Review Article

Post harvest handling of fruit crops

Abstract

Fruits are classified as perishable agricultural commodities. When fruits are harvested prematurely or when they are overripe, their storage life is shortened and their quality deteriorates. Therefore, it is important to harvest fruits at the appropriate stage of maturity in order to ensure good quality and better storage. Nevertheless, the inadequate implementation of proper handling techniques for agricultural produce has led to a significant occurrence of post-harvest losses, resulting in the wastage of valuable resources such as time and financial investments. The lack of appropriate handling procedures and chemical treatment methods is leading to significant losses in commodities. Therefore, it can be deduced that producers are currently experiencing significant economic detriment as a result of inadequate handling techniques, insufficient understanding of the underlying factors contributing to postharvest loss, and a dearth of effective preservation methodologies. However, the mitigation of loss can be achieved through the implementation of appropriate management and handling procedures. This review focuses on various aspects of post-harvest handling methods for preservation of fruits for longer time, which will help farmers to derive more profit through processing and value addition.

KEY WORDS:Post-harvest, handling, fruits, storage, packaging, Shelf-life

INTRODUCTION

The current global population, estimated at 7.87 billion, is experiencing an annual growth rate of approximately 1.03%. Based on projections, it is anticipated that by the year 2050, the world population will reach approximately 9.6 billion. India, with a population of approximately 1.38 billion individuals, constitutes approximately 17.5% of the global human population (**U.N. World population prospects, 2021**). In the present era, the most significant obstacle lies in the provision of a consistent, secure, and nutritionally sound food supply to accommodate the rapidly expanding populace. Henceforth, a total of 195 nations have collectively resolved to embrace sustainable development goals (SDG) as a means to tackle the pressing issue of malnutrition through a comprehensive approach, with the intended completion date set for the year 2030 (**Achadi*et al*. 2016**). The heightened consciousness among consumers regarding the physiological advantages associated with the consumption of fruits serves as a significant impetus for their consistent incorporation into a nutritionally well-rounded dietary regimen. The global demand for fruit with high nutritional value has experienced a substantial surge in recent years. This surge can be attributed to the desire to improve individuals' nutritional requirements and capitalize on the positive impact these fruits have on immunity and metabolism of human body **(Meena *et al*. 2022)**. Nevertheless, a significant issue pertaining to these particular crops revolves around their inherent perishability and their ability to respire and transpire subsequent to the harvesting process. This phenomenon leads to an undesirable occurrence of excessive softening, which is strongly linked with ripening, during the storage phase following harvest (**Hegazy, 2013; Shipman *et al*., 2021**).This can be termed as "post-harvest loss of fruits" since the quality and shelf-life of fruits tends to start decreasing after the harvesting. The primary factors contributing to postharvest losses are the occurrence of deterioration of fruits, mechanical harm, inadequate handling practices, suboptimal temperature and humidity control, and challenges related to hygiene during the handling process**(Singh *et al*., 2022)**. The phenomenon known as postharvest loss (PHL) possesses the capacity to detrimentally impact the state of food security and nutrition by exerting influence upon the four fundamental pillars of food security, namely availability, access, usage, and stability. When the reduction of losses occurs, there is an observable improvement in both the accessibility and availability of the fruits **(Alegbeleye*et al*., 2022)**. The mitigation of post-harvest losses in fruits serves as a supplementary method to enhance production. It may not be imperative to escalate the production of fruits in response to increasing demand, provided that there is a significant reduction in post-harvest losses. The cost associated with mitigating post-harvest losses, in general, is comparatively lower than the cost incurred in producing an equivalent quantity of fruits and vegetables with similar quality attributes (**Sudheer and Indira, 2021**).So, this review is an attempt to describe about various techniques and problems associated with post-harvest handling of fruit crops.

