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Post-harvest handling to reduce loss of fruits and vegetables

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Abstract

The main concerns of food security and global hunger in many countries is post-harvest loss. The amount of fruit and vegetable loss goes up to 50% accordingly, reduction of fruit and vegetable loss and waste is one of the major issues for providing sustainably to the world's population in the future. The main causes of post-harvest losses in fruit and vegetable occur during harvesting, post-harvest handling and packaging, processing stages, transportation and storage practices, distribution and consumption. So, the use of proper post-harvesting techniques, proper packaging, transportation and storage practice is very important to minimize the amount of post-harvest loss. So basically, this paper shows an analysis which shows the reasons of post-harvest losses of the fruit and vegetables and correct methods to decrease the losses.

Keywords: Post-harvest, loss, fruit, vegetables, food security

Introduction

Horticulture commodities harvested at an early stage of maturity have a worse quality and decay faster than those produced at a later stage of maturity. Harvesting beyond optimum maturity, on the other hand, results in a reduced storage life. As a result, the fruits should be harvested at the appropriate stage of maturation for improved quality and storage. And the operations, such as cooling, cleaning, sorting, grading, packaging, and shipping, are all part of the post-harvest handling process. It has some type of loss in both quality and quantity of perishable goods at all phases of post-harvest handling. The major goals of post-harvest horticulture are to increase shelf life, maintain quality, and reduce undesired changes. The best possible outcome attained in post-harvest handling operations is preserving the original quality of fruits or vegetables (Toivonen J & Terry, 2014).

Fresh horticulture crops have a wide range of morphological structures (roots, stems, leaves, and so forth), compositions, and physiological characteristics. As a result, commodity criteria and suggestions for maximum postharvest post-harvest of fruit and vegetables differ per commodity. Fresh horticultural crops have a high-water content and are susceptible to desiccation, mechanical, and phycological damage. They are also susceptible to bacterial and fungal attack, resulting in pathological collapse. Respiration, ethylene synthesis and action, rates of compositional changes, mechanical physiological traumas, water stress, sprouting and roots, physiological diseases, and pathological breakdown are all biological (internal and external) causes of degradation.

What is post-harvest loss

Post-harvest loss is defined as the loss that occurs between the time of harvesting and the time of consumption as a result of qualitative, quantitative, and food waste. Quality losses are those that affect the nutrient content, acceptability, and edibility of a specific product, and they are more common in developed countries (Kader, 2002) ^[11]. PHL can happen at any point in the post-harvest process. This article discusses the most prevalent forms of PHL, how to change them, and the cost-effectiveness of various technologies for doing so.

Food produced after harvest is one of several direct ways in which the value of distribution between consumer and producer is influenced. This is characterised as measurable quantitative (weight or volume loss) and qualitative (unwanted changes in the visual characteristics of food and lower nutritious content) losses that can occur at any point in the supply chain, from harvest through end usage (Hodges *et al.* 2011; De Lucia and Assennato 1994; Buzby) ^[9].

Such losses may cause the produce's worth to fall below its market value (Hodges *et al.* 2011) ^[9].

During harvesting, post-harvesting activities, handling, and storage, about 3.9 percent to 6 percent cereals, 4.3 percent to 6.1 percent pulses, 2.8 percent to 10.1 percent oilseeds, 5.8 percent to 18.1 percent fruits, and 6.9 percent to 13 percent vegetables were lost, according to an assessment of crop losses conducted by the Indian council of agricultural research in 2016. (Jha *et al.* 2016). On the other hand, according to the estimates of the committee on doubling farmers income (2019), farmers in India are unable to sell about 40% of total fruits and vegetable produce in the markets, resulting in a loss of around 63,000 crore per year due to their inability to sell produce in which they have already invested (Pandey 2018).

Due to the fact that approximately 80% of Indian farmers are small and marginal, post-harvest losses have a first-order effect on them. Apart from post-harvest losses, post-storage facilities in India enable smallholder farmers to sell their produce at cheap prices soon after harvest. Quality and quality losses owing to improper storage, particularly of high-value crops, have, on the other hand, been a key contributor to low farmer revenue and seasonal food deficiencies in households. Simultaneously, by empowering farmers in terms of market choice, the potential stranglehold of intermediaries and traders can be diminished with storage facilities in particular and PHM in general.

