Review Article

Postharvest losses and Management of horticultural produce A review

Abstract

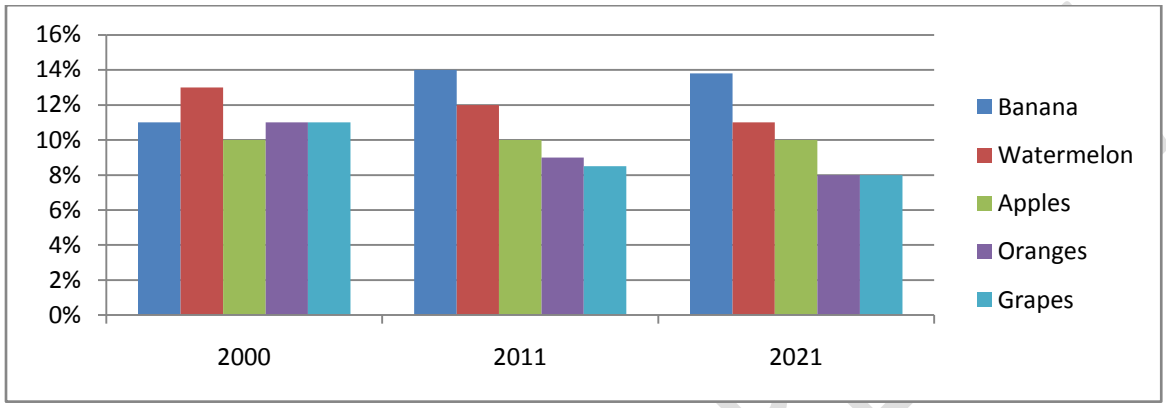
Horticultural postharvest losses pose a significant challenge to the supply chain and economic growth, particularly in impoverished nations. This review paper explores the multifaceted issues surrounding postharvest losses in horticultural crops and emphasizes the critical role of technological innovations in mitigating these losses. Various stakeholders within the value chain, including farmers, handlers, and consumers, face substantial risks due to insufficient postharvest handling techniques. The study underscores the urgency of adopting advanced postharvest technologies, focusing on enhanced harvesting and packaging strategies.By using cutting-edge technologies, it is possible to lower losses after harvest and raise the general standard of fresh produce. The improper use of packing materials and inadequate packaging methods significantly contribute to these losses, making it imperative to address these aspects for sustainable solutions. This comprehensive review not only identifies the reason for fruit and vegetable losses after harvesting within the countries but also provides actionable insights into mitigating measures. This article intends to support the creation of a robust and successful horticulture supply chain by addressing the issues and offering workable solutions.The integration of technological advancements in harvesting, handling, and packaging processes emerges as a key element in the overall strategy to reduce postharvest losses and promote economic growth in resource-constrained regions.

Key Words –Developing nation, Fruits/Vegetables, canning, ethylene, harvesting

1. Introduction

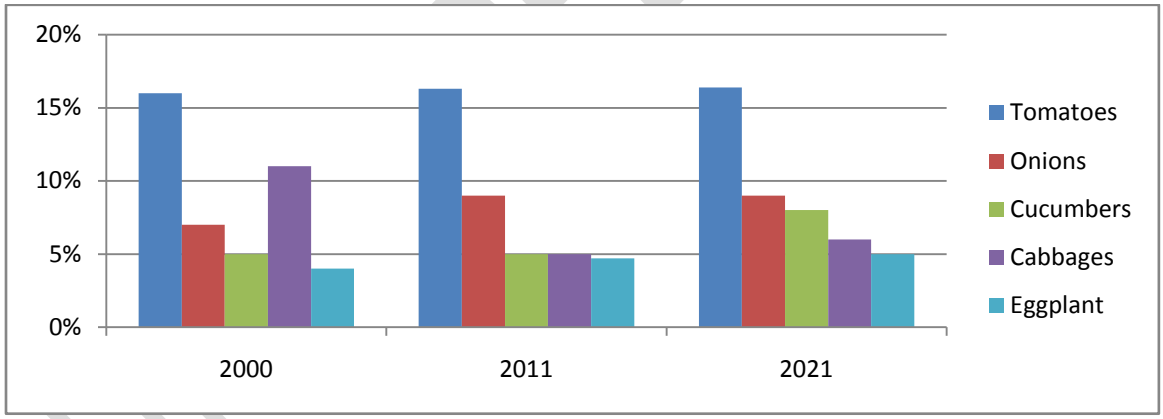
Items from horticulture are necessary to maintain people's diets and health. They are rich source of water soluble vitamins like (niacin, riboflavin, ascorbic acid and thiamine) as well as fat soluble vitamin like (retinol , tocopherol) etc. also greater than 90 percent of ascorbic acid in people's diet is obtained from fruits and vegetables. They are an excellent source of dietary fiber, calcium, phosphorus, iron, and magnesiumalong with this it increases the good micro-flora in the intestine (Yahia *et al*., 2019).Crops, veggies, fruits, flowers, spices, and aromatic and therapeutic plants are all considered horticultural crops, are primarily cultivated for their culinary value and appeal, with their consumption patterns influenced by factors such as availability, quality, and affordability. Unlike staple cereals or essential industrial crops, horticultural crops do not occupy a central role in agriculture, according to (Alazar, 2007). The Indian horticulture industry has expanded due to the joint efforts of farmers, government, and investors. The horticulture industry has shown positive growth due to the support from government agencies and educational institutions in terms of research and training of professionals (Banjaw, 2017). Fruit and vegetable losses after harvest can amount to as much as fifty percent since fresh food has a limited shelf life and there are inadequate facilities for processing and marketing it.Inadequate pre-production and post-harvest management practices exacerbate these losses,adversely affecting prices for

consumers, farmer revenue, and produce's nutritional content. Subpar quality of harvested produce stems from the use of inadequateplanting materials and less-than-ideal habits of cultivation, such as methods of harvest and managing. Perishable food without proper storage on the farms or access to a pack house packing station is often sold immediately after harvest without processing or wrapping. Solid debris from urban horticulture crops can clog drains and cause water blockages and cause environmental pollution with unsanitary conditions (Expert Consultation, 2010).