Post-harvest Factors affecting post-harvest quality of fruits

The following are only a few of the numerous postharvest conditions that might lower the quality of freshly harvested crops:

1. Maturity Stage
2. The harvesting techniques
3. The Harvesting time
4. Precooling
5. Sorting and Grading
6. Palliative care, packaging, and packaging materials
7. Packing materials (foam net, paper cuttings, rice straw, etc.) used as Cushioning.
8. Storage
9. Forms of Storage
10. Temperature during warehousing and shipping
11. Relative humidity (RH) when in storage or transit
12. Loading and unloading routine

Post-harvest handling of Fruits

Pre-cooling: The aforementioned practice is a mandatory procedure implemented in developed nations for nearly all perishable commodities. The process of expediting the reduction in temperature of recently harvested agricultural products from their initial field temperature (referred to as pulp temperature) to the optimal temperature for storage is scientifically referred to as precooling **(Brosnan and Sun, 2001).** This phenomenon holds significant importance as it effectively enhances the longevity of the agricultural yield. The reduction of field heat has been observed to have a significant impact on the rate of respiration and all biochemical reactions occurring within newly harvested produce.

Given that fruits, vegetables, and flowers exhibit signs of vitality even after being harvested, it is evident that these agricultural products persist in engaging in the process of respiration. Respiration leads to the degradation of produce, encompassing the reduction of nutritional content, alterations in texture and flavor, and diminishment of mass **(Duan *et al*., 2020)**. These processes are inherently irreversible, yet their rate of progression can be substantially reduced through the implementation of precooling techniques prior to storage or distribution **(Sargent *et al*., 1988)**. The application of the four fundamental precooling methods is contingent upon the inherent texture and commercial worth of the product. The aforementioned methods encompass forced air cooling, hydro cooling, vacuum cooling, and icing. Every method was devised with particular crops in consideration **(Ahmad and Siddiqui, 2015)**.

Forced Air cooling: Forced air cooling is the most effective precooling technique for fruits, utilised globally to prevent field heat, disease development, softening, and weight loss. This procedure removes field heat by quickly moving cold air across a product. Fans in a cool storage area draw air from produce crates into the cooling unit **(Thomson *et al*., 2008)**. The utilization of forced air is highly efficient in the cooling of various commodities, with a particular emphasis on its suitability for berries and stone fruits, which are more effective to this specific cooling technique.

Vacuum Cooling: The produce is introduced into a hermetically sealed chamber, wherein the atmospheric pressure is significantly diminished. Under reduced atmospheric pressure conditions, a phenomenon occurs wherein a portion of the water present in the produce undergoes a process akin to boiling, facilitated by the utilization of the produce's internal thermal energy. This process leads to the conversion of water into its gaseous state, consequently resulting in a reduction of the produce's overall temperature. The extraction of heat and moisture from the vacuum tube is achieved through the utilization of mechanical refrigeration (**McDonald and Sun, 2000)**.

Hydro Cooling: The process of hydro cooling involves the utilization of chilled water to lower the temperature of perishable agricultural commodities. Therefore, the process of cooling packed fruits using this particular method presents challenges. The process of cooling water typically involves the utilization of mechanical refrigeration, although alternative methods such as the utilization of cold well water and ice are occasionally employed. The dimensions of hydro cooling units exhibit variability contingent upon the scale of the operation, nevertheless, substantial refrigeration or copious amounts of ice are indispensable for maintaining the water at the targeted temperature range of 33–36 °F. The produce undergoes a cooling process facilitated by a water bath or sprinkler system. A considerable assortment of fruits that possess the ability to endure exposure to moisture can be subjected to the process of hydro cooling**(Teruel *et al*., 2004).**

Icing: Crushed or slurry ice is introduced directly into the container containing the perishable agricultural commodities. The utilization of this method has demonstrated efficacy in the precooling process of specific vegetable containers. The produce has the capability to undergo rapid cooling within a brief duration, thereby enabling the preservation of its temperature during transportation as well **(El-Ramady*et al.*, 2015)**.

Sorting and Grading

This process is primarily undertaken to ensure the high standard of packaging and removal of produce that is afflicted with diseases or defects from the batch. The implementation of appropriate sorting and grading methodologies provides a level of confidence in the quality of agricultural products. This activity is typically conducted either within the agricultural field or within designated storage facilities**(Ahmad and Siddiqui, 2015)**. Both manual and mechanical graders are employed for the purpose of grading. Mechanical graders are capable of efficiently grading fruits and vegetables that possess a spherical shape. Grading can be accomplished by evaluating the attributes of color, size, and the magnitude of imperfections. On the other hand, the process of Sorting relies entirely on human labor to eliminate fruits or vegetables that are afflicted with diseases, defects, or damages **(Londhe *et al*., 2013)**.