Causes of post-harvest losses of fruits and vegetables

Harvesting

The key aspect that impacts the quality and shelf life of fruits and vegetables is when they are harvested at their peak of ripeness. As a result, some farmers may harvest crops at an early stage without realising it. Fruits that have not been fully ripened are more susceptible to mechanical damage and deterioration, and they may develop undesirable characteristics such as high acidity and low sugar as a result of ripening. Overripe fruits, on the other hand, have a short shelf life. Fruits are more sensitive to physiological abnormalities in both circumstances of over ripening and under ripening.

Fruits that are harvested sooner, on the other hand, have less nutritional and economic value. In rare circumstances, the entire product is damaged and unfit for ingestion. Techniques for harvesting can also result in losses (Kasso & Bekele, 2016) ^[13]. When highly perishable goods, such as fruits and vegetables, are subjected to one or more treatments, the chances of losing them increase. As a result, throughout the harvesting and post-harvesting periods, farmers do not have any storage containers. This causes significant damage to fruits, vegetables, roots, and tuber plants, resulting in significant losses. Frost, hail, drought, heavy rainfall, fertilising, and pruning in the pre harvest period are some of the cultural activities that cause fruit and vegetable losses. During the harvest period, errors in harvesting time estimation, harvesting at the inappropriate time, and faulty harvesting procedures, such as failure to apply chilling to fruits, can result in losses.

Storage

A cold chain is a continuous supply of a product at a specific temperature from manufacture to consumption. In perishable food, a continuous cold chain ensures that the product does not deteriorate before reaching the consumer. Pre-cooling is the first step in effective cold chain management, which

continues with cold storage, cold transport, and chilled display cases. According to the International Refrigeration Institute (IIR). Following the application of several treatments to post-harvest items, such as washing, sorting, and packaging, the products may need to be stored for periods ranging from a few hours to a few months. Time management can be improved by storing products, and marketing and consuming can be done more leisurely.

Of course, this circumstance holds true if the storage procedure is carried out in proper conditions; otherwise, substantial product losses may occur. Even if the products are stored in the best possible circumstances, the quality and consume ability of the products is dependent on the stage of the entire food supply chain. Storage is uniformly provided throughout the whole supply chain in developed countries, beginning with production. The shelf life of perishable goods is significantly extended when cold storage is paired with post-harvest technologies such as a controlled environment. The biggest cause of post-harvest losses in underdeveloped nations is a lack of suitable storage facilities.

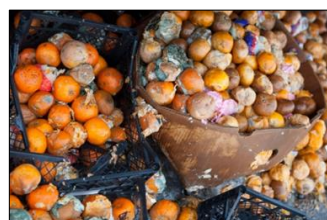
Transportation

Because transportation adds to the time between production and consumption, it can be one of the leading sources of product loss, particularly for fresh products. Perishable food distribution with refrigerated vans is routine practise in developed countries. In such instances, losses occur when the vehicle's cooling system fails, when an accident happens, or when there is a delay in the loading/unloading regions.

Perishable foods cannot be properly preserved in poorer countries due to a lack of appropriate transportation, inadequate roads, and ineffective logistics management. Furthermore, in many nations, loading and unloading procedures are performed by inexperienced and uneducated individuals who, in general, do not handle things with care. Azabaaolu (2018) claims that this causes mechanical damage to agricultural items. Food products are frequently packaged and loaded incorrectly, and they are occasionally tossed into automobiles. Food losses during transit are increasing due to bad roads in rural areas, where the majority of the production is done. Even when it is raining, cars might become trapped in the mud, resulting in a loss.