Graph **1:**Top fruit production shares worldwide

Source: (FAO, 2022)



graph 2: Top vegetables production shares worldwide

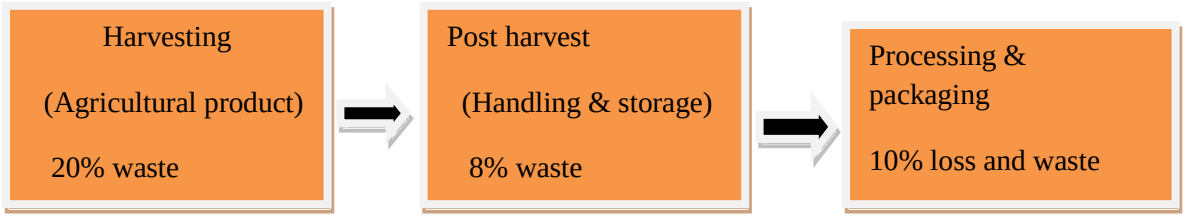
Source: (FAO, 2022)

Following the harvest, there may be qualitative as well as quantitative losses. The term "quantitative losses" describes how food loses bulk or volume,decreasing the volume of food suitable for people to consume. These losses might be valued in terms of weight, money, or energy. Before food is thrown out, eaten, or used in another way, it experiences qualitative losses. These losses include decreases in the

produce's nutritive content, edibility, safety, and eventually economic worth.One of the main issues with after-harvesting systems and growth in the economy is qualitative degradation, in particular the growing countries, as improper postharvest handling techniques put impoverished value chain participants, such as farmers, handlers, and consumers, at serious risk. While the lack of frequently linked to qualitative losses, this is less of an issue for those who can afford to upgrade their logistical systems (Yahia *et al*., 2019). While both developed and developing countries experience substantial postharvest losses and waste in horticulture products,the degree of these reductions varies according to the handling chain's step. Developing countries typically suffer greater losses during the post harvest and handling stages, primarily due to inadequate infrastructure and improper handling practices. In contrast,Waste at the retail and consumer levels is often higher in industrialized nations. Often attributable to stringent cosmetic standards and consumer preferences (Kader, 2005). Around a third of the global population global fruit and vegetables production is believed to be lost in the postharvest period, excluding inedible waste. In the UK, postharvest losses from harvest to retailer are approximated at 9 percent,omitting goods that, because of quality and esthetic requirements, were left in the field. In 2008, projections indicated that the United States experienced losses of $42.8 billion in fruits and vegetables at the commercial and consumption stages, equating to approximately $141 per person (Buzby *et al*., 2011). From this standpoint, it is becoming progressively crucial to mitigate or ideally eliminate the waste of fresh fruits and vegetables. Consequently, it is imperative to implement advancements in postharvest technology, including suitable harvesting methods and packing techniques, to diminish postharvest losses and increase the overall quality of fresh produce. This will ultimately lead to increased consumption of fresh fruits. The main forms of deterioration that contribute to the disposal of fresh fruits and vegetables include moisture loss, bruising, and eventual decay (Kitinoja and AlHassan, 2010; Ray and Ravi, 2005). It is not feasible to entirely halt the natural transformation of fresh food; there are measures that can be taken to mitigate these changes. These include maintaining a low temperature, regulating relative humidity during storage, ensuring proper packaging and shipping, and so forth (Ahmad and Siddiqui, 2015).

2. Reasons for agriculture losses after harvest

Increasing food production serves as a viable solution to address the growing demand for substance. Instead of merely focusing on boosting output, it is more prudent to ensure the efficient delivery of food to consumers while safeguarding agricultural products against loss that occurs during several phases, including processing, retailing, fields, shipping, and storage.This approach aims to mitigate the strain on water resources, fields, and the environment. Following production, agricultural products undergo before reaching customers, there are several after harvest unit processes dealing with stages and storage procedures, all of which have specific losses. Consequently, the cumulative effect of these steps results in a diminished availability of food. Recent research conducted in India reveals specific percentages significant losses that occur after harvest, after-harvest activities, handling and storage for various crops, including grains, pulses, oilseeds, (Nanda *et al*., 2012).