Washing

The practice of fruit washing is relatively infrequent in India, particularly among farmers. The establishment of this facility has been undertaken by fruit business enterprises either within their pack house or at a cold storage facility. The process of washing may not be deemed essential for certain fruits, such as grapes and litchi. The removal of natural wax from grapes during the washing process, as well as the introduction of browning in litchi fruit, are crucial factors contributing to their extended shelf life and enhanced visual appeal. Fruits such as Apple, Plum, and guava are strongly advised to undergo a thorough washing process prior to being placed in storage.In the context of pome fruits, it has been observed that the act of washing prior to storage yields advantageous outcomes. This practice serves to augment the humidity levels within the designated storage chamber, specifically the Controlled Atmosphere Storage Chamber (CASC), thereby resulting in a reduction of spoilage occurrences **(Özden, Ç., &Bayindirli, 2002).**

Application of ethylene inhibitors/growth regulators for postharvest treatment

It was observed that the presence of 1-methyl cyclopropene had an inhibitory effect on the production and/or action of ethylene in fruits during the processes of ripening and storage**(Yuan et al., 2010)**. It has been reported that gibberellic acid (GA), kinetin, and silver nitrate can slow down respiration rates of fruits**(Ahmad and Siddiqui, 2015)**.

Thermal treatments

Thermal Treatment might be hot water, vapour heat, or hot water rinse brushing. Heat treatments are a common non-chemical strategy for reducing postharvest deterioration and insect infestation in many fruits.

Hot water treatment: Fruits can be subjected to immersion in heated water as a means of managing diverse postharvest pathogens (such as larvae and inoculums) and enhancing the pigmentation of the fruit peel. In the context of mangoes, it is advised to subject them to a high water temperature (HWT) of 50-52 °C for duration of 5 minutes. This specific thermal treatment is employed to effectively eliminate larvae of the fruit fly and concurrently manage and diminish the prevalence of microbial infections that may arise during the marketing process. The aforementioned treatment facilitates the achievement of homogenous ripening within a span of 5-7 days **(Anwar and Malik, 2007).**

Vapor heat treatment: The observed treatment exhibited a high degree of efficacy in the management of fruit fly infection within confined containers **(Schirra *et al*., 2000; Armstrong and Mangan, 2007).** The boxes within the designated space are arranged in a vertical configuration in a room and then it is subjected to an increase in thermal energy and moisture content through the introduction of steam via injection **(Singh and Saini, 2014).** The temperature and exposure duration are carefully manipulated to effectively eliminate all developmental phases of insects, namely eggs, larvae, pupae, and adults, while ensuring the preservation of the fruit's integrity **(Anwar and Malik, 2007).** A scientifically recommended treatment for citrus, mangoes, papaya, and pineapple involves subjecting them to a temperature of 43 °C in an environment saturated with air for duration of 8 hours, followed by maintaining this temperature for an additional 6 hours**(Ahmad and Siddiqui, 2015)**.

Hot water rinse brushing (HWRB): In this particular system, the fruits undergo a process wherein they are propelled towards brushes and subsequently enter a pressurized recycled hot water rinse. The temperature of this rinse falls within the range of 48 to 63 °C, and the fruits remain in this rinse for duration of 10 to 25 seconds. The HWRB system has been implemented in Israel and numerous other countries within the context of commercial packing lines, specifically for a diverse range of fruits and vegetables.The strawberry fruits subjected to high-temperature water bath treatment at 60 °C exhibited a reduced level of decay compared to the control fruits (**Jing *et al*., 2010**).

Fumigation (Sulfitation): The utilization of sulphur dioxide gas (SO_2) in fumigation has proven to be an effective method for managing postharvest diseases in grapes, particularly in the case of powdery mildew caused by the pathogen *Botrytis cinerea*.

