). This technique is highly precise in providing the in-depth information physiological changes in fruit tissues during development, ripening, storage and processing for internal quality evaluation. Wider application of MRI in detecting the morphological changes during growth, ripening and processing operations are well illustrated (Chen et al. 1989; MacFall and Johnson 1994; Faust et al. 1997). Water core as internal deformities of apple have been demonstrated. Magnetic resonance image of orange showing the segments with the membranes is reported (Hinshaw et al. 1979). As hydrogen nuclei show higher response to magnetic fields, NMR to measure moisture content and its distribution has been demonstrated. Variations in moisture concentration and state of water were assessed under ripe, defected and decayed fruits to evaluate the maturity and quality parameters for understanding the physiological processes (Faust et al. 1997).

Changes in the mealiness of apple under controlled atmospheric storage were assessed for apple using MRI techniques. MRI was also applied to assess the seed of oranges in online inspection (Hernandez et al. 2005). MRI has effectively been used to determine the distribution of apparent micro-porosity in fruits. The microscopic quality characterization could also be performed as the unit operation where changes in the moisture and ice formation during freezing of fruits are examined. Packaged foods could successfully be examined using MRI technique.

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M.S. Ahmad, M.W. Siddiqui, *Postharvest Quality Assurance of Fruits*,
DOI 10.1007/978-3-319-21197-8