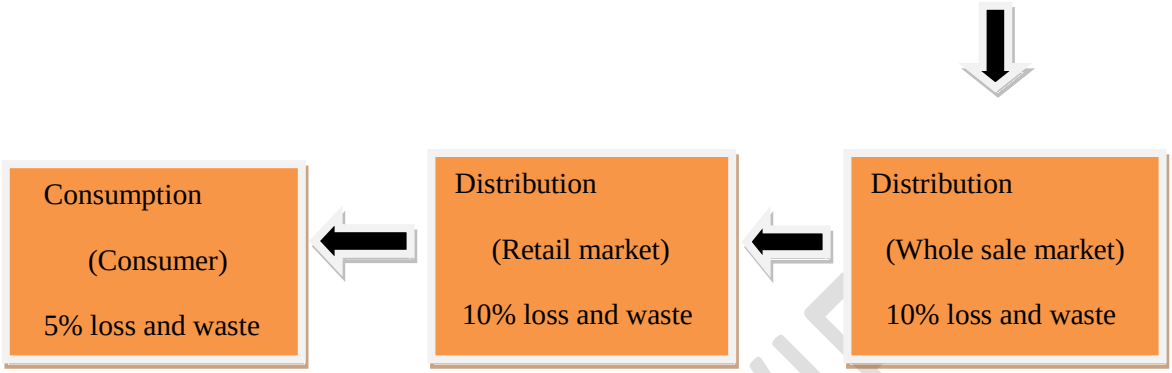


Figure1. An example of the waste generated along the whole fresh fruit and vegetable distribution chain

2.1.Harvesting

Fruit and vegetable quality and shelf life are greatly affected by the date of harvest. Premature harvesting, driven by financial concerns, can result in unripe produce with poor flavor and increased susceptibility to damage.Conversely, ripe fruits have a lower shelf life. Overripe and under ripe fruits are more likely to cause physiological issues. The nutritive and financial worth of crops is diminished by early harvesting. In certain instances, entire batches may be lost due to unripe or overripe produce. (Azabağaoğlu, 2018; Kader, 1995).Harvesting methods may result in losses as well (Kasso and Bekele, 2016). These losses can be increased several times when farmers not having the proper cold or containers for storing either during or after the collecting process.This resulted in detoriation of the quality of fresh horticultural products and produce.Inadequate implementation of cultural practices" is replaced with "inadequate cultural practices". "Including pre harvest irrigation, fertilization, pruning, infections, physiological disorders, hail, drought, excessive rainfall, and plant nutrition" is replaced with "including a variety of factors". Furthermore, "improper harvesting techniques, and inaccurate harvest timing" is substituted for "inaccuracies in determining the appropriate harvest time, harvesting at the wrong moment, improper use of harvesting techniques, and failure to pre-cool crops like cherries during the harvest season." result in losses that range from 4% to 12%(Özdemir *et al*., 2003; Özcan, 2010).

2.2. Storehouse

Storage technologies provide opportunities to enhance marketing efforts, boost value, and overcome quarantine limitations. Additionally they play a pivotal role in advancing and

globalizing the horticulture sectors. Temperature serves as the foundational technology for various storage systems, and effective temperature management remainsirreplaceable. While other storage technologies can enhance its impact, controlling relative humidity, optimizing the storage environment, implementing proper packing, and utilizing chemical treatments can all be coordinated alongside cold storage (Watkins and Ekman, 2004).The metabolism of ethylene is complexly impacted by temperature. Elevated production of ethylene during refrigerated storage might indicate damage to perishable items that are sensitive to cold conditions (Cooper *et al*., 1969). While volatile aroma components play a critical role in strawberry flavor, the impact of low-temperature storage on these compounds has received less attention compared to other quality factors. Following harvest, strawberries produce a diverse range of volatile compounds. Although this emission persists throughout chilly storage, the temperature has an impact on the particular chemicals that are created (Forney *et al*., 2000; Miszczak *et al*., 1995).

2.3.Transportation

The movement of goods from producers to consumers is a crucial aspect of commerce, particularly for newly manufactured products. Direct delivery from producers to consumers is an efficient approach. Transportation costs have a significant impact on consumer prices, especially in complex distribution system that serves large cities and remote locations. In some cases, these transportation costs may even exceed the price of the components that are needed to produce the goods (Condratchi and Movileanu, 2012).The preservation of perishable food faces challenges in less affluent countries due to insufficient transportation, poor road conditions, and ineffective management of logistics. Additionally in numerous nations, individuals lacking literacy and skills often handle loading and unloading tasks, leading to careless treatment of goods and consequent mechanical damage to agricultural products (Azabağaoğlu, 2018).

2.4. Improper packaging

To maximize losses and prolong the freshness of fresh f&V, proper packaging is essential. Inadequate packaging techniques and the use of unsuitable packing material significantly contribute top post-harvest losses. Insufficient protection against damage can accelerate the detoriation of fresh produce when low-quality packaging materials are utilized. Unfortunately, the widespread use of inexpensive but subpar packing material is a common practice globally, especially in developing and underdeveloped nations (Kitinoja and AlHassan, 2010).

2.5.Consumer’s waste

Consumer preferences refer to the views that individuals hold regarding a product, whether it is a service or an item, and are shaped through the evaluation of the choices currently accessible (Kotler and Keller, 2008). Analyzing consumer behavior encompasses more than just examining what individuals purchase; it is also delves into the reason behind their purchases, the

timing, location, manner, and frequency of their acquisitions, aiming to fulfill their needs and desires (Schiffman *et al.*, 2010).Roughly 50% of the food is discarded by households consists of fresh fruits and veggies (FAO, 2011). A report states that fruits and vegetables contribute to 39% of total domestic waste (WRAP, 2008). Another study indicates a similar proportion of around 40% in household garbage. Factors leading to financial wastages among consumers involve excessive spending, inadequate home storage practices, and insufficient preparation. The quantity of waste produced by individuals is impacted by various factors, such as material possessions and sociocultural aspects, including income, gender, lifestyles, and choices in home storage (Porat *et al.*, 2018).