Waxing: The edibility of these waxes has been observed and documented by numerous individuals involved in the field, indicating their potential as a viable postharvest intervention for prolonging the storage duration of various fruits, such as mango, Kinnow, and sweet orange (**Ahmad *et al*., 2005; Abbasi *et al*., 2011; Shahid and Abbasi, 2011).**The advantageous outcomes of waxing primarily encompass an enhanced visual aspect, diminished moisture depletion and contraction, mitigated postharvest deterioration, and an extended duration of storage.The materials most frequently utilized in this context encompass paraffin, carnauba, and shellac. Each of these raw materials possesses distinct and disparate properties that dictate its lustre, gas permeability, and other physical attributes.

Packaging of fruits

Packaging can be precisely characterized as the amalgamation of artistic, scientific, and technological principles that are employed to guarantee the secure transportation of a product to the ultimate consumer, while maintaining its optimal condition, all while minimising the associated costs (**Selin, 1977**). When considering the selection of packaging containers for fresh produce, it is imperative to prioritise the prevention of physical injury and pressure damage during handling. In order to achieve an optimal shelf-life, it is imperative to minimise physical damage through the utilization of appropriate packaging (**Thompson, 1996**). The materials used for packaging generally include wooden crates, jute sacks, polyethylene, High Density polyethylene, Cardboard boxes/ CFB (corrugated fiber board) boxes. There are different packaging techniques according to the nature of produce:

1. **Modified atmosphere packaging**: Modified Atmosphere Packaging (MAP) is a cutting-edge technological approach which involves the deliberate alteration of the gas

composition within the package, achieved either through the natural respiration of the enclosed commodities or by purposefully manipulating the gas composition through the addition or removal of specific gases (**Boun and Huxsoll, 1991).** In the context of modified atmosphere packaging (MAP), it is important to note that there are two distinct methods employed to alter the atmospheric conditions within the packaging. The first method, known as passive MAP, involves the modification of the atmosphere through the natural respiration process of the commodity contained within the pack**(Thomas and O'Beirne, 2000)**. On the other hand, the second method, referred to as active MAP, entails the manipulation of the atmosphere by creating a slight vacuum within the packages. One potential method for the development of active modified atmosphere packaging (MAP) involves the strategic placement of gas absorbers within the packaging structure. The aforementioned absorbers have the capacity to absorb oxygen (O_2), carbon dioxide (CO_2), and/or ethylene (C_2H_4), thereby inducing alterations in the gaseous composition within the packaging (**Arte´s, 2000; Kader, 2002**). In both instances, the gas composition within the package deviates from that of the typical atmospheric air. The aforementioned modification has a direct impact on the duration for which a product can be stored, as it effectively maintains its overall quality. One of the primary limitations associated with the implementation of modified atmosphere packaging (MAP) resides in the possibility of a significant decline in oxygen (O_2) levels, which may reach a point where anaerobic respiration becomes prevalent (**Wilson *et al*., 2019**). This shift towards anaerobic respiration can subsequently lead to the generation of undesirable off-odors due to the occurrence of fermentation processes. Hence, the efficacy of Modified Atmosphere Packaging (MAP) is contingent upon the judicious choice of an appropriate film material, taking into account its permeability (specifically, the gas transmission rate) as well as the respiration rate of the product in question.

2. **Active Packaging**: Active packaging can be defined as a complex arrangement wherein the package engages with either the product or the headspace. The primary objective of this interaction is to uphold the nutritional and sensory attributes, as well as increasing the shelf life and safety of the food product (**Villa-Rodriguez *et al*., 2015**).Active packaging is predicated upon novel technologies that perpetually observe the dynamic gas environment, potentially engaging with the food surface, through the expulsion or

introduction of gases within a package, or via scavenging mechanisms **(Vermeiren *et al*., 1999)**.In this instance, a chemical reagent is introduced into the packaging film, effectively capturing the ethylene gas emitted by maturing fruits or vegetables. The phenomenon under consideration is commonly referred to as ethylene scavenging, and it is important to note that this chemical reaction exhibits irreversibility **(Gaikwad *et al*., (2020).** A minimal quantity of scavengers is necessary for the elimination of ethylene. This nascent technology exhibits intriguing prospects for pragmatic implementation in the domain of post-harvest management.