Improper packaging

Timely and correct harvesting, the use of refrigerated cars in interstate transportation, cold storage, and the use of moisture-resistant packaging can all help to reduce losses. Fresh markets and wholesale markets are where farmers sell their produce. Fresh produce is sold in unpackaged form or in bundles at the retail level. If fresh product is not sold soon, this form of market handling drastically diminishes its shelf life (Kiaya, 2014) ^[14].



a. improper packaging



b. spoilage of produce

Fresh fruit and vegetable packaging plays a vital role in avoiding losses and extending shelf life. As a result,

inappropriate packaging and the use of inadequate packaging material are two of the leading causes of fruit and vegetable loss at the post-harvest stage. Poor-quality packaging materials are unable to fully preserve fresh products from harm and might even hasten deterioration. Unfortunately, due to their low cost, low-quality packaging materials are frequently used in many regions of the world. In particular, in developing and underdeveloped countries, the usage of low-quality packaging containers is more widespread. Even delicate fruits and vegetables are packaged in poly-sacks, which cause significant damage to the products. According to research conducted in several nations in Sub-Saharan Africa and South Asia, 46 percent of horticulture crops were packaged in fabric bundles or huge sacks, 31% in open baskets, and 8% had no packaging at all. Kitinoja and Alhassan (2010, Kitinoja & Alhassan)^[95].

Consumers' waste

The consuming stage begins with the purchasing of fruits and vegetables by consumers and ends with their consumption. Fruit and vegetable losses are significant during the consuming stage of the food supply chain. Fresh fruits and vegetables account for about half of all food wasted in households. Fruit and vegetables account for 39 percent of total household waste, according to FAO research from 2011. According to research conducted by WRAP (2008), this ratio accounts for 40% of total home garbage. Over-purchasing, a lack of planning, poor home-storage management, and other factors contribute to consumer waste. Gender, lifestyle, income, and home storage facilities are all socio-cultural and material elements that influence the amount of garbage generated by consumers (Porat *et al.*, 2018)^[22]. According to studies, major food losses occur in developing countries due to technical and managerial limitations in harvesting techniques, storage, transportation, and processing activities, a lack of proper cooling facilities, infrastructure, packaging, and marketing systems, and a lack of proper cooling facilities, infrastructure, packaging, and marketing systems. In wealthy countries, however, postharvest loss is primarily due to customer behaviour, quality standards, and tight safety policies for fruits and vegetables (FAO, 2011, 2015).

Ways to reduce post-harvest losses and waste of fruits and vegetables

Harvesting Factors

Harvesting is a crucial unit action that determines the quality and shelf life of food, as well as minimising large-scale losses of fruits and vegetables. The purpose of good harvesting is to increase agricultural productivity, reduce crop losses and quality deterioration, and maintain harvested produce in good condition until it is consumed or sold. Postharvest losses and product quality are influenced by maturity criteria, harvesting procedures, harvesting containers, harvesting tools, field packing, and transit conditions to the packinghouse. Setting an ideal fruit and vegetable maturity date is critical for a successful harvest. Harvest maturity refers to when the fruit is ready to be picked. Harvesting is a crucial unit action that determines the quality and shelf life of food, as well as minimising large-scale losses of fruits and vegetables. The purpose of good harvesting is to increase agricultural productivity, reduce crop losses and quality deterioration, and maintain harvested produce in good condition until it is consumed or sold. Postharvest losses and product quality are influenced by maturity criteria, harvesting procedures,

harvesting containers, harvesting tools, field packing, and transit conditions to the packinghouse.

Setting an ideal fruit and vegetable maturity date is critical for a successful harvest. Harvest maturity refers to when the fruit is ready to be picked. For some fruits and vegetables, maturity induces size, shape, solidity, fruit opening, firmness, juice content, textural qualities, softness, colour, nutrient composition such as sugar, starch, oil, dry matter content, soluble solid, and titratable acidity. Several criteria, like as sugar concentration, pH, and acidity levels, are commonly employed to assess grape maturity. Soluble solids concentration (SSC) of 14 to 17.5 percent, depending on cultivar and producing location, determines harvest timing. There is also a minimum colour criterion for red and black coloured variations (Mencarelli *et al.* 2005)^[17].