Figure2. Improper packaging Figure3. Improper loading

Figure4. Not proper marketFigure5. Not proper storage

Figure6. Not proper market for saleFigure7. Not proper regulation

Figure8. Improper transport facilitiesFigure9. Not proper market


Figure10. Not proper handlingFigure11. Improper transportation

3. Others factors leading to post harvest losses

3.1. Insufficient structure

It is important to note that unlike other enduring agricultural goods, fruits and vegetables need to be promptly transported to markets due to their quick perishability any delay could lead to loss (Caixeta-Filho, 1999; Sudarshan *et al*., 2013; Tolani and Hussain, 2013).For this reason, efficient transportation is essential to the horticultural product supply chain. Examples of insufficient infrastructure include limited transit choices, an underdeveloped transportation

network, impractical roadways, and the absence of affordable temperature-controlled vehicles (Accorsi *et al*., 2017; Cardoen *et al*., 2015; Lorentz *et al*., 2007; Modi *et al*., 2009; Murthy *et al*., 2009; Narula, 2011; Negi and Anand, 2015; Shukla and Jharkaria, 2013).

3.2.Absence of communication between farmers and facilities

Processing businesses usually acquire raw materials through intermediaries or agents instead of directly from farmers, leading to reduced prices for farmers and increased costs for processors (Subrahmanyam, 2000). A key issue revolves around linkage, influencing the accessibility of suitabletechniques used in F&V processing.The ratio of raw materials to completed goods tends to increase due to this connection factor. It's noteworthy that agricultural seasonality affects processing sectors, leading to price fluctuations. Implementing measures to stabilize F&V markets not only mitigates the risk of price fluctuations but also eases the exchange of valuable pricing information between producers and processing units (Rottger, 2004).

3.3.Ignorance of high-quality seeds

Optimal weather conditions, top-notch seeds, and fertile soil take into consideration while trying to improve agricultural output (Afadhali, 2015; Mwendwa, 2015; Nsom, 2015). Several Indian farmers lack awareness regarding the benefits of using seeds of excellent quality for agricultural cultivation, including improved wellness and greater resilience to pests and illnesses (Negi and Anand, 2015).

3.4.Inadequate facilities for tracking traceability, and record keeping

From the agricultural field to the retailer, traceability ensures the monitoring of specific farm products within a supply chain. Adequate documentation is essential at every point in the distribution process to facilitate item tracking. Companies must recognize food items, gather relevant data, and share it with various participants in the distribution chain to ensure effective food tracing (Dabbene *et al*., 2013; Tolani and Hussain, 2013; Wilson and Clarke, 1998; Winkworth-Smith *et al*., 2015). The effectiveness of link for supplies is raised by effective information exchange and coordination between the many parties (Chen, 2003; Gaur *et al*., 2005). When traceability is implemented well, commodity prices are lowered and, in the event of a recall, distributed products may be retrieved from the same vendor. Nonetheless, the technology has its limits. For example, there is significant implementation and maintenance costs associated with the traceability facilities and the tracking software may not be user-friendly for all supply chain participants (Negi and Anand, 2015).

3.5. Many middleman

From the field to the store, traceability guarantees on monitoring of specific agricultural products throughout the supply chain. Thorough documentation is crucial at every phase of the distribution chain to make item tracking easier. Companies must recognize food items, gather pertinent data, and disseminate it among various participants within the system of supply to ensure efficient commodity tracing. Effective exchange of information and coordination among the various stakeholders enhances theeffectiveness of the manufacturing chain. In India, the agricultural supply system is significantly affected by powerful traditional traders with political clout. The excessive involvement of intermediaries in the distribution process disrupts the seamless flow of crucial information, resulting in coordination challenges and decreased overall efficiency. These intermediaries, who profit significantly, contribute to a decline in farmers' earnings. The addition of extra commission brokers in the supply chain might boost product turnover but could also lead to financial deprivation (Balaji and Arshinder, 2016; Sachan *et al*., 2005).

3.6. Failure to consume

Unexpected changes to meal habits can lead to food being wasted, even for customers who make mindful food selections (Evans, 2011). Or time constraints could require the substitution or removal of some items (Bava *et al*., 2008).F&V from the previous regular shop may be swapped out for new ones in certain circumstances. "Fresher," products and disposed of (Evans, 2011). Customers sometimes lack knowledge on how to determine if fruit is ripe or how to ripen it and certain fruits are overlooked if they take an excessively lengthy time to mature (Harker *et al*., 2007).

3.7.The setting for food

Providing consumers with dependable and trustworthy access to nutritious and safe food is an essential aspect of the food industry (Morland *et al*., 2002; Gao *et al*., 2012).Domestic food waste appears to be a bigger problem in wealthy metropolitan areas that are dependent on international supply systems, according to trends (Parfitt *et al*., 2010; Thyberg and Tonjes, 2016). F&V that were before only available during certain seasons are now offered year-round for these wealthy customers (Thyberg and Tonjes, 2016). Almost every home has at least one refrigerator. Considering that the single most significant element influencing the preservation of F&V quality is temperature (Wills *et al*., 1998), Keeping F&V at room temperature in the house is probably going to cause it to deteriorate quickly.When people choose to store their fruits and vegetables in refrigerators, the way they manage the inventory within the refrigerator can result in waste, particularly if products are missed or are thought to have become contaminated by coming into touch with other foods (Waitt and Phillips, 2016). Among the primary reasons why food is wasted among US consumers is concern regarding food contamination (Neff *et al*., 2015). The most important part of food disposal is frequently the habits related to emptying refrigerators of past-due produce. Some people do this all the time, throwing away goods they feel are no longer fresh or won't provide the desired sensory experience. However, other customers take a more impromptu approach, carrying out these purges when a certain component

is needed for a dish (Waitt and Phillips, 2016). Rather than the features of residential refrigerators, these disposal practices are probably going to be a bigger source of F&V waste.