3. **Smart or Intelligent Packaging:** The packaging exhibits the capability to autonomously modulate the intake of oxygen and the outflow of carbon dioxide in response to the ambient temperature**(Yam *et al*., 2005)**. By employing this method, an optimal environment is upheld within the packaging or surrounding the product throughout the duration of storage and distribution. Therefore, by prolonging the state of freshness and facilitating the transportation of products with superior quality, the consumer is able to receive goods that maintain their optimal condition for an extended period of time. Smart packaging can be classified into two distinct categories: packaging that includes integrated circuits (ICs) and packaging that does not include integrated circuits (ICs), commonly referred to as chipless smart packaging**(Ghoshal, 2018).**

Storage of fresh fruits

Fruits exhibit a characteristic of being subject to seasonal variations in their availability. Annually, the process of harvesting occurs within a predetermined timeframe. The year-round demand for various fruits such as Guava, apple, Mango, grapes, and others is observed. This requirement can only be met by ensuring that fruits are appropriately stored during the harvesting season and subsequently sold during the off-season, specifically after the finish of the season (**Siddiqui *et al*. 2015**). The enhancement of quality cannot be achieved through storage, however, it is possible to uphold the existing quality or reduce the rate at which quality deteriorates within a predetermined timeframe (**Siddiqui and Dhua, 2010**). The monetary value of fruits exhibits an upward trend subsequent to their storage.Hence, it is imperative that only fruits of high quality (possessing the ability to be stored for extended periods) are designated for storage. The second crucial prerequisite entails the meticulous regulation of temperature and relative humidity within the storage chamber.

Traditional Storage Systems

Natural or field storage: The most rudimentary and primitive form of storage, known as the most basic and archaic system, continues to be employed for numerous agricultural produce. In the region of Jammu and Kashmir, located in India, it is observed that storage facilities are constructed within apple orchards. These storehouses are specifically designed to accommodate the storage of apples, which are packed in a manner that allows for minimal compression within wooden containers. The Evaporative Cool chamber operates based on the fundamental principle of evaporative cooling (**Roy and Khurdiya, 1986**). It is widely recognised as a highly significant and economically viable storage system. The notable characteristic of this chamber resides in its lack of power dependency for the purpose of cooling fruits. Consequently, the term Zero Energy Cool Chamber (ZECC) is employed to describe it. These chambers exhibit suitability solely for brief storage durations. The process of water evaporation occurs through the utilization of thermal energy derived from the surrounding environment leading to a subsequent decrease in temperature of chamber. The water vapours are subsequently dispersed by the unsaturated airflow leading to cooling **(Roy and Pal, 1989).**The ZECC facility is designed to regulate and sustain a controlled temperature within the range of 5 to 25 °C **(Kaur *et al*., 2021).**This temperature range is influenced by external factors such as ambient temperature and relative humidity, which impact the overall climate conditions within the facility. The aforementioned chamber is deemed appropriate for the preservation of a wide array of fruits and vegetables, with the exception of the allium species, specifically onion and garlic.

Modern Storage Systems

1. **Low Temperature Storage:** The reduction in temperature has been observed to have a decelerating effect on the metabolic processes of the product, as well as on the activity of microorganisms, which have been identified as the primary contributors to the degradation of product quality (**Makule*et al*., 2022**). Consequently, the preservation of food reserves is extended over an extended duration due to a decreased rate of respiration. Additionally, the process of ripening is delayed, and the vapour pressure between the food products and the surrounding environment is minimized, resulting in a reduction in the loss of water. A refrigerated chamber is a hermetically sealed and thermally insulated space commonly referred to as a cold storage facility **(Tashtoush, 2000).**Henceforth, cold storage can be

defined as a distinct enclosure or compartment, wherein the temperature is meticulously maintained at a significantly low level, in accordance with specific requirements, facilitated by mechanical apparatus.In numerous contemporary cold storage facilities, a humidifier is additionally installed to generate and sustain the necessary humidity levels **(Tang *et al*., 2020)**. A high relative humidity (RH) serves as a protective barrier against water loss, which has a significant impact on the texture, freshness, colour appearance, and overall quality of fresh produce.Uniform air circulation throughout the room is imperative. In order to optimise air circulation, it is imperative to ensure that packages are stacked in a precise and accurate manner.