Tomato fruit age, morphologies, colour and structure, inner colour and structure, seeds dropping when the fruit is sliced, and green colour turning pink are some maturity indices that correlate significantly with physical and chemical and nutritional features such as total soluble solids (TSS), total titratable acidity (TTA), and protein content (Okiror *et al.*, 2017)^[19]. After harvesting, temperature control is critical for avoiding postharvest losses and extending shelf life. Fresh produce can be cooled using a variety of methods, including hydro cooling, evaporative cooling, room cooling, forced air cooling, serpentine forced air cooling, and so on (Elansari, 2009)^[5]. The manner of harvesting has an impact on the quality of fruits and vegetables. Horticultural crops can be irreversibly damaged by poor harvesting procedures. Horticultural crops can be irreversibly damaged by poor harvesting procedures. In order to avoid damage during harvest, it is vital to standardise harvesting practises for each and every fruit and vegetable. To reduce mechanical damage, it's crucial to avoid unwanted wounding, bruising, crushing, or damaging of produce by equipment or containerizing. Harvesting methods include manual and mechanised harvesting, as well as a combination of both. Mechanical harvesting employs a large number of mechanical devices to gather food on a commercial basis. To prevent damage and waste, pickers should use delicate digging, cutting, picking, and handling or pulling the fruit or vegetable from the plant. Manual harvesting is used when the crop is at various stages of maturity, whereas machine harvesting is used exclusively when the entire crop is harvested at once. Hands-only harvesting or sharp knives can be used to harvest all or portion of the produce. To prevent the spread of virus illnesses from plant to plant, knives must be kept sharp and clean.



a. manual harvesting

b. proper harvesting stage

Manual harvesting is used when the crop is at various stages of maturity, whereas machine harvesting is used exclusively when the entire crop is harvested at once. Hands-only harvesting or sharp knives can be used to harvest all or portion of the produce. To prevent the spread of virus illnesses from plant to plant, knives must be kept sharp and

clean. Fruit and vegetable harvesting can also be done with hand-held or pole-mounted picking shears (FAO, 1989) [5]. Harvesting containers include picking baskets, bags, sacks, carts, and buckets made of various materials such as plastic, wood, natural, or synthetic fibres. Workers harvesting fruits and vegetables in the field should be able to handle them easily. Bags are used to collect a variety of crops. Fruits with firm skins, such as citrus fruits and avocados, can be harvested using harvesting bags with shoulder or waist slings. Potatoes, onions, and pumpkins are all often grown in sacks. Plastic containers labelled "food grade" that can be rinsed and sterilised between usage are also great. Plastic buckets with smooth surfaces and no sharp edges are ideal containers for gathering easily crushed fruits like tomatoes. Depending on the type of fruit or vegetable, the appropriate harvesting container should be used.

Best storage and transportation practices

The most expensive aspect of the marketing route is frequently transportation. Distance, perishability, and the value of the commodity all influence how fresh fruit and vegetables are transported (Harris, 1988). To maintain product quality, the globalisation of fresh product trade necessitates the development of superior long-distance transportation infrastructure. Multiple stages are required to convey fresh produce from the point of origin to the place of consumption. A lot of links in the chain of fresh fruit and vegetable movement from the field to the customer are provided by transportation. During transportation, produce must be kept in the best possible condition. The most significant ways of ensuring quality preservation of perishables are adequate temperature control and air circulation systems (Vigneault *et al.*, 2009) [28]. The cold chain is a logistics system that protects the quality of perishable goods from point of origin to point of consumption by using thermal and refrigerated packaging technologies and logistical planning to extend the shelf life of these shipments (Negi & Anand, 2014) [18]. Temperature variations during transport and storage are the key determinants of shelf life (Hertog *et al.*, 2014) [9].

(Vigneault *et al.*, 2009) [28]. During transit, the produce is vulnerable to physical and chemical damage, as well as microbiological infection. As a result, it is vital that a complete food safety and quality programme devote sufficient attention to transportation management. When it comes to storing and transporting fresh fruits and vegetables, each type has its unique set of requirements. Regardless of the method chosen, the fundamentals of transportation remain the same: *Care should be taken when loading and unloading; *Transition time should be kept to a minimum; *The product should be effectively protected in terms of its suitability for physical harm.



a. Proper storage of fruits b. storage in plastic crates



a. Washing oranges b. proper packaging of bananas



a. proper packaging b. storing of fruits and vegetables

Temperature is the main environmental condition influencing produce quality because it has a profound effect on the rates of biological reactions. Other factors affecting produce quality are: initial quality, environmental humidity and water loss, atmospheric gas concentration, mixed loads, physical injury and stress and transport conditions (surface road conditions, time of the day, etc.) (Vigneault *et al.*, 2009) [28]. Temperature is the most important environmental factor impacting produce quality since it has a significant impact on biological reaction rates. Initial quality, climatic humidity and water loss, air gas concentration, combined loads, severe injury and stress, and transportation conditions (surface road conditions, time of day, etc.) are all elements that affect produce quality