4. Fruits and vegetables losses after harvest in developing nation

It is expected that the changing tastes of middle-class consumers in developing nations like China and India, who have more purchasing power, would significantly impact global food consumption. By the middle of this century, there may be a 50–70% increase in the global food consumption due to this **(**Godfray *et al*., 2010; Parfitt *et al*., 2010; Bond *et al*., 2013). Even while the global need for food is growing, about a billion people continue to struggle with insufficient food and nutritional deficits (Bond *et al*., 2013; UNEP, 2014).Upcoming food safety issues are heavily impacted by environmental factors like water shortage, deforestation, and global warming. It is the maintenance of a delicate equilibrium to guarantee an enough quantity of wholesome and nutritious food for the global population (Wheeler and Von Braun, 2013; Liu, 2014).Food wastagehas been prioritized in the global combat hunger and for enhanced food safety due to its ability to increase food accessibility and environmental well-being. Reducing FLW promotes sustainable environmental practices, strengthens food security, and increases food supply (FAO, 2011; Shafiee-Jood and Cai, 2016)

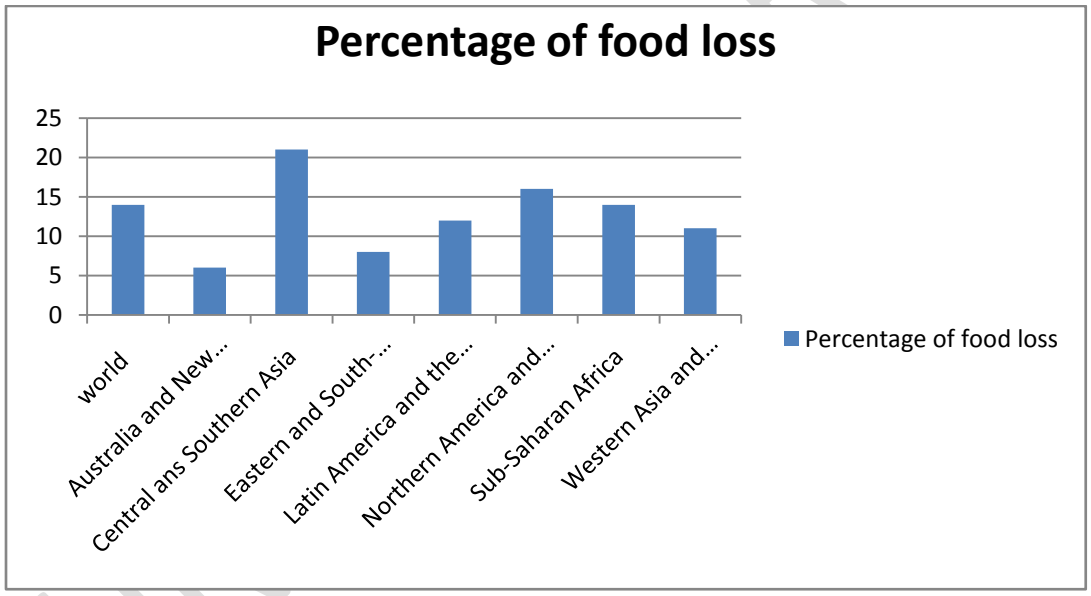


Figure 12: Post harvest losses at global level

Source: (FAO, 2019)

Table 1: Harvest and post harvest losses of fruits and vegetables in India

Crop	Harvesting (%)	Collection (%)	Sorting (%)	Packaging(%)	Transportation (%)	Total loss in farm operations (%)	Farm level storage (%)	Cold storage (%)	Wholesaler level storage (%)	Retailer level (%)	Processing unit level storage (%)	Total loss in storage (%)	Overall loss (%)
Apple	4.6	0.4	4.8	0.1	1.2	11.1	0.04(2.3)	0.12(1.5)	0.52(1.0)	0.23(1.1)	0.29(1.7)	1.2	12.3
Banana	1.3	0.4	0.9	0.4	1.1	4.2	0.04(1.6)	0.16(3.3)	1.83(2.4)	0.36(2.4)	0.01(0.3)	2.4	6.6
Citrus	0.9	0.5	1.8	0.3	1.3	4.8	0.03(1.9)	0.00(0.0)	0.69(1.3)	0.77(2.3)	0.01(0.2)	1.5	6.3
Grapes	0.9	0.2	3.2	0.3	1.9	6.6	0.41(5.5)	-	0.54(1.6)	0.84(2.2)	0.30(2.7)	1.7	8.3
Guava	4.4	1.2	4.6	0.9	2.8	13.9	0.41(2.1)	-	1.83(5.9)	1.80(3.8)	0.06(5.7)	4.1	18.0
Mango	4.1	0.7	2.8	0.5	2.5	10.6	0.06(1.5)	-	0.92(2.5)	0.93(2.7)	0.19(0.9)	2.1	12.7
Papaya	1.4	0.3	2.0	0.2	1.1	5.1	0.08(2.1)	0.00(0.0)	1.02(2.3)	1.20(2.4)	0.00(0.0)	2.3	7.4
Sapota	1.5	0.2	1.4	0.1	1.1	4.3	0.02(0.8)	-	0.75(1.7)	0.73(1.7)	-	1.5	5.8
Cabbage	1.1	1.1	1.6	0.3	1.3	4.6	0.14(2.1)	0.06(1.1)	0.88(2.2)	1.19(2.6)	0.03(2.3)	2.3	6.9
Cauliflower	0.8	0.3	1.7	0.2	1.9	4.8	0.06(1.5)	0.04(0.5)	1.00(2.2)	0.89(2.3)	-	2.0	6.8
Green pea	3.5	1.1	3.3	0.2	0.5	8.6	0.06(1.2)	0.01(0.3)	0.71(1.3)	0.92(2.4)	-	1.7	10.3
Mushroom	1.4	1.8	4.3	1.6	2.0	11.0	-	-	-	1.50(1.7)	-	1.5	12.5