2. **Controlled Atmosphere Storage**

Controlled atmosphere storage is a method commonly employed in the preservation of fruit, wherein the fruit is stored within an environment that is deliberately manipulated to possess reduced levels of oxygen (ranging from 1% to 3%) and elevated levels of carbon dioxide (also ranging from 1% to 3%) when compared to the typical atmospheric conditions**(Ahmad and Siddiqui, 2015)**. The primary tenet underlying controlled atmosphere (CA) storage involves the deliberate augmentation of carbon dioxide (CO_2) levels while concurrently diminishing the presence of oxygen (O_2) within an impermeable storage enclosure**(Bessemans*et al*. 2016)**. The storage units for CA (controlled atmosphere) typically consist of multiple chambers, wherein each chamber has a capacity ranging from 50 to 250 metric tones**(Badran, 1969).** The refrigeration system maintains 1–2 °C and 90–95% RH. Controlled atmosphere (CA) storage works best for pome fruits, notably apples and pears. This approach revolutionized apple and pear fruit sales worldwide**.** Apples can be kept in the refrigerated storage for 2–3 months, but they won't stay juicy beyond that.Apples stored in CA display no yellowing, maintain juice levels, and retain their crisp texture even after 5-6 months.

Transportation

Fresh horticultural produce undergoes transportation through two distinct methods within the confines of a given state, while between states, it is subjected to transportation through three distinct methods. The prevailing method of transportation within the states primarily consists of utility vehicles with a load capacity ranging from 1 to 6 metric tonnes, as well as trucks with a load capacity ranging from 8 to 16 metric tonnes. Trucks, trains and aeroplanes are three modes of transportation commonly employed for inter-state travel. Within the realm of inter-state transportation, it is evident that trucks, with a weight capacity ranging from 8 to 16 metric tonnes, reign supreme as the prevailing and paramount mode of conveyance**(Ahmad and Siddiqui, 2015)**. Subsequently, trains assume a secondary position in terms of prevalence and significance, while air transport occupies the lowest rung on the hierarchy of transportation mediums. Fresh produce is primarily transported between states using non-refrigerated trucks. The transportation of goods via ships in India is of minimal significance. The operational capacity of the Reefer van is limited to the summer months, during which it is utilized for the transportation of high-value domestic produce as well as imported fruits. The operation of the refer van and the demand for fresh produce are both experiencing an upward trend.

Reduction and prevention of contamination in fresh and fresh-cut produce

At various stages of manufacturing and distribution, fresh fruits are at risk of contamination by spoilage microorganisms and inorganic contaminants. As a result, various disinfectants are employed for the purpose of cleansing fruits. These treatments encompass a range of chemical agents such as chlorine-based compounds, hydrogen peroxide, ozone, cold plasma, electrolyzed water, and organic acids. Additionally, irradiation utilizing ultra violet (UV) radiation and heat treatments (HTs) are also employed in this context **(Florkowski *et al*., 2021)**.

CONCLUSION

The postharvest shelf life and quality of fruits are heavily influenced by various factors such as postharvest handling practices, treatments, and harvesting methods. Given the inherent perishability of fruits, it is imperative to utilize them promptly. Postharvest handling methods do not possess the inherent capability to enhance the quality of produce. However, they do have the potential to preserve the condition of the produce, provided that the handling process is executed meticulously. The fresh-cut sector prioritizesoptimizing processing lines to reduce quality losses and innovate products. Consumers want unique goods with bioactive chemicals that benefit human health. So, Post harvest technology need to adapt according to consumer needs. A perpetual interchange between scientists and the post-harvest processing industry is imperative to ensure the triumph of the post-harvest handling system. It is recommended that novel experiments be performed in authentic environmental contexts after their evaluation in simulated settings, namely laboratories or controlled cell chambers, in order to validate the findings within realistic scenarios.

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