Provide air circulation, extraction, and air supply; * Keep consistent relative humidity – water losses by the yield should be limited; * Whenever necessary, the transport vehicle should not hold back in the sun, and the produce should be kept safe with a cover; * Providing shelter from the sun and rain at transporting areas (Paltrinieri, 2016) [5]. Storage is the skill of preserving the quality of agricultural products and preventing them from deteriorating beyond their typical shelf life for a set amount of time (Kiaya, 2014) [14]. Fruit and vegetable storage is critical for increasing the duration that food is available and avoiding malnutrition. The approach, on the other hand, is entirely founded on scientific methods. As a result, understanding the fundamental principles of fruit and vegetable preservation is essential (Khan *et al.*, 2017) [13]. To successfully preserve horticultural produce, a variety of storage structures are employed around the world. In general, the facility must be kept cool (refrigerated, or at the very least vented and shaded), and the produce placed in storage must be of high quality when first received (Kiaya, 2014) [14]. Controlled Environment Storage (CAS), which involves managing the gaseous atmosphere in a storage facility in addition to temperature and humidity, has been found to improve postharvest quality maintenance. Because increased CO2 levels usually have an adverse impact on the formation and multiplication of microorganisms, one of the major advantages of controlled environment storage is the prevention of food deterioration from pests and diseases. As a result, storing fruits and vegetables in a controlled environment may reduce the quantity of postharvest pesticides needed to protect them from insects and bacteria (Thompson, 1998) [2].

"Zero energy cool chambers (ZECC)" are storage devices related to direct evaporative cooling principles. The fundamental benefit of this low-cost on-farm cooling method is that it does not require any energy or power to work, and the materials needed to build it, such as bricks and sand bamboo, are readily available and inexpensive (Khan *et al.*, 2017) [13]. A 50 percent efficient evaporative cooling system has a substantial impact on the temperatures of non-air-conditioned and shady rooms (Lawrence and Tiwari 1989) [16]. Taha *et al.* (1994) [27] built and tested a specific sort of cooling system under various settings, concluding that the temperature difference was reduced by 10–13 °C.

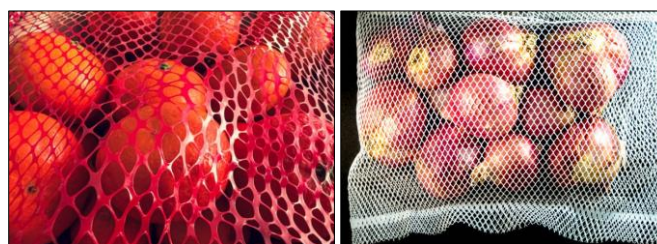
Packaging in reduction of post-harvest losses and wastes

Fresh fruits and vegetables have a short shelf life at room temperature, varying from a few days to a few weeks. They are living organisms that continue to function physiologically and biochemically after being harvested. Fresh food has an approach to managing humidity of up to 98 percent and includes 80-90 percent moisture or even more. As a result, under typical air circumstances, they dry quickly (transpiration). Due to cell shrinking, this produces wilting and shrivelling. Improved packaging might significantly reduce current postharvest losses of fruits and vegetables (Verma, 2000) [27].

Due to its physical, morphological, and physiological (primarily transpiration, respiration, and ethylene production rate) character and susceptibility to microbial deterioration, varied fresh food requires different methods of packaging. Temperature, relative humidity, and airflow all have a part in influencing the perishable produce's post-harvest life.