Onion	2.7	0.2	1.6	0.1	0.4	5.2	0.54(2.7)	0.38(2.2)	0.38(2.2)	0.81(2.2)	0.01(0.1)	2.3	7.5
Potato	3.2	0.7	2.2	0.1	0.5	6.7	0.36(3.9)	0.78(1.4)	0.96(3.9)	0.19(2.4)	0.01(0.4)	2.3	9.0
Tomato	1.7	1.1	3.2	0.8	3.1	9.9	0.17(4.6)	0.01(1.6)	1.23(2.7)	0.98(2.3)	0.11(2.0)	2.5	12.4
Tapioca	3.6	0.5	1.5	0.5	1.3	7.5	1.09(4.1)	-	0.58(1.5)	0.44(1.7)	0.19(2.3)	2.3	9.8

Source: (Nanda *et al*., 2012)

Table 2: shrinking produce diversity in U.S.A stores

Fresh fruit and vegetables	U.S retail weight, total (millions lbs./year)	Shrink in 2011 (%)	Shrink in 2012 (%)	Uneaten whole fresh fruit (millions lbs./year)	Nonedible share (%)	Fruit loss (edible) (millions lbs./year)
Papaya	288	54.8	30.3	124	33	83
Pineapple	1917	30.5	35.8	617	49	315
Apricots	29	39	28.9	9	7	8
Watermelon	4187	23.3	27.7	1063	48	553
Honeydew	444	33.8	18.5	100	54	46
Mango	743	22.8	20.8	157	31	108
apples	4856	20	19.2	932	10	839
Avocados	1578	25	17.2	300	26	222
Grapefruit	723	25.2	14.6	136	50	68
Turnip greens	0.4	61.7	63.9	71	30	50
Mustard greens	0.4	60.4	61.6	76	7	70
Okra	0.4	35.6	53.5	49	14	42
Kale	0.3	30.7	24.2	28	39	17
Squash	4.3	24	22.9	309	17	256
Radishes	0.4	17.9	27.2	29	10	26
Eggplant	0.8	18.1	22.9	51	19	41
Pumpkin	4.7	16.5	21.9	267	30	187
Cauliflower	1.1	17.5	17.3	59	61	23
tomatoes	17.3	11.9	14.7	790	9	719

Source: (Buzby *et al.*, 2015)

5. Methods to reduce losses after harvest

Various post-harvest processes must be used to preserve crops nutrition, color, and texture. Despite the natural decline in the quality of horticultural produce over time, the application of specific procedures and standard storage techniques can effectively slow down degradation, thereby extending shelf or storage life.

5.1. Drying

The most ancient method of preserving food involves extracting moisture from it, known as dehydration, to prolong its durability. In this method, the moisture content of the fruit's tissue diminishes gradually, significantly reducing the likelihood of fruit decay. In tropical regions, this technique can be achieved by utilizing the heat from direct sunlight. Despite the discoloration of fruit tissues during the drying process, this approach represents the earliest form of drying, which has undergone enhancements through various methods over time (Gupta and Nath, 1984).

Different methods for drying are available, such as dehydrator dryers that utilize artificial heat with controlled humidity, temperature, and airflow. Oven dryers also regulate temperature through the oven's heat source. Various traditional drying techniques have been employed, including low-temperature drying within the range of 15 to 50°C and high-temperature drying at temperatures exceeding 50°C. Freezing fruit juice and other liquids at temperatures between -10 and -40°C is another approach for drying (Aravindh and Sreekumar, 2015).

5.2.Canning

The lifespan of the produce is prolonged through preservation in a sealed container. This approach applies to perishable acidic fruits and vegetables, involving storage in a container and heat treatment. The tomato, for instance, is immersed in boiling water for about a minute and then placed within a can that contained contents halfway with acetic acid, Vitamin C, or citric acid to facilitate the peeling of the skin (Parnell *et al*., 2004). The act of acidification involves the addition of substances such as vinegar or lemon juice. This process is employed to halt the proliferation of the harmful bacterium *Clostridium botulinum*.

5.3. Freezing

This method involves preserving fruit by placing it in a freezer. When a liquid drops below its freezing point, it undergoes a phase change referred to as freezing. By employing this method, the fruit's lifespan is extended because it hinders the growth of microorganisms, reducing degradation. A vital aspect of this preservation method is the fruit's capacity to preserve its color and sustain a relatively high nutritional quality (Parnell *et al*., 2004). Cold storage rooms and freezers use a variety of freezing techniques. These consist of cryogenic freezing, liquid immersion freezing, air blast freezing, and contact (plate) freezing (Johnston, 1994). When employing the freezing technique, with the predominant methods being air blast freezing and contact freezing, commonly utilized for preserving fruits and vegetables (Bouzari *et al*., 2015).

5.4.Fresh storage

Preserving the optimal physical and physiological environments to prolong the shelf life constitutes an integral aspect of fresh storage.Fruits that are stored are kept in their original, fresh state, with efforts focused on minimizing the degradation process and metabolic mechanisms to extend shelf life without compromising freshness. To achieve the desired storage temperature, cooling methods are employed. Various chilling techniques, such as evaporative coolers, controlled environment storage, and freezers, are applied to keep tomato fruits in storage (Ayomide *et al*., 2019).

5.5. Refrigerators

Perishables are stored around the globe today using this extremely well-known and well-established method. For a few days, it is an effective way to store fruits and vegetables (Rodriguez *et al*., 2001). Refrigeration, the method employed to lower the temperature of a space below that of its environment, involves various techniques such as the gas cycle, thermoelectric, vapor compression, and vapor adsorption. Commonly found in residential refrigerators, the vapor compression cycle plays a key role in cooling by employing a compressor, evaporator, condenser, and refrigerant. InHeat is transmitted from the items that are kept to the refrigerant during this procedure, achieving the desired refrigeration effect (Bhatt, 2001).

5.6.Regulated atmospheric pressure

The idea behind a controlled environment is to delay a fruit's respiratory process by raising the level of CO2 and lowering the level of O2 in the atmosphere. This extension of shelf life is achieved by altering the usual air composition (El-Ramady *et al*., 2015). The duration fruits remain fresh can be prolonged by combining them with refrigeration, which alters the temperature within the storage space. The composition of standard air includes 21% O2, 78% N2, 0.93% Ar, 0.04% CO2, and fluctuating levels of water vapor. The controlled atmosphere is stabilized by the introduction of anon reacting gas, specifically nitrogen (Babrinsa *et al*., 2015).

5.7.Use of ethylene action inhibitors

Sometimes, to increase the amount of time that product may be stored, waxing, high carbon dioxide levels, low oxygen levels, and ripening inhibitors are combined (Izumi and Watada, 1994; Tessema, 2013). Finding the best remedies for endogenous ethylene (C2H4) and ripening inhibition, however, is still difficult. As a result, many chemical combinations have been tested in order to maintain ethylene levels below the cutoff. When employed in conjunction with regulated storage atmospheres, ethylene absorbents like potassium permanganate (KMnO4) and calcium chloride (CaCl2) have considerable economic potential, albeit small-scale farmers may not be able to afford them (Tessema, 2013).

5.8.Developments in cold chain management and logistics

The cornerstones of postharvest technology have been and now are maintaining the cold chain from harvest to market and optimizing storage temperature for fruits and vegetables (Kader, 2003). Although ideal storage and transit settings may be envisioned in theoretical models, the real world is frequently messier. Sophisticated logistics systems require thorough monitoring since deviations from ideal circumstances are common(Jedermann *et al*., 2014).A new paradigm for inventory management in the retail industry is made possible by the combination of temperature data with large primary producer databases that include information on variety, yield, location, season, pre-harvest procedures, and quality evaluations. This change enables shops to prioritize the consumption of items depending on their expiration date by switching from the antiquated FIFO model to the more advanced FEFO approach(Jedermann *et*

al., 2014). While the FEFO strategy involves a thorough grasp of the produce's quality journey, the FIFO model merely requires information on the produce's arrival date. This includes evaluating the product's initial quality upon arrival, taking into account the temperatures throughout storage and transit, and finally predicting the product's remaining shelf life. Growers' labels now only contain limited information on variety, identity, provenance, and harvest time. However, information technology is about to make cloud-based, dynamic data available that includes all pre- and post-harvest factors. With the use of this improved data, virtual labels will be created, enabling a dynamic FEFO model for efficient produce management.

5.9.Developments in retail packaging

Packaging does more than just hold food; it actively preventsWaste and loss of food across the whole distribution system, maintaining its freshness and quality until it gets to your table (Verghese *et al*., 2015). In the world of produce, readily available "retail packages" like apple bags, banana bunches, or individually wrapped zucchinis provide several enticing advantages beyond simple convenience. These pre-packaged options offer informative labels, protection from damage, improved hygiene, extended shelf life, and in some cases, even controlled atmospheres to optimize freshness (Verghese *et al*., 2015). Creating an efficient packaging approach for fruits and vegetables involves customizing a strategy. Each packaging unit should ensure appropriate cooling, ventilation, and temperature regulation to suit the respiration patterns and environmental preferences of individual products, with a particular focus on managing low O2 andhigh CO2 levels (Kader *et al*., 1989). By modifying the air inside the package, MAP acts as a shield, protecting the delicate freshness and quality of mangoes, strawberries, and even prepared kale during their transport and shelf life (Brecht *et al*., 2003).While plastic sheets and containers have long been the standard for packaging, edible waxes, and coatings have become more well-known as reliable alternatives in recent years. These substitutes, which are acceptable to eat and are made of proteins, lipids, and polysaccharides often in composite forms, offer similar protective barriers between food and surroundings (Valdes *et al*., 2017).

5.10. Efforts to raise consumer awareness

Food waste that goes unnoticed is common; polls show that people are shockingly unaware of how much food is wasted and how it affects the surroundings and the finances(Neff *et al*., 2015). 1,862 customers in the UK were interviewed, and the results indicate a general underestimation of personal food waste quantities (Lyndhrust *et al*., 2007). Public education on food waste is still vital because it gives people knowledge about how to reduce the amount of trash they produce. One notable example of this is the United Kingdom WRAP-initiated "LOVE FOOD HATE WASTE “crusade. Remarkably, even if the total amount of households increased by 4 percent, throughout five years (2007–2012), this initiative successfully reduced household food and beverage waste by 1.3 million tons (WRAP, 2013).