As a result, the packaging necessities for fresh fruit and vegetables can be summarised as follows: (1) protection against bacterial contamination and degradation, (2) safety against bruising and physical injury, (3) protection against moisture / losing the weight, (4) providing air circulation for respiration and gas exchange, (5) slowing respiration rate,

delaying ripening, and increasing storage life, and (6) attempting to control ethylene levels in the package (Ahmad & Siddiqui, 2016; Ahvenainen, 2003; Ramaswamy, 2014) [1].



a. Storage bags for oranges b. proper storage for onions



a. proper cushion pads for apples b. plastic containers for proper packaging

Packaging plays a critical role in decreasing food waste across the supply chain. It's important for increasing the shelf life of fresh fruit and keeping it safe during the post-harvest stages. Fresh fruit and vegetable packaging reduces food waste by designing smarter and better packaging that keeps food fresher for longer. As a result, good quality packing systems for reducing food losses should be created. Table 1 lists packing options for reducing food waste during the post-harvest period. It details some of the issues that lead to food waste in food supply chains, as well as possible packaging solution

Table 1: lists of packing options for reducing food waste during the post-harvest period

Possible reasons for fresh fruits and vegetables losses	Potential packaging solutions
Compression of overfilled packages causes bruising.	The usage of shallow containers with a smooth surface the mass of the product in the container has decreased.
Transport-related vibration damage (roller bruising)	Transport packaging optimization for exporting Retainers, individual packing, and padding are all used.
Injuries caused by impact	The use of hard boxes with each item cushioned
Injuries caused by puncturing	The usage of sturdy containers with good grips is recommended. Smooth containers and handling facilities are used.
withering or moisture loss	Improved and innovative methods like MAP and packing materials are being used.
Growth caused by microbes	Irradiation and MAP therapy combined
Insufficient airflow	Respiration was enabled through the use of packing materials.

The materials used in traditional packaging methods may prevent fresh fruits and vegetables from external forces to some extent. To decrease post-harvest losses and extend the shelf life of fresh fruits and vegetables, appropriate packaging materials and advanced packaging technologies must be created. In fact, there are a variety of innovative packaging technologies available for the packing of fresh fruits and vegetables. The most important advanced packaging technologies include modified atmosphere packaging (MAP), active packaging, and smart (intelligent) wrapping.

They are a cutting-edge concept that entails the inclusion of bioactive substances into packaging systems or the alteration of the atmosphere within the container with the goal of preserving or prolonging the shelf-life of fresh food. By

employing well-designed MAP, for example, the shelf life of packed products can be extended by 50–200%. (Siddiqui, 2016) [25]. Table 2 shows how the shelf life of some products changes with regular weather conditions and modified environment packaging technique. Despite the fact that modern packaging technologies have a significant impact on the shelf life of fresh product, they are not widely used in industry (Siddiqui *et al.*, 2018) [26].

Conclusion

Fruit and vegetable postharvest shelf life and quality are heavily influenced by postharvest handling practises, treatments, and harvesting methods. Fruits and vegetables should be consumed as soon as possible due to their

perishable nature. Although postharvest treatment methods cannot greatly increase quality, they can help to maintain it if handled with care. Failure to implement these postharvest management practises has resulted in significant losses, particularly in poor nations such as Nepal. By carefully manipulating postharvest handling methods, postharvest loss can be significantly reduced and shelf life can be extended. Careful harvesting, handling, employing crucial cultural methods, storage, packaging, and shipping can all help to reduce losses. Fruits and vegetables have been proven to benefit from controlled environment storage and low temperature treatment. Postharvest losses in fruits and vegetables will continue to be a big concern for handlers in underdeveloped nations until simple postharvest techniques are implemented.

Minimizing fruit and vegetable postharvest losses is a particularly efficient technique of combating poverty, guaranteeing food security, and maintaining product quality. The inadequate infrastructure (poor harvesting, transportation, storage, and processing methods) is a primary cause of fresh fruit and vegetable loss in many developing nations, whereas fruit and vegetable losses in wealthy countries occur primarily at the consumer stage. To reduce post-harvest losses, it is vital to employ the proper post-harvest innovations and technology. Coordination and control of post-harvest stages, in addition to post-harvest technology, play a major role in reducing post-harvest losses.

In India, significant progress has been made in the establishment of Postharvest Loss Reduction Strategies for Fruits and Vegetables. Postharvest losses in fruits and vegetables can be reduced and better-quality food can be made available to consumers with the availability and usage of enhanced technology. In order to improve their performance and lower their costs, postharvest technologies must be improved further. Changes must be made by both the government and the business sector to guarantee that all aspects of the postharvest handling chain are enhanced.

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