5.11. Publication of suggested storage guidelines

A crucial bottleneck in the supply chain, wholesale marketplaces' uneven cooling and poor temperature control can result in reduced shelf life and substantial fruit and vegetable loss from incorrect storage. This emphasizes how important it is to share best practices at this critical juncture (Kader, 2003). Providing clear, personalized storage rules for customers and shop management is crucial for effectively tackling the problem of fruit and vegetable waste. Specific temperature and humidity requirements apply to each variety of food, and by communicating this information across the supply chain, the danger of rotting may be significantly reduced (Porat *et al*., 2018). "The Food Keeper" was developed in the U.S as an outcome of cooperation between the Food Marketing Institute, and the USDA. This book gives consumers with helpful guidance on how to store a range of goods in pantry, refrigerator, and freezer areas, including fresh fruit (FMI, 2014).

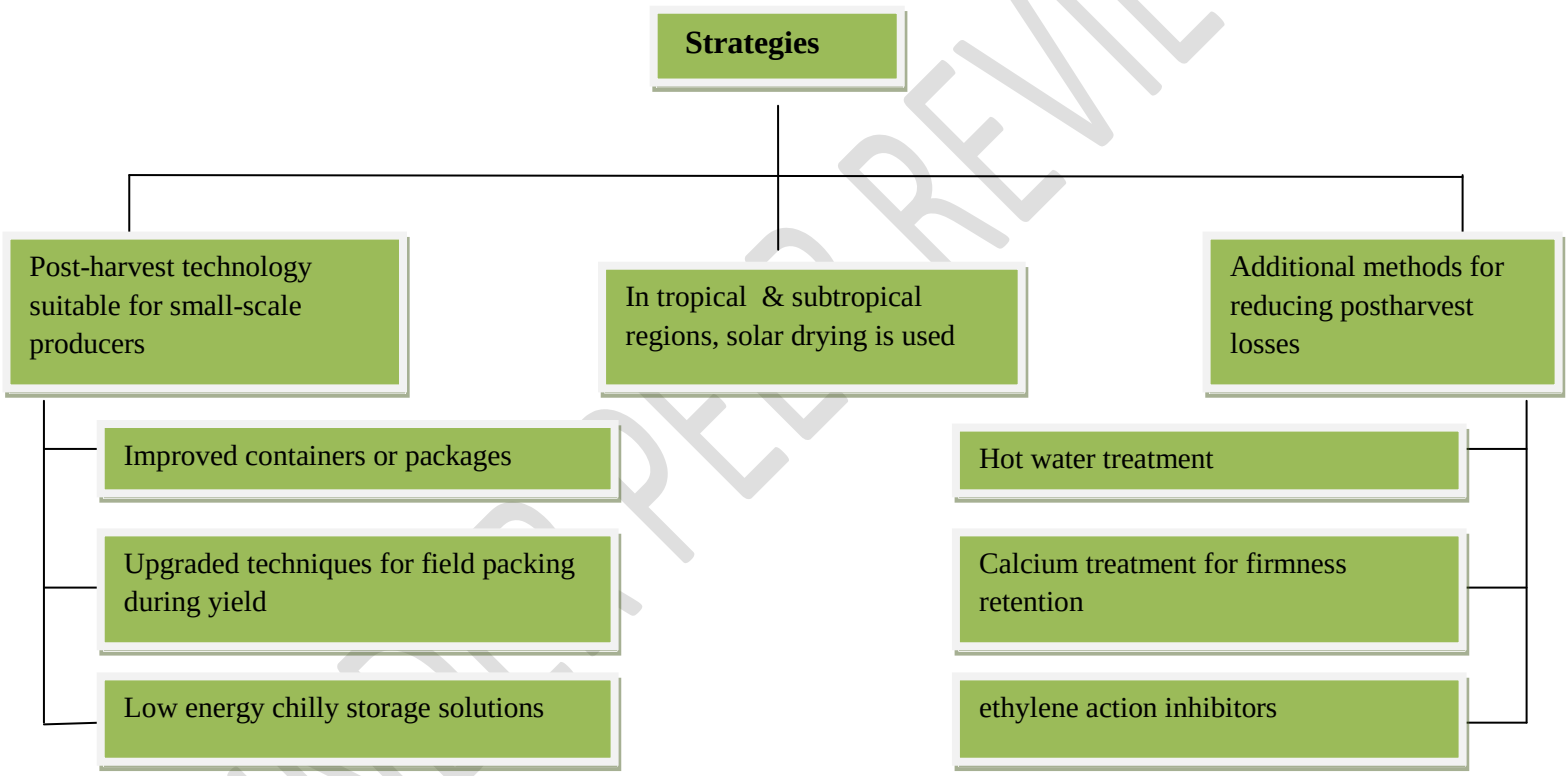


Chart 1. Additional methods to lower postharvest losses in fruits and vegetables

6. CONCLUSION

During the fight against poverty, ensuring that everyone has access to enough wholesome food, and maintaining the freshness and quality of products, reducing waste after fruits and vegetables are picked may be a highly effective weapon. Poor infrastructure at every stage of the process, from picking to storing to transporting and processing is the primary cause of wasted

fruits and vegetables in underdeveloped nations.As a crucial tactic for attaining ecological and worldwide food safety,recently, nations and global bodies have prioritized and directed their focus toward FLW prevention.The UN has set an extraordinarily ambitious goal to reduce world food wastage by 2030 as a result of this. However, the most of the trash in wealthy countries comes from the consumers. Lowering these losses requires the adoption of appropriate post-harvest innovations and technology. Additionally, reducing waste and increasing access to nutrient-dense food is made possible by efficient coordination and management throughout the post-harvest phases.

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